# ANALYZING THE IMPACT OF BURNING ON VEGETATION IN HIMALAYAN CHIR PINE (*PINUS ROXBURGHII* SARG.) FORESTS, INDIA

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**Abstract.** The study was conducted in three Forest Divisions i.e. Solan, Nahan and Rajgarh of Himachal Pradesh, India to determine the impact of controlled burning on the diversity of shrubs and herbs in chir pine forests. A total 2.00 ha was selected for study on each site. The controlled burning was conducted in 1.5 ha ($B_1$) during January 2017 and 1.0 ha ($B_2$) in January 2018. A 0.50 ha was designated for control treatments on each site. The field observations of phytosociology were recorded during November, 2018. A total number of 49 species was found at all three sites. The number of species varied from 27 at Lawasachowki ($B_2$) to 35 at Mangotimor (C). The diversity of shrubs ranged from 2.17 at Bagpashog ($B_2$) to 2.66 at Mangotimor (C), whereas for herbs it ranged from 2.82 at Mangotimor (C) and Lwasachowki (C) to 3.25 at Bagpashog ($B_2$). The density of shrubs and herbs of control (C) were significantly different from burning treatments ($B_1$ and $B_2$). The density and diversity of shrubs were found higher in control as compared to burning treatments on each sites and vice versa for herbs.
**Keywords:** *controlled burning, shrubs, herbs, density, diversity*

## Introduction

Himalaya is one of the hotspots of the biodiversity (Myers et al., 2000; Singh et al., 2009) and provides ecological niches for plants and human beings (Sharma et al., 2018). Himalaya provides various ecosystem services, sustain biodiversity, regulate hydrological integrity and maintain slope stability (Chawla et al., 2008; Sharma et al., 2009). The plant diversity and communities in Himalaya changes with environmental gradient and also due to variation in geological conditions, topography, river systems, rainfall, altitude and climate (Sharma et al., 2014). The climate change, human and cattle population pressure, over grazing, habitat loss (Sharma et al., 2014) and development of infrastructures like roads, are the major threats to Himalayan ecosystems leading to increased rate of ecological degradation and disturbance to the equilibrium of Himalayan mountain ecosystem (Ahmad et al., 1990). Forest fire is one of the major challenges and requires proper planning of land use management in the region (Avesani et al., 2000).

The forest fire impacts the ecosystems through variety of ways as biogeochemical cycling, atmospheric chemistry and ecosystem structures (Joseph et al., 2009) and also modifies the atmosphere by mixing the greenhouse gases (Simmonds et al., 2005; Chiriaco et al., 2013) and contribute in acceleration of climate change (Stocks et al., 1998; Kiem et al., 2006; Gavin et al., 2007). The forest fires destroy the biomass (Chiriaco et al., 2013; Jharya et al., 2014) and impacts nutrients availability in the soil (Verma et al., 2019) resulting into the accelerating the soil erosion on the slopes in the


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Himalaya. The forest fire contributes for altering the plant communities (Whelan, 1995; Arevalo, 2014) changes the dynamics and structure of vegetation of landscape (Baeza, 2007; Arevalo, 2014). The woody and non woody vegetation are prone to forest fire which lead to decrease in the moisture content on plants (West, 1965; Gandiwa, 2011) leading to chnages into the functioning of the plants. The forest fire can be prevented by improving awareness among the people about damages caused by the fire and also by employing the legal enforcement and application of suitable silviculture practices such as fire lines and controlled burning (Bhardwaj and Narkhede, 1997).

Chir pine (*Pinus roxburghii* Sarg.) forests in Western Himalayas are prone to forest fire with recurrent fire incidences (Negi et al., 2016). Fire in chir pine forest influence plant community structure and also causing huge economic and environmental losses (Negi et al., 2016; Konsam et al., 2017; Sannigrahi et al., 2020). The fire affected area in the chir pine forest constitutes 2.36% of forest area of India (FSI, 2019). The incidences of the forest fire is decreased by the old age practice of controlled burning during winter when surface temperature is low (Anderson, 1983; Rego et al., 1991; Brose et al., 1998; Blake et al., 2000; Allain and Grace, 2001; Hutchinson et al., 2005; Baeza et al., 2007; Knapp et al., 2007; Gairola et al., 2008; Brose, 2010; Gandiwa, 2011; Balch et al., 2013; Arevalo et al., 2014; Edgar and Griscom, 2017; Kumar, 2019; Kumar et al., 2020; Alba et al., 2021; Jaffe et al., 2021; Jang et al., 2021; Perles et al., 2021). However, succinct analysis and authenticated database on impact of controlled burning on woody and non woody vegetation in Chir pine forests is not available inspite of the fact that the controlled burning can assist to decrease the chances of forest fire in chir pine forest (Kumar et al., 2020).

The lack of information about the impacts and control of forest fire undermine the efforts of the forest department to control the recurrent fire. Moreover, forest fire leads huge losses to exchequer leading to loss of properties and lives (Negi et al., 2016). The impact of controlled burning on understorey of forests is poorly known, therefore, controlled burning evaluations are a requirement for the effective management of vegetation in the forest ecosystems. Moreover, under the current global changes, the evaluations of impacts of forest fire would guide for fire control mechanism and also led to refrain the losses of properties and lives.

With this in view, the study hypothesizes that the controlled burning affects the density and diversity of the forest fire fuel specially the shrubs and herbs of the forest ecosystems. Therefore, objective of the present study was to analyze the impact of controlled burning conducted twice on phytosociology of understory vegetation in chir pine forests. The result of the study would supplement to the current understanding about the forest fire control mechanism along with generation of specific knowledge about forest fire management.

## Material and methods

### *Selection of sites*

The study focuses the Indian Himalayan forests of the Nahan and Solan Forest Circles of Himachal Pradesh (HP), India. The focus of the study was higher altitude zone (>1200 m above mean sea level) in Upper Himalayan Chir pine Forests (Group 9/C1b as per Champion and Seth, 1968 classification of Forests of India). Total three sites i.e., Mangotimor, Bagpashog and Lawasachowki were selected randomly for investigations in the forests (*Table 1*, *Figs. 1 and 2*) in Parwanoo, Sarahan and Jamta


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Forest Ranges, respectively. The monthly weather details of the areas are reported in *Figs. 3 and 4*. The dominant species at study sites were *Pinus roxburghii* with associate species as *Quercus leucotrichophora*, *Myrica esculenta* and *Pyrus pashia*. The climate of the study sites was transition between sub-temperate and sub-tropical. The winter, summer and rainy seasons are found in the area and the precipitation in the region is received in the form of the rains. The calcareous shales, carbonaceous shales, dolomite limestone are found on the ground of chir pine forests (Gupta et al., 2009). The depth of the soil in the study sites varied from 40 cm to 70 cm. The slope of the sites ranged from 10° to 25°.

***Table 1.*** *Site details of the selected sites in Nahan and Solan Circles of Himachal Pradesh Forest Department*

| Name of the site | Name of Forest Division | Geo-coordinate | | Elevation (amsl) | Aspect |
|---|---|---|---|---|---|
| | | Latitude (N) | Longitude (E) | | |
| Mangotimor | Solan | $30^0$ 53′ 49.3″ | $077^0$ 00′ 06.5″ | 1550m | Sothern Eastern |
| Bagpashog | Rajgarh | $30^0$ 45′ 41.5″ | $077^0$ 09′ 52.6″ | 1522m | North West |
| Lawasachowki | Nahan | N$30^0$ 40′ 32.8″ | E$077^0$ 11′ 45.7″ | 1344m | Sothern Eastern |

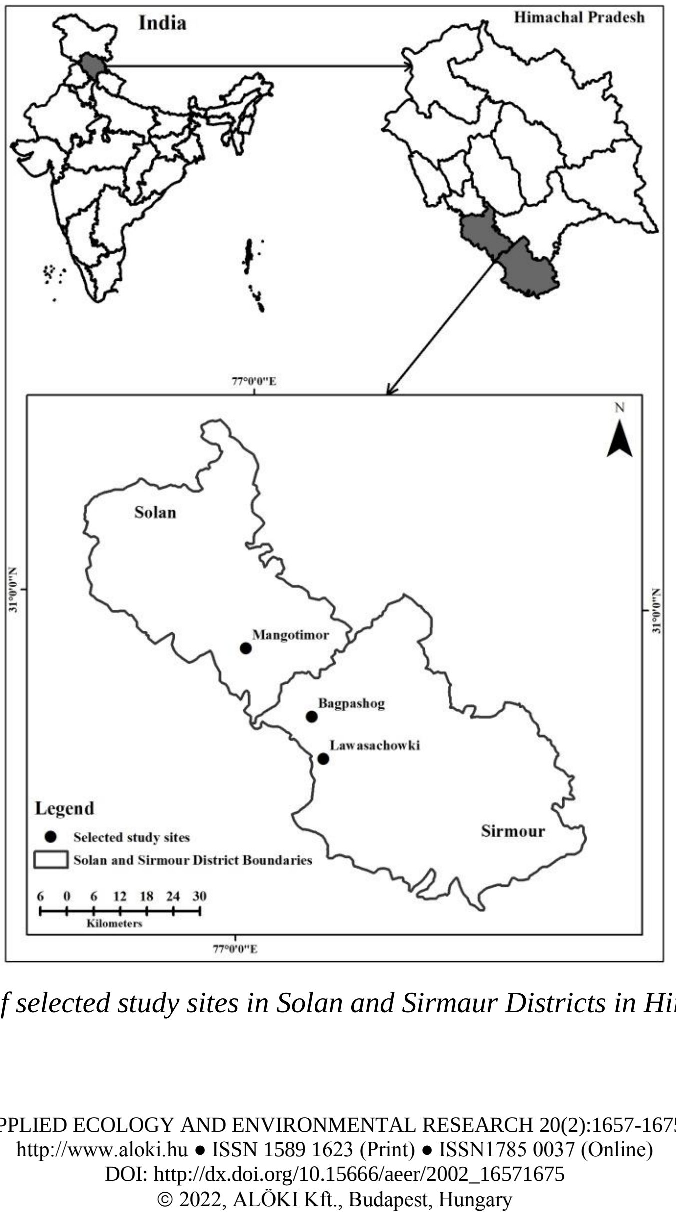


***Figure 1.*** *Map of selected study sites in Solan and Sirmaur Districts in Himachal Pradesh*

a) b) c)

***Figure 2.*** *Photographs of the study sites, a. Mangotimor b. Bagpashog and c. Lwasachowki*

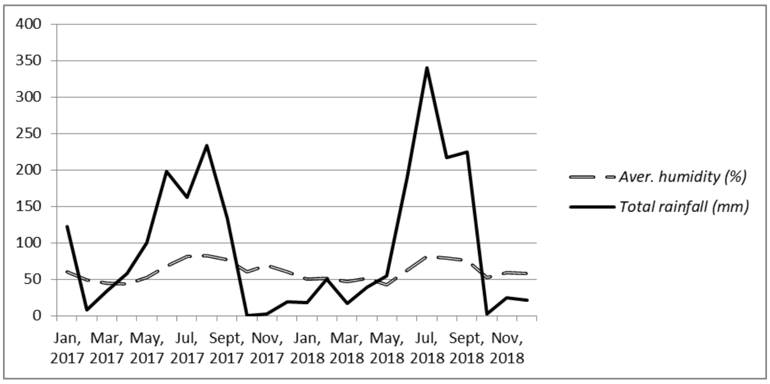


***Figure 3.*** *Monthly average humidity (%) and total rainfall (mm) from January 2017 to December, 2018*

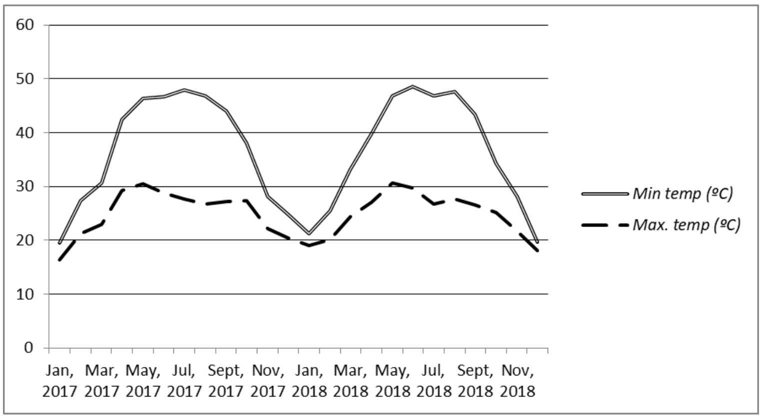


***Figure 4.*** *Monthly max. temp (ºC) and min. temp (ºC) from January 2017 to December, 2018*

## *Fire management treatment*

The forest fire can be managed by using controlled burning. Controlled burning is controlled firing of forest fuel either in their natural or modified state under specific environmental condition to fulfill the objective of plan resource management (Bhardwaj and Narkhede, 1997). The three treatments for forest fire evaluations were control (C), once burnt ($B_1$) and twice burnt ($B_2$). A total area of 2.00 ha homogenous patch of forests on each site was selected for the study and out of which the controlled burning ($B_1$) was conducted once in 1.50 ha on each site with 0.50 ha designated as control (C)


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during January, 2017. In January 2018, controlled burning was again conducted only in 1.00 ha out of the burnt area in 2017 on each site and considered as twice burnt ($B_2$), and remaining 0.50 ha of the burnt area in 2017 remains intact and treated as $B_1$. The designated control site of 0.50 of 2017 ha was control (C) on each site i.e. controlled burning was not undertaken on each sites in the area.

### *Collection of data*

Total 20 quadrates for shrubs and 40 quadrates for herbs on each site were laid out randomly in control (C), once burnt ($B_1$) and twice burnt ($B_2$) areas. The size of the quadrates was 5 m x 5 m for shrubs and 1mx1m for herbs (Mishra, 1968). The number of individual and diameter of shrubs, saplings of trees and herbs including natural regeneration of trees for phyto-sociological analysis were recorded in 0.50 ha, 0.50 ha and 1.00 ha for C, $B_1$ and $B_2$, respectively during November, 2018.

### *Analysis of data*

The density (D), frequency (F %), abundance (A) and importance value index (IVI) were determined as per Curtis and McIntosh, 1950. The sum total of relative value of density, basal area, and frequency was used for calculating IVI. Abundance to frequency ratio (A/F) was calculated and the distribution pattern (A/F) was used to categories as contiguous (>0.050), random (0.025-0.050) and regular (<0.050) (Curtis and Cottam, 1956). The Shannon-Wiener Diversity Index (H) was calculated for determining the plant diversity (*Eq. 1*) (Shannon-Wiener, 1963).

$$H = -\sum_{i=1}^{S} (ni/N)\, ln\, (ni/N) \qquad \text{(Eq.1)}$$

Concentration of dominance (Cd) was measured by Simpson’s Index (*Eq. 2*) (Simpson, 1949).

$$Cd = \sum_{i=1}^{S} (ni/N)^2 \qquad \text{(Eq.2)}$$

where ni = Importance value of species i and N= total importance value of all the species in both the indices.

### *Statistical analysis*

The effect of controlled burning on number of individuals of shrubs and herbs were evaluated as per the analysis of variance (ANOVA) with 3 treatments i.e. control (C), once burnt ($B_1$) and twice burnt ($B_2$). The mean of the four quadrates selected randomly from each patch i.e. for the three treatments was considered as one replication for herbs, whereas mean of two quadrates was treated as replication for shrubs. Total replications were ten for each treatment i.e., control (C), once burnt ($B_1$) and twice burnt ($B_2$) for shrubs and herbs on each site. The Least Significant Difference (LSD) test was applied for evaluation of critical difefrences between two treatment means.


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## Results

The phytosociological analysis was conducetd for collected field data. The differences in the impacts of the treatments were compared through ANOVA. The details of the analysis have been described in subsequent paragraphs for each site for shrubs and herbs.

A total of 49 species was found across the three sites which belong to 49 genera and 28 families. The number of species was 45 at C, 49 at $B_1$ and 45 at $B_2$. A total number of species in control was 28 at Lawasachowki and 32 at Mangotimor. The total number of species in once burnt ($B_1$) varied from 28 (Lawasachowki) to 35 (Mangotimor), whereas in twice burnt ($B_2$), the number of speices ranged from 27 (Lawasachowki) to 33 (Mangotimor).

*Carissa carandas, Myrsine africana, Rubus ellipticus* and saplings of *Pinus roxburghii* were present across three sites at all three treatments. *Buddleja asiatica* was present only in $B_2$ at Mangotimor (*Table 2*). The saplings of *Myrica esculenta* was present only in C at Bagpashog. The saplings of *Pistacia integerimma* and *Rosa moschata* were present in C and $B_1$ at Mangotimor. The saplings of *Punica granatum* at Mangotimor were present in $B_1$ respectively. The saplings of *Sapium insigne* were present only in C and $B_2$ at Lwasachowki (*Table 2*).

***Table 2.*** *Density/25 m$^2$ of shrubs under control (C) and burnt ($B_1$ and $B_2$) sites in Himalayan Chir Pine Forests*

| S.No. | Name of species | Mangotimor | | | Bagpashog | | | Lawasachowki | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | C | $B_1$ | $B_2$ | C | $B_1$ | $B_2$ | C | $B_1$ | $B_2$ |
| 1 | *Berberis lycium* | 1.05 | 0.95 | 0.5 | 1.5 | 1 | 0.75 | | | 0.75 |
| 2 | *Buddleja asiatica* | | | 0.4 | | | | | | |
| 3 | *Carissa carandas* | 3.7 | 1.3 | 0.75 | 0.95 | 0.75 | 0.4 | 1.75 | 1.25 | 0.65 |
| 4 | *Colebrookea oppositifolia* | 0.9 | | 0.4 | 1 | 0.8 | 0.65 | 0.9 | 1.2 | 0.5 |
| 5 | *Ficus palmata** | 0.5 | 0.55 | 0.5 | | | | | | |
| 6 | *Flacourtia indica** | 0.6 | | | | | | 0.95 | 0.95 | 0.25 |
| 7 | *Lantana camara* | 1.25 | 0.6 | 0.85 | | | | | | |
| 8 | *Maesa indica* | | | | | | | 1.45 | 1.45 | 0.95 |
| 9 | *Mallotus philippensis** | | | | | 0.35 | 0.2 | 0.7 | 0.6 | 0.3 |
| 10 | *Murraya koenigii* | | | | 0.7 | 1.45 | 0.45 | 1.5 | 1.25 | 0.95 |
| 11 | *Myrica esculenta** | | | | 0.55 | | | | | |
| 12 | *Myrsine africana* | 2.4 | 2.85 | 0.65 | 1.5 | 1 | 0.95 | 1.25 | 1.1 | 0.6 |
| 13 | *Pinus roxburghii** | 0.45 | 0.3 | 0.5 | 0.4 | 0.3 | 0.2 | 0.6 | 0.4 | 0.25 |
| 14 | *Pistacia integerimma** | 0.25 | 0.5 | | | | | | | |
| 15 | *Prinsepia utilis* | 1.15 | 1.45 | 0.4 | | | | | | |
| 16 | *Punica granatum** | | 0.3 | | | | | | | |
| 17 | *Pyrus pashia** | 0.5 | 0.65 | 0.4 | 0.55 | 0.4 | 0.25 | 1 | 0.6 | |
| 18 | *Rosa moschata* | 0.35 | 0.65 | | | | | | | |
| 19 | *Rubus ellipticus* | 1.4 | 1.05 | 0.5 | 1 | 0.6 | 0.4 | 1.95 | 1.1 | 0.4 |
| 20 | *Sapium insigne** | | | | | | | 0.9 | | 0.2 |
| 21 | *Toona ciliata** | 0.35 | | 0.25 | 0.35 | | | 0.4 | 0.5 | |
| 22 | *Woodfordia fruticose* | 0.45 | 0.5 | 0.6 | | | | 0.6 | 0.45 | |
| 23 | *Zanthoxylum armatum* | 0.75 | 0.95 | 0.35 | 0.9 | | | | | |
| TOTAL | | 16.05 | 12.6 | 7.05 | 9.4 | 6.65 | 4.25 | 13.95 | 10.85 | 5.8 |

* Saplings of trees


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The data on groundflora (herbs, seedlings/natural regeneration of trees and shrubs) of burnt and unburnt treatments revealed that *Adiantum lunulatum*, *Anaphalis triplinervis, Cheilanthes farinosa, Chrysopogon montanus, Cirsium wallichii, Cissampelos pareira, Dicliptera bupleuroides, Fragaria vesca, Heteropogon contortus, Oxalis corniculata, Viola serpens* along with seelings of *Pinus roxburghii* were present in all the treatments and sites (*Table 3*). The seedlings of *Ficus palmata* was present in $B_1$ and $B_2$ only at Bagpashog and Lwasachowki. The seedlings of *Flacourtia indica* were present in $B_1$ and $B_2$ at Lwasachowki. The seedlings of *Lantana camara* and *Sapium insigne* were present in $B_1$ and $B_2$ at Mangotimor. *Thymus linearis, Pteris cretica* and seedlings of *Myrica esculenta* and *Prinsepia utilis* were present in $B_1$ and $B_2$ at Bagpashog (*Table 3*).

### *Density of shrubs and herbs*

*A. Study site: Mangotimor*

*Density (Ind./25 m$^2$) of shrubs*

The highest density (3.70) at C was recorded for *Carisssa carandas* followed by *Myrsine africana* (2.40) and lowest (0.25) for *Pistacia integerrima* (*Table 2*). The maximum density (2.85) at once burnt ($B_1$) was found for *Myrsine africana* followed by *Prinsepia utilis* (1.45) and minimum (0.30) was recorded for *Pinus roxburghii* and *Punica granatum*. On twice burnt ($B_2$) site, maximum density (0.85) was recorded for *Lantana camara* followed by *Carissa carandas* (0.75) and minimum (0.25) for *Toona ciliata* (*Table 2*). Significance difference in total number of individuals/25 m$^2$ of all shrubs were found between C (16.05), $B_1$ (12.60) and $B_2$ (7.05) (*Table 4*).

*Density (Ind./m$^2$) of herbs*

The highest density (3.03) at C was recorded for *Carex meiogyna*, followed by *Chrysopogon montanus* (2.55) and lowest (0.08) was recorded for *Solanum xanthocarpum* and *Parthenium hysterophorus* (*Table 3*). At once burnt ($B_1$), highest density (5.88) was recorded for *Heteropogon contortus*, followed by *Chrysopogan montanus* (5.85) and lowest (0.18) was recorded for *Parthenium hysterophorus* at Mangotimor ($B_1$). The highest density (3.90) at twice burnt ($B_2$) was recorded for *Heteropogon contortus* followed by *Chrysopogan montanus* (3.83) and lowest (0.15) for *Sapium insigne* and *Anaphalis triplinervis* (*Table 3*). Significance difference in total number of individuals of all herbs/m$^2$ was observed between C (12.98), $B_1$ (36.23) and $B_2$ (22.93) (*Table 4*).

*B. Study site: Bagpashog*

*Density (Ind./25 m$^2$) of shrubs*

The highest density (1.50) at C was recorded for *Myrsine africana* and *Berberis lycium* followed by *Colebrookea oppositifolia* (1.00), *Rubus ellipticus* (1.00) and lowest (0.35) for *Toona ciliata* (*Table 2*). The highest density (1.45) at once burnt ($B_1$) was recorded for *Murraya koenigii*, followed by *Berberis lycium* (1.00), *Myrsine africana* (1.00) and least dominant (0.30) was *Pinus roxburghii*. The maximum density (0.95) at twice burnt ($B_2$) was recorded for *Myrsine africana* followed by *Berberis lycium* (0.75) and least dominant (0.20) was *Mallotus philippensis* and *Pinus roxburghii* (*Table 2*). Significance difference in number of individual/25 m$^2$ of all shrubs was found between C (9.40), $B_1$ (6.65) and $B_2$ (4.25) (*Table 4*).


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***Table 3.*** *Density /m² of herbs under control (C) and burnt ($B_1$ and $B_2$) sites in Himalayan Chir Pine Forests*

| **S.No.** | **Name of species** | **Mangotimor** | | | **Bagpashog** | | | **Lawasachowki** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **C** | **$B_1$** | **$B_2$** | **C** | **$B_1$** | **$B_2$** | **C** | **$B_1$** | **$B_2$** |
| 1 | *Adiantum lunulatum* | 1.03 | 1.65 | 2.03 | 0.45 | 0.53 | 0.73 | 0.45 | 0.53 | 0.73 |
| 2 | *Ageratum conyzoides* | | 3.28 | 1.13 | | | | 0.3 | 0.53 | 0.65 |
| 3 | *Ajuga bracteosa* | | | | 0.3 | 0.53 | 0.65 | | | |
| 4 | *Anaphalis triplinervis* | 0.33 | 0.43 | 0.15 | 0.38 | 0.65 | 0.75 | 0.38 | 0.65 | 0.75 |
| 5 | *Artemisia vulgaris* | | | | 0.23 | 0.5 | 0.63 | | | |
| 6 | *Berberis lycium*** | | 0.7 | 0.45 | 0.23 | 0.73 | 0.83 | | | |
| 7 | *Carex meiogyna* | 3.03 | 3.98 | 2.25 | | | | | | |
| 8 | *Carissa carandas* | 0.2 | 0.43 | 0.3 | | | | 0.23 | 0.5 | 0.63 |
| 9 | *Cheilanthes farinosa* | 0.2 | 1.73 | 0.85 | 0.28 | 0.55 | 0.3 | 0.25 | 0.73 | 0.83 |
| 10 | *Chrysopogon montanus* | 2.55 | 5.85 | 3.83 | 2.3 | 5.38 | 4.73 | 1.78 | 5.88 | 4.73 |
| 11 | *Cirsium wallichii* | 0.2 | 0.35 | 0.2 | 0.23 | 0.63 | 0.85 | 0.23 | 0.63 | 0.85 |
| 12 | *Cissampelos pareira* | 0.15 | 0.35 | 0.23 | 0.13 | 0.4 | 0.4 | 0.23 | 0.55 | 0.3 |
| 13 | *Dicliptera bupleuroides* | 0.23 | 1.48 | 0.7 | 0.4 | 0.35 | 0.5 | 0.38 | 0.35 | 0.5 |
| 14 | *Ficus palmata** | | | | | 0.53 | 0.55 | | 0.43 | 0.4 |
| 15 | *Flacourtia indica*** | | | | | | | | 0.53 | 0.55 |
| 16 | *Fragaria vesca* | 0.38 | 0.83 | 0.63 | 0.65 | 0.48 | 0.58 | 0.4 | 0.45 | 0.58 |
| 17 | *Galium aparine* | | 0.58 | 0.43 | 0.38 | 0.58 | 0.43 | | | |
| 18 | *Geranium wallichianum* | | 0.3 | 0.2 | 0.18 | 0.45 | 0.58 | 0.08 | 0.58 | 0.43 |
| 19 | *Heteropogon contortus* | 2.28 | 5.88 | 3.9 | 2.3 | 5.88 | 5.33 | 2.3 | 5.38 | 5.33 |
| 20 | *Hydrocotyle asiatica* | 0.4 | 0.75 | 0.35 | | | | | | |
| 21 | *Lantana camara*** | | 4.98 | 0.65 | | | | | | |
| 22 | *Leucas lanata* | | 0.45 | 0.6 | 0.25 | 0.73 | 0.65 | 0.38 | 0.73 | 0.65 |
| 23 | *Mallotus philippensis** | | | | | | | 0.18 | 0.35 | 0.5 |
| 24 | *Murraya koenigii*** | | | | | | | 0.38 | 0.78 | 0.65 |
| 25 | *Myrica esculenta*** | | | | | 0.33 | 0.5 | | | |
| 26 | *Myrsine africana*** | | | | 0.3 | 0.58 | 0.5 | 0.3 | 0.45 | 0.5 |
| 27 | *Oxalis corniculata* | 1.13 | 0.28 | 2.23 | 0.28 | 0.35 | 0.5 | 0.3 | 0.7 | 0.63 |
| 28 | *Parthenium hysterophorus* | 0.08 | 0.18 | 0.45 | | | | | | |
| 29 | *Pinus roxburghii** | 0.13 | 0.23 | 0.18 | 0.2 | 0.43 | 0.45 | 0.23 | 0.3 | 0.45 |
| 30 | *Prinsepia utilis*** | | | | | 0.63 | 0.48 | | | |
| 31 | *Pteris cretica* | | | | | 0.78 | 0.63 | | | |
| 32 | *Pyrus pashia** | 0.1 | 0.53 | 0.23 | 0.18 | 0.45 | 0.55 | | | |
| 33 | *Rubia cordifolia* | | | | 0.18 | 0.63 | 0.5 | | | |
| 34 | *Rubus ellipticus*** | 0.15 | | | 0.25 | 0.35 | 0.65 | 0.2 | 0.38 | 0.48 |
| 35 | *Sapium insigne* | | 0.23 | 0.15 | | | | | | |
| 36 | *Solanum xanthocarpum* | 0.08 | | | 0.3 | 0.78 | 0.5 | | | |
| 37 | *Sonchus asper* | | | | 0.28 | 0.45 | 0.63 | 0.23 | 0.53 | 0.55 |
| 38 | *Thalictrum foliolosum* | 0.15 | 0.43 | 0.25 | | | | | | |
| 39 | *Thymus linearis* | | | | | 0.7 | 0.53 | | | |
| 40 | *Viola serpens* | 0.13 | 0.43 | 0.6 | 0.28 | 0.38 | 0.63 | 0.2 | 0.83 | 0.8 |
| 41 | *Zanthoxylum armatum*** | 0.1 | | | 0.23 | 0.53 | 0.45 | | | |
| TOTAL | | 13.03 | 36.31 | 22.97 | 11.17 | 26.27 | 25.99 | 9.41 | 22.77 | 22.47 |

*Natural regeneration of trees and ** Natural regeneration of the shrubs


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***Table 4.*** *Mean and result of ANOVA for density of shrubs and herbs under control (C) and burnt ($B_1$ and $B_2$) traetment in the selected sites in Himalayan Chir Pine Forests*

| **Name of site** | **Treatment (Mean)** | | | | **F value** | | **LSD$_{(0.05)}$** |
|---|---|---|---|---|---|---|---|
| | **C** | **$B_1$** | **$B_2$** | **SE** | **Calculated** | **Critical value** | |
| Shrubs | | | | | | | |
| Mangotimor | 16.05 | 12.6 | 7.05 | 1.222 | 13.151 | 3.554 | 2.568 |
| Bag Pashog | 9.40 | 6.65 | 4.25 | 0.73 | 24.894 | 3.554 | 1.53 |
| LawasaChowki | 13.95 | 10.85 | 5.80 | 0.75 | 60.860 | 3.554 | 1.57 |
| Herbs | | | | | | | |
| MangotiMor | 12.98 | 36.23 | 22.93 | 2.791 | 34.919 | 3.554 | 5.865 |
| Bag Pashog | 11.10 | 26.175 | 25.92 | 2.861 | 18.201 | 3.554 | 6.011 |
| LawasaChowki | 9.35 | 22.70 | 22.43 | 1.899 | 32.269 | 3.554 | 3.990 |

*Density (Ind./m$^2$) of herbs*

The highest density (2.30) at C was recorded for *Heteropogon contortus* and *Chrysopogon montanus* followed by *Fragaria vesca* (0.65) and least dominant (0.13) was *Cissampelos pareira* (*Table 3*). The maximum density (5.88) at once burnt ($B_1$) was recorded for *Heteropogon contortus*, followed by *Chrysopogon montanus* (5.38) and minimum (0.33) for *Myrica esculenta*. The maximum density (5.33) at twice burnt ($B_2$) was recorded for *Heteropogon contortus* followed by *Chrysopogon montanus* (4.73) and minimum (0.30) for *Cheilanthes farinosa* (*Table 3*). The number of individuals of all herbs/m$^2$ was significantly different between C (11.10), $B_1$ (26.17) and $B_2$ (25.92). No significant difference was found between $B_1$ (26.17) and $B_2$ (25.92) (*Table 4*).

*C. Study site: Lawasachowki*

*Density (Ind./25 m$^2$) of shrubs*

The highest density (1.95) at C was shown by *Rubus ellipticus* followed by *Carissa carandas* (1.75) and lowest (0.40) for *Toona ciliata* (*Table 2*). The maximum density (1.45) at once burnt ($B_1$) was recorded for *Maesa indica* followed by *Carissa carandas* (1.25) and minimum (0.40) for *Pinus roxburghii*. *Maesa indica* (0.95) and *Murraya koenigii* (0.95) at twice burnt ($B_2$) showed highest value for density (Ind/25 m$^2$) followed by *Berberis lycium* (0.75) and least dominant (0.20) was *Sapium insigne* (*Table 2*). Significant difference in number of individuals/25 m$^2$ of all shrubs was found between C (13.95), $B_1$ (10.85) and $B_2$ (5.80) (*Table 4*).

*Density (Ind./m$^2$) of herbs*

The maximum density (2.30) at C was recorded for *Heteropogon contortus* followed by *Chrysopogon montanus* (1.78) and minimum (0.08) for *Geranium wallichianum* (*Table 3*). The highest density (5.88) at once burnt ($B_1$) was recorded for *Chrysopogon montanus* followed by *Heteropogon contortus* (5.38) and lowest (0.30) for *Pinus roxburghii*. Maximum value of density at twice burnt ($B_2$) was observed for *Heteropogon contortus* (5.33), followed *Chrysopogon montanus* (4.73) and lowest (0.30) for *Cissampelos pareira* (*Table 3*). The number of individuals of all herbs/m$^2$ between C (9.35) was significantly different from $B_1$ (22.70) and $B_2$ (22.43), whereas no significant difference was found between $B_1$ (22.70) and $B_2$ (22.43) (*Table 4*).


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### *Dominance of shrubs and herbs the basis of importance value index (IVI)*

*A. Dominance of shrubs*

*Carissa carandas* (44.04), *Myrsine africana* (38.56) and *Carissa carandas* (30.84) were dominant species at C, $B_1$ and $B_2$, respectively at Mangotimor. *Pinus roxburghii* had the least IVI (10.70) at C and 10.69 at $B_1$ at Mangotimor. The least dominant was *Toona ciliata* (11.11) at $B_2$ at Mangotimor (*Table 5*).

***Table 5.*** *Importance value index (IVI) of shrubs under control (C) and burnt ($B_1$ and $B_2$) sites in Himalayan Chir Pine Forests*

| S.No. | Name of species | Mangotimor | | | Bagpashog | | | Lawasachowki | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | C | $B_1$ | $B_2$ | C | $B_1$ | $B_2$ | C | $B_1$ | $B_2$ |
| 1 | *Berberis lycium* | 18.26 | 19.04 | 17.75 | 41.64 | 32.88 | 43.07 | | | 32.72 |
| 2 | *Buddleja asiatica* | | | 16.28 | | | | | | |
| 3 | *Carissa carandas* | 44.04 | 23.81 | 30.84 | 28.91 | 32.43 | 32.23 | 31.06 | 25.81 | 29.6 |
| 4 | *Colebrookea oppositifolia* | 13.06 | | 20.15 | 30.4 | 31.2 | 38.99 | 15.82 | 27.56 | 26.49 |
| 5 | *Ficus palmata** | 12.09 | 14.78 | 20.4 | | | | | | |
| 6 | *Flacourtia indica** | 13.96 | | | | | | 22.82 | 25.5 | 21.4 |
| 7 | *Lantana camara* | 16.24 | 13.46 | 25.28 | | | | | | |
| 8 | *Maesa indica* | | | | | | | 31.23 | 34.89 | 34.53 |
| 9 | *Mallotus philippensis** | | | | | 23.54 | 22.98 | 16.84 | 18.94 | 25.74 |
| 10 | *Murraya koenigii* | | | | 23.37 | 44.5 | 36.98 | 27.98 | 32.76 | 33.16 |
| 11 | *Myrica esculenta** | | | | 20.87 | | | | | |
| 12 | *Myrsine africana* | 34.89 | 38.56 | 27.3 | 38.12 | 35.68 | 45.74 | 25.6 | 30.52 | 31.81 |
| 13 | *Pinus roxburghii** | 10.7 | 10.69 | 23.67 | 14.4 | 32.26 | 22.61 | 21.39 | 18.85 | 21.32 |
| 14 | *Pistacia integerimma** | 15.55 | 18.02 | | | | | | | |
| 15 | *Prinsepia utilis* | 21.13 | 32.64 | 18.69 | | | | | | |
| 16 | *Punica granatum** | | 30.23 | | | | | | | |
| 17 | *Pyrus pashia** | 17.79 | 21.92 | 21.12 | 22.86 | 31.65 | 26.24 | 24.5 | 22.81 | |
| 18 | *Rosa moschata* | 11.16 | 17.57 | | | | | | | |
| 19 | *Rubus ellipticus* | 22.54 | 25.19 | 21.57 | 30.26 | 35.87 | 31.17 | 26.92 | 24.2 | 24.84 |
| 20 | *Sapium insigne** | | | | | | | 26.23 | | 18.38 |
| 21 | *Toona ciliata** | 12.41 | | 11.11 | 20.15 | | | 15.34 | 19.02 | |
| 22 | *Woodfordia fruticosa* | 10.76 | 15.47 | 21.52 | | | | 14.28 | 19.13 | |
| 23 | *Zanthoxylum armatum* | 25.43 | 18.63 | 24.33 | 29.03 | | | | | |
| TOTAL | | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 |

*Saplings of trees

*Berberis lycium* (41.64), *Murraya koenigii* (44.5) and *Myrsine africana* (45.74) was dominant species at C, $B_1$ and $B_2$, respectively at Bagpashog. The least dominant at Bagpashog was *Pinus roxburghii* (14.40), *Mallotus philippensis* (23.54) at $B_1$ and *Pinus roxburghii* (22.61) at $B_2$ (*Table 5*).

*Maesa indica* was dominant species in treatments i.e., C (31.23) and $B_1$ (34.89) at Lawasachowki, whereas *Maesa indica* (34.53) showed highest value of importance value index (IVI) for dominant species at $B_2$. The least dominant was *Woodfordia fruitcosa* (14.28) at C, *Pinus roxburghii* (18.85) at $B_1$ and *Sapium insigne* (18.38) at $B_2$ at Lawasachowki (*Table 5*).


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*B. Dominance of herbs*

*Heteropogon contortus* showed the highest IVI value (42.87) at Mangotimor (C) and 44.82 at Lawasachowki ($B_1$) (*Table 6*). The least dominant at Mangotimor was *Cissampelos pareira* (4.04) at C, *Leucas lanata* (4.53) at $B_1$, *Circium wallichii* (3.48) at $B_2$. At Lawasachowki, the least dominant was *Geranium wallichianium* (3.46) at C, *Myrisine africana* (6.75) at $B_1$ and *Geranium wallichianum* (5.32) at $B_2$ (*Table 6*).

***Table 6.*** *Importance value index (IVI) of herbs under control (C) and burnt ($B_1$ and $B_2$) sites in Himalayan Chir Pine forests*

| S.No. | Name of species | Mangotimor | | | Bagpashog | | | Lawasachowki | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | C | $B_1$ | $B_2$ | C | $B_1$ | $B_2$ | C | $B_1$ | $B_2$ |
| 1 | *Adiantum lunulatum* | 17.58 | 16.44 | 20.08 | 9.57 | 12.35 | 9.87 | 9.88 | 14.19 | 12.51 |
| 2 | *Ageratum conyzoides* | | 14.97 | 13.24 | | | | 7.67 | 7.12 | 9.67 |
| 3 | *Ajuga bracteosa* | | | | 7.52 | 5.98 | 7.74 | | | |
| 4 | *Anaphalis triplinervis* | 6.03 | 10.23 | 6.58 | 17.03 | 10.01 | 10.5 | 36.71 | 11.61 | 13.27 |
| 5 | *Artemisia vulgaris* | | | | 13.99 | 8.59 | 11.73 | | | |
| 6 | *Berberis lycium*** | | 9.27 | 10.58 | 5.5 | 6.68 | 6.27 | | | |
| 7 | *Carex meiogyna* | 39.61 | 22.12 | 21.34 | | | | | | |
| 8 | *Carissa carandas* | 15.53 | 12.96 | 8.45 | | | | 13.05 | 10.01 | 15.1 |
| 9 | *Cheilanthes farinosa* | 10.24 | 11.85 | 9.25 | 8.03 | 14.07 | 7.21 | 5.96 | 7.94 | 7.67 |
| 10 | *Chrysopogon montanus* | 35.91 | 26.88 | 27.59 | 34.65 | 37.99 | 30.9 | 36.95 | 42.58 | 36.86 |
| 11 | *Cirsium wallichii* | 10.22 | 7.97 | 3.48 | 7.08 | 7.95 | 7.96 | 5.95 | 9.33 | 9.76 |
| 12 | *Cissampelos pareira* | 4.04 | 9.11 | 7.49 | 9.04 | 5.77 | 8.62 | 11.58 | 16.1 | 9.35 |
| 13 | *Dicliptera bupleuroides* | 9.11 | 12.26 | 12.49 | 14.69 | 7.85 | 6.11 | 8.38 | 9.01 | 7.57 |
| 14 | *Ficus palmata** | | | | | 8.22 | 9.69 | | 9.81 | 11.06 |
| 15 | *Flacourtia indica*** | | | | | | | | 9.62 | 12.33 |
| 16 | *Fragaria vesca* | 11.43 | 9.99 | 7.19 | 12.09 | 7.18 | 7.26 | 14.23 | 8.55 | 9.08 |
| 17 | *Galium aparine* | | 12.19 | 5.82 | 20.05 | 8.97 | 4.31 | | | |
| 18 | *Geranium wallichianum* | | 6.82 | 4.3 | 11.57 | 7.34 | 7.26 | 3.46 | 10.45 | 5.32 |
| 19 | *Heteropogon contortus* | 42.87 | 29.35 | 29.35 | 33.55 | 35.89 | 36.03 | 41.9 | 44.82 | 43.11 |
| 20 | *Hydrocotyle asiatica* | 11.16 | 8.39 | 4.7 | | | | | | |
| 21 | *Lantana camara*** | | 20.53 | 9.35 | | | | | | |
| 22 | *Leucas lanata* | | 4.53 | 8.58 | 11.11 | 6.87 | 7.22 | 18.77 | 8.15 | 8.9 |
| 23 | *Mallotus philippensis** | | | | | | | 10.78 | 9.42 | 7.54 |
| 24 | *Murraya koenigii*** | | | | | | | 12.01 | 8.93 | 12.17 |
| 25 | *Myrica esculenta*** | | | | | 6.87 | 6.08 | | | |
| 26 | *Myrsine africana*** | | | | 7.96 | 8.97 | 6.08 | 8.05 | 6.75 | 11.56 |
| 27 | *Oxalis corniculata* | 15.17 | 4.9 | 21.03 | 7.71 | 8.15 | 9.05 | 8.03 | 9.49 | 12.17 |
| 28 | *Parthenium hysterophorus* | 7.09 | 5.8 | 11.17 | | | | | | |
| 29 | *Pinus roxburghii** | 13.08 | 6.54 | 8.19 | 9.77 | 7.25 | 11.06 | 15.87 | 7.87 | 14.32 |
| 30 | *Prinsepia utilis*** | | | | | 7.95 | 10.51 | | | |
| 31 | *Pteris cretica* | | | | | 7.49 | 9.57 | | | |
| 32 | *Pyrus pashia** | 8.04 | 9 | 14.9 | 5.62 | 7.75 | 6.2 | | | |
| 33 | *Rubia cordifolia* | | | | 11.57 | 7.95 | 9.01 | | | |
| 34 | *Rubus ellipticus*** | 6.8 | | | 11.11 | 8.15 | 9.58 | 9.28 | 8.87 | 13.56 |
| 35 | *Sapium insigne* | | 13.74 | 18.71 | | | | | | |
| 36 | *Solanum xanthocarpum* | 10.81 | | | 7.96 | 7.49 | 9.05 | | | |
| 37 | *Sonchus asper* | | | | 7.71 | 5.65 | 9.57 | 6.1 | 10.35 | 7.67 |
| 38 | *Thalictrum foliolosum* | 6.15 | 6.76 | 7.6 | | | | | | |
| 39 | *Thymus linearis* | | | | | 8.01 | 9.63 | | | |
| 40 | *Viola serpens* | 7.49 | 7.42 | 8.54 | 8.03 | 7.72 | 9.57 | 15.39 | 19.03 | 9.44 |
| 41 | *Zanthoxylum armatum*** | 11.64 | | | 7.08 | 8.89 | 6.35 | | | |
| TOTAL | | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 |

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At Bagpashog, *Chrysopogon montanus* showed highest value of IVI (34.65) at C and 37.99 at $B_1$, whereas *Heteropogon contortus* (36.03) was dominant species at $B_2$. The least dominant was *Berberis lycium* (5.5) at C, *Sonchus asper* (5.65) at $B_1$, *Galium aparine* (4.31) at $B_2$ at Bagpashog (*Table 6*).

### Distribution pattern

The distribution pattern was contiguous (A/F >0.05) for all the shrubs, saplings and herbs at all three sites.

### Concentration of dominance (Cd)

The highest value of Cd for shrubs (*Table 7*) was 0.117 at Bagpashog ($B_2$) followed by 0.114 at Bagpashog ($B_1$) site and lowest (0.075) at Mangotimor ($B_2$). The highest value of Cd for herbs (*Table 8*) was 0.075 at Mangotimor (C) preceded by 0.074 at Lwasachowki (C) site and lowest (0.048) at Bagpashog ($B_2$).

***Table 7.*** *Concentration of dominance (C) and diversity index (H) for shrubs under control (C) and burnt ($B_1$ and $B_2$) sites in Himalayan Chir Pine Forests*

| Name of site | Control (C) | | Burnt ($B_1$) | | Burnt ($B_2$) | |
|---|---|---|---|---|---|---|
| | Cd | H | Cd | H | Cd | H |
| Mangotimor | 0.079 | 2.66 | 0.080 | 2.58 | 0.075 | 2.61 |
| Bagpashog | 0.098 | 2.36 | 0.114 | 2.19 | 0.117 | 2.17 |
| Lwasachowki | 0.082 | 2.53 | 0.087 | 2.46 | 0.094 | 2.38 |

***Table 8.*** *Concentration of dominance (C) and diversity index (H) for herbs under control (C) and burnt ($B_1$ and $B_2$) sites in Himalayan Chir Pine Forests*

| Name of site | Control (C) | | Burnt ($B_1$) | | Burnt ($B_2$) | |
|---|---|---|---|---|---|---|
| | Cd | H | Cd | H | Cd | H |
| Mangotimor | 0.075 | 2.82 | 0.052 | 3.09 | 0.054 | 3.06 |
| Bagpashog | 0.055 | 3.07 | 0.052 | 3.22 | 0.048 | 3.25 |
| Lwasachowki | 0.074 | 2.82 | 0.068 | 2.94 | 0.063 | 2.97 |

### Shannon-Wiener index (H)

The highest value of Shannon-Wiener index (H) for shrubs (*Table 7*) was 2.66 at Mangotimor (C) followed by 2.61 at Mangotimor ($B_2$) and lowest was 2.17 at Bagpashog ($B_2$). The highest value of Shannon-Wiener Index (H) for herbs was 3.25 at Bagpashog ($B_2$) followed by 3.22 at Bagpashog ($B_1$) and lowest was 2.82 at Mangotimor (C) and Lwasachowki (C) (*Table 8*).

## Discussion

The floristic composition and structure of communities are the main attributes of the forest ecosystems and depend upon environment and anthropogenic activities (Gairola et al., 2008; Shaheen et al., 2012; Bisht and Bhatt, 2013; Dar and Sundarapandian, 2016) like burning. The control burning in forests is a mechanism applied for management of forest fire (Whelan, 1995; Arevalo et al., 2014) and has been significantly affected by the number of individuals of shrubs and herbs of chir pine forests and depend on time, intensity and way of controlled burning undertaken. The intensity of controlled burning also decides the floristic composition as the low intensity fire substantially changes the understory composition and density (Brown, 1960; Swan, 1970; Nyland et al., 1982; Reich et al., 1990; Blake and Schuette, 2000). The change in composition of woody plants after burning is observed by Blake and Schuette (2000). In the study, controlled burning did not completely burn all available fuel loads on the ground rather total number of shrubs varied from 9 at Bagpashog ($B_1$ and $B_2$) to 16 at Mangotimor (C). The probable cause may be the associated factors which restrict the complete loss of fuel loads on the site. Moreover, the intensity of burning depends on temperature, wind speed, humidity, aspect, slope, plant type and fuel load (Maclean, 1992; Pyne and Bryant, 1994; Pyne, 1997; Blake and Schuette, 2000).

The result indicates that the controlled burning has varied impacts on woody vegetation of understory and herbs on the ground floor in chir pine forests. However, literature on the aspects for the chir pine forests is lacking. The consistent pattern for IVI was not observed for shrubs and herbs in all the three treatments and similar as Kumar et al. (2020). Density and diversity of shrubs were higher in control as compared to fire occurrence for both the burnt treatments and similar to Allain and Grace (2001). The new shoots of shrubs and natural regeneration of trees which emerge after controlled burning are easily palatable and grazed by cattle, however, these new shoots attract the herbivores in the burnt sites. The burning with intensity of the grazing affects the natural regeneration of trees and shrubs and ultimately affecting the diversity of woody vegetation of understory. The controlled burning also destroys the woody plants and has also been reported by various workers (Ensline et al., 2000; Gandiwa and Kativu, 2009; Gandiwa, 2011). The re-sprouting of woody vegetation has also been reported for woody plants after burning (Marrinan et al., 2005; Gandiwa, 2011). The higher temperature during burning decreases physiological functions, growth and increases the mortality of seedlings (Smith et al., 2017; Sharma et al., 2020). These are probable reasons of low density and diversity of shrubs and saplings of trees. The establishment of natural regeneration after burning was poor due to grazing pressure on the sites. The density and diversity after burning can be increased by following rotational grazing.

Total number of herbs varied from 21 at Lawasachowki (C) and Mangotimor (C) to 30 at Bagpashog ($B_1$ and $B_2$). Total density and diversity of herbs were higher in burnt sites ($B_1$ and $B_2$) as compared to C and is supported by various researchers (Elliot et al., 1999; Royo et al., 2010; Kumar et al., 2020). Density of the herbs was increased after controlled burning and may be due to decrease in competition among different species for soil nutrient and increase in solar insolation. The frequent occurrence of forest fire in chir pine forests (Kumar and Thakur, 2008; Singh et al., 2016; Attri et al., 2020) led to adaptation to forest fire. The various researchers have also reported the higher stems per plant in burnt sites as compared to unburnt sites (San Jose and Farinas, 1983; Scholes and Walker, 1993; Ensline et al., 2000). The higher density of herbs also changes or improves the microclimate of burnt sites by reducing soil erosion. The present result reveals that controlled burning significantly affect the number of the individuals of shrubs and herbs. The contiguous distribution pattern was observed for shrubs and herbs and has also been reported by as a common phenomenon in forest (Kershaw, 1973; Singh and Yadava, 1974; Kunhikannan et al., 1998; Gairola et al., 2011; Dar and


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Sundarpandian, 2016; Kumar et al., 2020). The variation in distribution pattern depends upon microenvironment and biotic factors (Joshi and Tiwari, 1990; Dar and Sundarpandian, 2016). The various factors like slope, soil type and soil moisture affect abundance and distribution pattern of the species (Nigh et al., 1985; Pallardy et al., 1988; Taft et al., 1995; Blake and Schuette, 2000). The higher value of concentration of dominance for herbs in control sites and shrubs in burnt sites revealed the homogeneous nature of community (Kohli et al., 2004; Kumar et al., 2020). The effect of the burning is mainly determined by intrinsic nature of understory vegetation which tends to regain its original structure (Fernandes and Botelho, 2003; Marino et al., 2010).

## Conclusions

The diversity and density of shrubs were higher in control as compared to burnt sites. The diversity and density of herbs were higher in burnt sites as compared to control. The study concludes that controlled burning may be beneficial for forest management as burning may modify the diversity of the species while maintaining the density for the chir pine forests of the Indian Himalayan region as frequent forest fire has been noted in the recent years in the region. The significance of the study is many folds as the comparative analysis reveals the importance of burning for the forest management alongwith generating the information about the controlled burning impact analysis. The study may be applicable at local level however for larger spatial domain needs further evaluation on actual ground level basis. Interestingly, the forest fire occurs in small patch of land but in absence of proper management practices it converts into a large fire incidences leading to huge loss, however checking the fire at local level by controlled burning may reduce the chances of big fire in forests.

The study conculdes that the burning has immediate impacts on the diversity and density of the herbs and shurbs of the forest. The recording of the observations on same phytosociological parameter after long duration on these sites may be made to observe the responses and for specific recommendation. Therefore, forest mangement should be reorient for immediate silvicultural treatment for strenghtening and managing the understorey.

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