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Effect of Wildfire on Herbaceous Vegetation in Cypress Mixed Oak Forest of Nainital, Kumaun Himalaya, India

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Abstract

Forest fire has diverse impacts on atmospheric chemistry, biogeochemical cycling and ecosystem structure and has adverse ecological, economic and social implications. Besides directly damaging the forest trees, the fire also adversely affects forest regeneration, microclimate, soil erosion, and wild life. In most of the cases, the forest fire causes retrogression of forest vegetation. Present study examined the effect of wildfire on herbaceous vegetation in cypress mixed oak forest of Nainital, Kumaun Himalaya, India. The study site is present at and around Aryabhatta Research Institute of Observational Science in Nainital district and three sites (viz., hill base [1750 m] hill slope [1800m] and hill top [1850 m]) were selected. The results revealed that a total of 36 herb species representing 18 families were identified, Asteraceae (7 species) being the most rich family with maximum number of herb species. Total herb density was 19.60 ind.m^{-2} at hill base, 21.8 ind.m^{-2} at hill slope and 33.7 ind.m^{-2} at hill top. The total herb biomass was 212.57 gm^{-2} at hill base, 116.22 gm^{-2} at hill slope and 141.97 gm^{-2} at hill top. The species composition and richness were significantly affected by burning, the magnitude of effect was generally small. Overall the differences were observed in species composition after fire as a larger group of perennial herbs, primarily grasses and summer forbs, exhibited the changes in density and biomass and overall biodiversity decreased after fire.

Keywords: Biomass; Density; Herb; Indian Himalaya; Wildfire

Introduction

The Central Himalaya accounts for 8.68% of the total Indian Himalayan region (59,436 km^2) and harbors rich biodiversity due to geographical and geological peculiarities subtending a wide range of vegetation types [1]. The Himalaya is recognized for its ecosystem services to the Asian region as well as to the world at large for maintaining slope stability, regulating hydrological integrity, sustaining high levels of biodiversity and human wellbeing. The Himalayan biodiversity is severely threatened by natural (catastrophic wind, landslides) and anthropogenic means (overgrazing, overlopping, habitat fragmentation due to overpopulation). The various disturbances present in the area are eroding this rich biological diversity day by day and has led to the expansion of xerophytic conditions [2]. One of the most prevalent causes of global deforestation and destruction of wildlife is fire. Forest fire is one of the major disasters in the forests of Uttarakhand that adversely affect many indigenous and endangered species every year. Forest fires spread at different speeds depending on vegetation, weather conditions, and physical features.

Quercus is possibly the greatest natural ecosystem-forming genus of the world, it serves as a 'keystone' species in the region because of its significant contribution in soil and water conservation and to sustain rural ecosystems [3]. The major forest forming species of the moist temperate forest of the Indian Himalayan region are Oaks (*Quercus* spp.) [3,4] and Cypress (*Cupressus torulosa*) [5]. The genus *Quercus* (oaks) belong to the family Fagaceae. Oaks are one of the most important groups of flowering plants and dominate large regions of the Northern Hemisphere [4]. *Quercus* includes about 35 species distributed between 1000-3500 m elevations in Indian Himalayan region. Among the 35 species of Oaks, 5 species are evergreen and grow naturally in the Uttarakhand state.

Associated with these oak woodlands is *Cupressus torulosa* D. Don, commonly known as Himalayan cypress which is an evergreen tree in the family Cupressaceae. This species is distributed throughout the Himalayan region at elevation between 1800 to 2800m [6]. It is indigenous to Western Himalaya and distributed throughout the outer and middle ranges of Himalaya from Chamba (HP) to the Nepal [7,8]. These forests are of immense significance from the environmental conservation and sustainable development view point as they provide a diverse range of resources and contribute significantly in carbon sequestration and water purification [9].

The herbaceous layer, also referred to as understory or ground layer vegetation is generally defined as all plants (woody or herbaceous) <1m in height, though taller woody vegetation may be included [10,11]. Plants in the understorey layer, maintain the structure and functioning of forests [2,4,12-14]. It is considered that oak and mixed oak forests support the herbaceous diversity [3,4]. Across oak forest landscapes, the herbaceous layer harbors great majority of plant diversity, including most rare plant species. In diverse landscapes and significant topographic heterogeneity, herb layer composition and diversity vary along with aspect related gradients of microclimate, soil moisture and fertility [15]. However, increasing anthropogenic pressures such as population explosion, overgrazing, land degradation for agricultural purposes within Himalayan zone from some decades has caused extensive deforestation, massive soil erosion in the hills, floods in the plains and consequently the silting of rivers [16].

Herb layer vegetation is also affected by natural and anthropogenic disturbances to the tree canopy, individual tree falls, catastrophic wind events and timber harvesting, which result in large increase in resource availability [11,17,18].

Fire is a common feature in Indian Himalayan forests every year, causing incalculable damage to the forest wealth and ecosystem. Any fire on a forestland which was not being used as a tool in forest protection and management and is not in accordance with an authorized plan may be referred to as a wildfire [18,19]. Primary causes of wildfires may be natural including lightening or volcanic eruption or human induced including smoking, unattended campfires, burning debris and fireworks. Surface fires usually cause minor damage to overstory trees but affect herb layer vegetation directly by killing aboveground stems and indirectly by altering the forest floor and the availability of light, water and nutrients [20,21]. Spatial and temporal variation in severity within a fire can have long-lasting impacts on the structure and species composition of post-fire communities and the potential for future disturbances [22]. Several studies showed variable effects of fire on herb layer-vegetation in oak forests [23-26].

In India, normal fire season extends from February to mid-June, early summer months are most prone to human induced fire. Frequently, many fires are caused during the burning of crop remains in the agricultural fields that are located near forest or due to a live cigarette or bidi butt thrown on the ground, even due to cooking and campfire activities of local people or tourists. Sometimes the local people deliberately set fire in Chir Pine (*Pinus roxburghii*) forests to promote growth of understory herbaceous vegetation which can be used as fodder during the monsoon season. In the summer of 2015, there was a severe fire in Uttarakhand Himalaya including the study area so an attempt has been made to highlight the effects of fire as an agent of transformation which affects biotic and abiotic component of natural ecosystem and thus altering productive, protective functions and services of forest ecosystems. The present paper is an attempt to analyze the effect of wildfire on herbaceous vegetation in cypress mixed oak forests of Nainital, Kumaun Himalaya, India.

Materials and Methods

Study Site

The study area is located near the town of Nainital (29°23′N - 79°27′E, 29.38°N- 79.45°E) at an altitude of 1,950 meters above sea level in Kumaun Himalaya. The study site was present at and around Aryabhatta Research Institute of Observational Sciences (ARIES) (1900 m) in Nainital district and three sites (viz., hill base [1750 m] hill slope [1800m] and hill top [1850 m] were selected (Photo plate 1). During 2015, in summers there was a heavy fire in Uttarakhand Himalaya including the study area.

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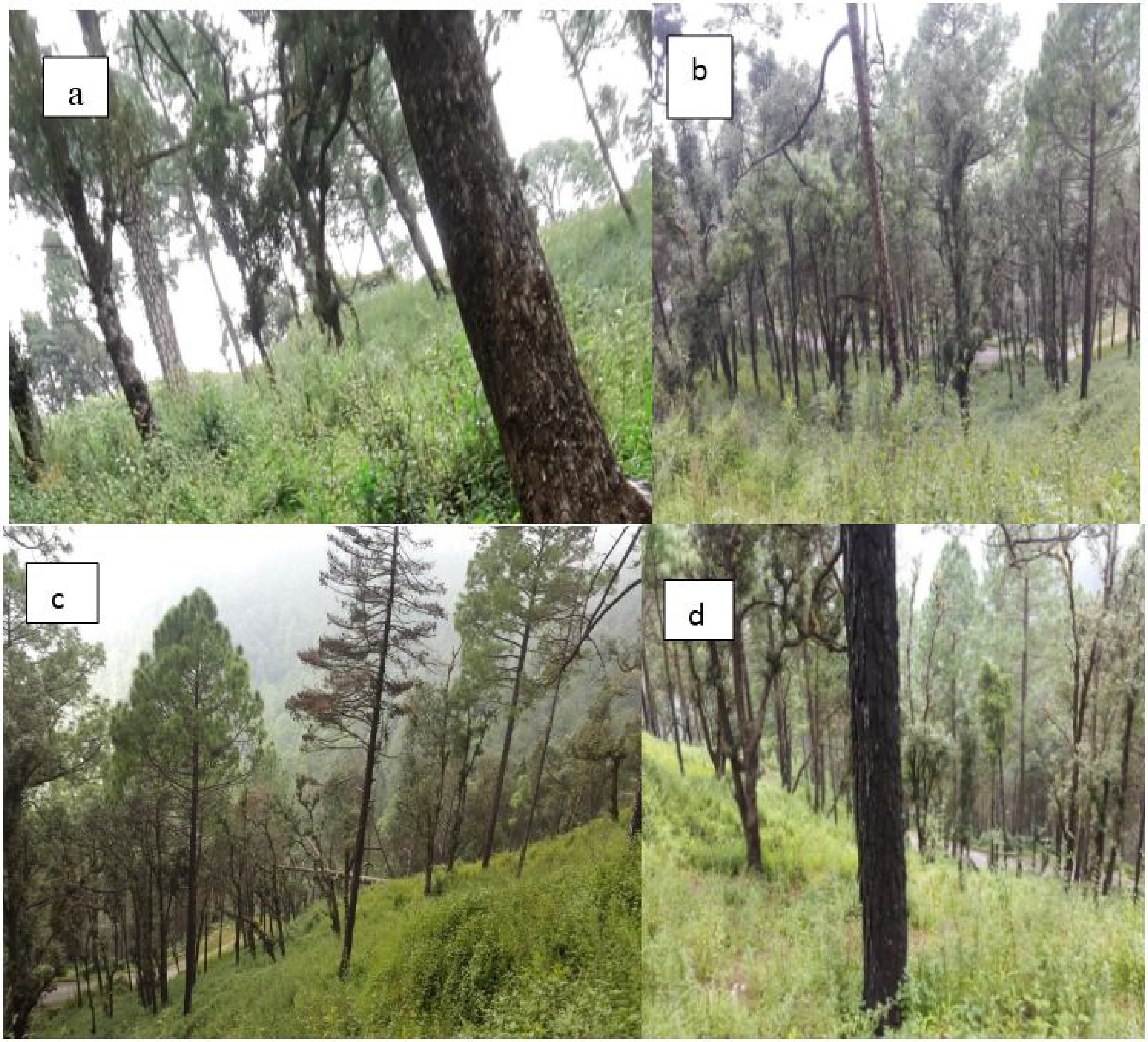

Photo plate 1: Photographs of the study sites (a-Hill top, b-Hill base, c-Hill slope, d- Image depicting severely burnt tree due to fire) in Uttarakhand state (India).

Climate

The climate of Nainital is classified as Koppen climate type, which is characterized by long-cold often snowy winter and short summer. It is temperate and monsoon type (Singh and Singh, 1992) and the year have four distinct seasons viz., monsoon (July to September), post-monsoon (October to November), winter (December to January) and summer (April to mid-June). Climatic data for the year 2016 was obtained from the State Observatory at Nainital. The mean annual rainfall was recorded 280.72mm and mean monthly rainfall ranged between 0mm (November) to 1076.34mm (July). The minimum temperature ranged from 6^{o}C (January) to 25^{o}C (June) and the mean maximum day temperature varied from 22°C (December) to 39°C (May) (Source: ARIES, Nainital) (Figure 1).

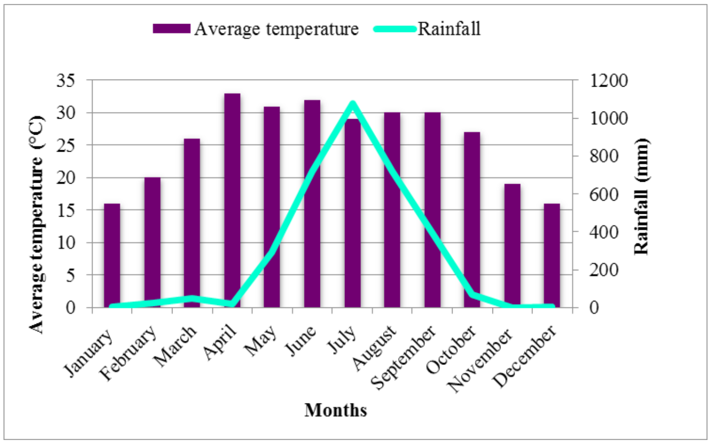

Figure 1: Metrological data of the study site for the year 2016 (Source: ARIES, Nainital).

Sampling

Plant species were collected carefully from the selected three sites (hill top, hill slope, hill base) and the collected specimens were properly spread in between the newspaper sheets for drying. The dried specimens were then mounted on the herbarium sheets of 29.2 x 41.9 cm. The collected plant material was identified by consulting the representative flora [27-30] and with the help of Prof. P.C. Pande, Taxonomist, Department of Botany, DSB Campus, Nainital. The herbarium was prepared by standard methods.

The vegetational analysis of herb species was conducted by doing stratified random sampling based position along a slope gradient by placing 10 quadrats of 1m x 1m size randomly at different locations on each of the three sites (viz., hill base, hill slope and hill top). The size and number of samples were determined following Saxena and Singh [31]. Grasses were sampled through tiller analysis and each tiller of grass was considered as an individual plant and creeping plants were counted on the basis of presence of functional roots. The vegetational data were quantitatively analyzed for abundance, density and frequency [32]. The Provenance value (PV) of herbs was determined as the sum of the relative frequency and relative density [33]. The ratio of abundance to frequency indicates distribution pattern which may be regular (A/F≤0.025) or random (A/F = 0.025 to 0.05) or contagious (A/F ≥0.05) [34]. The diversity index (H') was computed by using Shannon-Wiener Index [35]. The concentration of dominance (CD) was computed by using Simpson's Index [36], species richness was calculated by following Whittaker [37] and equitability was computed by following Pielou [38] and Index of similarity was calculated following Mueller-Dombois and Ellenburg [39]. The statistical analysis was performed using SPSS (version 16.0).

Result

Composition

36 herb species, belonging to 36 genera and 18 families were identified (Table 7) and number of herb species ranged from 15 (hill base) to 18 (hill top). The herbs were roughly distributed in a proportion of about 1/3rd in each site. From the identified species, pteridophytes were represented by one or two species and the rest of the species were angiosperms. Maximum herb species were contributed by family Asteraceae (7 species) followed by Poaceae (5 species) and Lamiaceae (4 species). *Arthraxon lanceolatus* dominated at hill base and hill slope, while *Selaginella spp.* dominated at hill top. These results are supported by the fact that higher altitude promotes heterogeneity. Higher number of herb species present at hill top may be due to open canopy of *C. torulosa* due to which more species got chance to establish themselves.

Herb Density and Provenance Value

Maximum herb density was observed at hill top (33.7 ind.m^{-2}) followed by hill slope (21.8 ind m^{-2}) and hill base (19.60 ind m^{-2}). At hill top, the maximum individual herb density was 11.4 ind m^{-2} for *Selaginella bryopteris* and minimum 0.1 ind.m^{-2} for *Cassia* spp. Provenance value (PV) indicated the dominance of *S. bryopteris* (PV=43.83), predominance of Craniotome versicolor (PV=20.51) and co-dominance of *Parietaria officinalis* (PV=18.73). At hill slope, the maximum individual herb density was 8 ind.m^{-2} for *S. bryopteris* and minimum 0.2 ind.m^{-2} for *Dicliptera bupleuroides* and *Clematis buchaniana* at hill base. Provenance value (PV) indicated the dominance of *Arthraxon lanceolatus* (PV = 56.43) predominance of *S. bryopteris* (PV = 47.51) and co-dominance of *Ainsliaea aptera* (PV = 14.48). At hill base, maximum individual herb density was 9.30 ind.m^{-2} for *A. lanceolatus* and 0.10 ind.m^{-2} for *Salvia officinalis, Cardamine amara, Bidens alba, Fragaria vesca, Cynodon dactylon and Erigeron belloides* (Table 1). In the present study, two types of distributional patterns, viz. random and contagious were observed. Random distribution was rare whereas, contagious distribution was common.

Species	Density (D) (ind. m^{-2})	Frequency (F) (%)	Abundance (A)	A/F	Relative Frequency (%)	Relative Density (%)	Provenance Value(PV)
Hill Base							
Salvia officinalis	0.10	10	01.00	0.10	03.13	00.51	03.64
Dicliptera bupleuroides	4.40	60	07.33	0.12	18.75	22.45	41.20
Arthraxon lanceolatus	9.30	70	13.29	0.19	21.88	47.45	69.32
Cardamine amara	0.10	20	01.00	0.05	06.25	00.51	06.76
Roylea cinerea	0.60	20	06.00	0.30	06.25	03.06	09.31
Achyranthes bidentata	0.80	30	02.67	0.09	09.38	04.08	13.46
Bidens alba	0.10	20	01.00	0.05	06.25	00.51	06.76
Fragaria vesca	0.10	10	01.00	0.10	03.13	00.51	03.64
Conyza agerotoides	0.50	10	05.00	0.50	03.13	02.55	05.68
Artemisia annua	1.00	10	10.00	1.00	03.13	05.10	08.23
Cynodon dactylon	0.10	10	01.00	0.10	03.13	00.51	03.64
Erigeron bellidiodes	0.10	10	01.00	0.10	03.13	00.51	03.64
Verbascum thapsus	0.60	10	6.00	0.60	03.13	03.06	06.19
Seigesbeckia orientalis	00.80	10	08.00	00.80	03.13	04.08	07.21
Eupatorium adenophorum	01.00	20	05.00	00.25	06.25	05.10	11.35
Total	**19.60**		**69.29**				**200**
Hill Slope							
Thalictrum foliolosum	0.5	10	05	0.5	2.70	2.29	5.00
Selaginella bryopteris	08	40	20	0.5	10.81	36.70	47.51

Ainsliaea aptera	0.8	40	02	0.05	10.81	3.67	14.48
Arthraxon lanceolatus.	07	90	7.78	0.09	24.32	32.11	56.43
Ageratum conyzoides	0.9	20	4.5	0.23	5.41	4.13	9.53
Justicia simplex	01	20	05	0.25	5.41	4.59	9.99
Achyranthes bidentata	0.5	30	1.67	0.06	8.11	2.29	10.40
Poa annua	0.4	10	04	0.4	2.70	1.83	4.54
Randia densiflora	0.7	40	1.75	0.04	10.81	3.21	14.02
Dicliptera bupleuroides	0.2	10	02	0.2	2.70	0.92	3.62
Clematis buchaniana	0.2	10	2	0.2	2.70	0.92	3.62
Carex hirta	0.3	20	1.5	0.08	5.41	1.38	6.78
Vitis himalayana	0.6	20	3	0.15	5.41	2.75	8.16
Strobilanthes callosa	0.7	10	7	0.7	2.70	3.21	5.91
Total	**21.8**						**200**
Hill Top							
Arthraxon lanceolatus	3.6	30	12.00	0.40	7.5	10.68	18.18
Clematis buchaniana	1.2	30	4.00	0.13	7.5	3.56	11.06
Fragaria vesca	1.1	10	11.00	1.10	2.5	3.26	5.76
Crysopogon zizanioides	2.3	30	7.67	0.26	7.5	6.82	14.32
Craniotome versicolor	2.7	50	5.40	0.11	12.5	8.01	20.51
Eupatorium adenophorum	1.8	20	9.00	0.45	5.0	5.34	10.34
Micromeria	1.7	30	5.67	0.19	7.5	5.04	12.54

Cynodon dactylon	0.8	20	4.00	0.20	5.0	2.37	7.37
Artemisia annua	1.0	10	10.00	1.00	2.5	2.97	5.47
Selaginella bryopteris	11.4	40	28.50	0.71	10	33.83	43.83
Cyanotis axillaris	1.1	20	5.50	0.28	5.0	3.26	8.26
Parietaria officinalis	2.1	50	4.20	0.08	12.5	6.23	18.73
Stellaria media	0.3	10	3.00	0.30	2.5	0.89	3.39
Paspalum conjugatum	0.5	10	5.00	0.50	2.5	1.48	3.98
Cassia occidentalis	0.1	10	1.00	0.10	2.5	0.30	2.80
Gallium aparina	1.5	10	15.00	1.50	2.5	4.45	6.95
Verbascum thapsus	0.3	10	3.00	0.30	2.5	0.89	3.39
Cynoglossum officinale	0.2	10	2.00	0.20	2.5	0.59	3.09
Total	**33.7**		**135.93**				**200**

Table 1: Vegetation analysis of herb layer in the Cypress mixed oak forest.

On the basis of percent similarity, Hill base and Hill slope were 20.68% similar, the Hill slope and Hill top showed 18.75% similarity and the Hill Top and Hill base were 48.48% similar in herb layer which showed maximum similarity (Table 2). Across the three sites, maximum diversity was observed in hill slope for *S. bryopteris* (0.53) and minimum in hill top for *Cassia occidentalis* (0.02). Maximum concentration of dominance was observed for *A. lanceolatus* (0.22) in hill base. Equitability was observed maximum for *S. bryopteris* and *A. lanceolatus* (0.20) in hill slope. (Table 3)

Sites	Hill Slope	Hill Top
Hill Base	20.68%	48.48%
Hill Slope	-	18.75%

Table 2: Index of similarity.

Species	Diversity index (H')	Concentration of dominance (Cd)	Equitability (e)
Hill base			
Salvia officinalis	0.04	0.00	0.01
Dicliptera bupleuroides	0.48	0.05	0.18
Arthraxon lanceolatus	0.51	0.22	0.19
Cardamine amara	0.04	0.00	0.01

Roylea cinerea	0.15	0.00	0.06
Achyranthes bidentata	0.19	0.00	0.07
Bidens alba	0.04	0.00	0.01
Fragaria vesca	0.04	0.00	0.01
Conyza agerotoides	0.13	0.00	0.05
Artemisia annua	0.22	0.00	0.08
Cynodon dactylon	0.04	0.00	0.01
Erigeron bellidiodes	0.04	0.00	0.01
Verbascum thapsus	0.15	0.00	0.06
Seigesbeckia orientalis	0.19	0.00	0.07
Eupatorium adenophorum	0.22	0.00	0.08
Hill slope			
Thalictrum foliolosum	0.12	0.00	0.05
Selaginella bryopteris	0.53	0.13	0.20
Ainsliaea aptera	0.17	0.00	0.07
Arthraxon lanceolatus.	0.53	0.10	0.20
Ageratum conyzoides	0.19	0.00	0.07
Justicia simplex	0.20	0.00	0.08
Achyranthes bidentata	0.12	0.00	0.05
Poa annua	0.11	0.00	0.04
Randia densiflora	0.16	0.00	0.06
Dicliptera bupleuroides	0.06	0.00	0.02
Clematis buchaniana	0.06	0.00	0.02
Carex hirta	0.09	0.00	0.03
Vitis himalayana	0.14	0.00	0.05
Strobilanthes callosa	0.16	0.00	0.06
Hill top			
Arthraxon lanceolatus.	0.34	0.01	0.12
Clematis buchaniana	0.17	0.00	0.06
Fragaria vesca	0.16	0.00	0.06
Crysopogon zizanioide	0.26	0.00	0.09
Craniotome versicolor.	0.29	0.01	0.10
Eupatorium adenophorum	0.23	0.00	0.08
Micromeria biflora	0.22	0.00	0.08

Cynodon dactylon	0.13	0.00	0.04
Artemisia annua	0.15	0.00	0.05
Selaginella bryopteris	0.53	0.11	0.18
Cyanotis axillaris	0.16	0.00	0.06
Parietaria officinalis	0.25	0.00	0.09
Stellaria media	0.06	0.00	0.02
Paspalum conjugatum	0.09	0.00	0.03
Cassia occidentalis	0.02	0.00	0.01
Gallium aparina	0.20	0.00	0.07
Verbascum thapsus	0.06	0.00	0.02
Cynoglossum officinale	0.04	0.00	0.02

Table 3: Diversity (H'), Concentration of dominance (Cd) and Equitability (e) of herbs in Cypress Oak mixed forest.

Herb Biomass

Maximum herb biomass (212.57 gm^{-2}) was observed at hill base, whereas minimum biomass was reported at hill slope (116.22 gm^{-2}) and the total biomass at hill top (141.97 gm^{-2}) ranged in between hill base and hill slope. At hill base, maximum biomass was contributed by *D. bupleuroides* (25.83%) and minimum biomass was contributed by *B. alba* (0.10%). At hill slope, *A. lanceolatus* contributed highest biomass (24.88%) and lowest contribution was reported by *P. annua* (0.30%). At hill top, *C. zizaniodes* contributed highest biomass (20.57%) and *C. offcinale* (0.77%) contributed lowest biomass (Table 4).

Herb species	AGB(gm^{-2})	BGB(gm^{-2})	Total
Hill base			
Salvia officinalis	1.01	0.97	1.98
Dicliptera bupleuroides	50.34	4.57	54.91
Arthraxon lanceolatus	48.59	2.07	50.67
Cardamine amara	1.75	1.02	2.77
Roylea cinerea	0.38	0.30	0.68
Achyranthes bidentata	14.35	6.66	21.01
Bidens alba	0.11	0.11	0.22
Fragaria vesca	0.11	0.12	0.23
Conyza agerotoides	4.28	0.29	4.57
Artemisia annua	1.32	0.08	1.40
Cynodon dactylon	0.88	0.05	0.93
Erigeron bellidiodes	0.35	0.02	0.37
Verbascum Thapsus	15.52	25.02	40.54
Seigesbeckia orientalis	2.30	0.10	2.40
Eupatorium adenophorum	21.19	8.70	29.89

Total	**162.48**	**50.08**	**212.57**
Herb Species	**AGB (gm^{-2})**	**BGB (gm^{-2})**	**Total**
Hill slope			
Thalictrum foliolosum	3.99	1.97	5.96
Selaginella bryopteris	4.08	1.22	5.30
Ainsliaea aptera	3.71	2.51	6.22
Arthraxon lanceolatus.	24.44	4.48	28.92
Ageratum conyzoides	2.35	2.25	4.60
Justicia simplex	3.38	1.30	4.67
Achyranthes bidentata	2.94	3.22	6.16
Poa annua	0.31	0.05	0.36
Randia densiflora	5.50	6.51	12.00
Dicliptera bupleuroides	0.36	0.34	0.70
Clematis buchaniana	1.48	0.17	1.65
Carex hirta	1.52	1.34	2.85
Vitis himalayana	15.84	1.10	16.94
Strobilanthes callosa	13.46	6.45	19.91
Total	**83.35**	**32.87**	**116.22**
Herb Species	**AGB(gm^{-2})**	**BGB(gm^{-2})**	**Total**
Hill top			
Arthraxon lanceolatus.	11.71	0.97	12.68
Clematis buchaniana	3.13	1.30	4.43
Fragaria vesca	3.64	0.18	3.82
Crysopogon zizanioides	11.76	17.45	29.21
Craniotome versicolor	13.12	1.79	14.91
Eupatorium adenophorum	12.77	2.66	15.43
Micromeria biflora	4.53	0.29	4.82
Cynodon dactylon	4.46	3.79	8.25
Artemisia annua	6.46	1.67	8.13
Selaginella bryopteris	9.50	1.71	11.21
Cyanotis axillaris	1.75	0.75	2.50
Parietaria officinalis	3.31	0.69	3.99
Stellaria media (L)Vill	0.39	0.90	1.29
Paspalum conjugatum	2.00	0.41	2.41

Cassia occidentalis	1.98	0.33	2.31
Gallium aparina	3.60	0.02	3.62
Verbascum Thapsus	10.46	1.41	11.87
Cynoglossum officinale	1.03	0.07	1.10
Total	**105.58**	**36.38**	**141.97**

Table 4: Herb layer biomass in the temperate Cypress dominated mixed-oak forest.

Dominance Diversity Curves

At hill base, one herb species was clearly dominant, one was predominant and rest of the species showed similar dominance. At hill slope, one herb species was clearly dominant, one was predominant and rest of the species showed similar dominance. At hill top, group of herb species showed similar dominance while one species was clearly dominant (Figure 2).

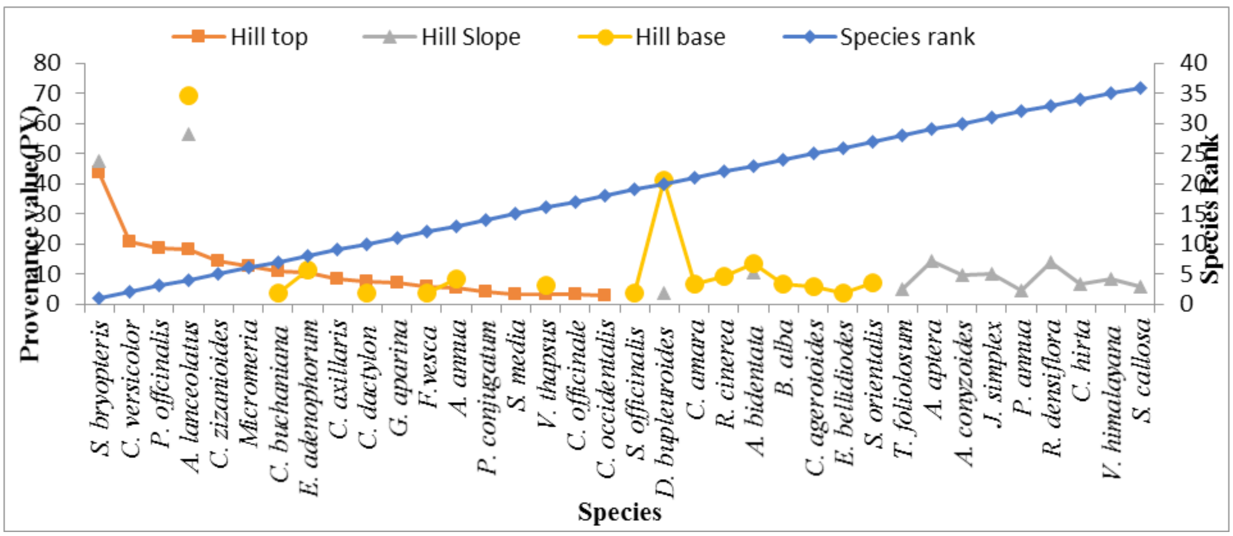

Figure 2: Dominance diversity curve of herb species at Cypress mixed Oak forest.

Discussion

In the present study a total of 36 herb species, belonging to 36 genera and 18 families were identified (Table 7) while 27 herb species from same site were reported previously by Karki et al. [40] that further supports the fact that the abundance of herbaceous plants increased after fire (Table 7). Hill top occupied highest numbers among the herb species followed by hill base and hill slope. The richest families were Asteraceae (7 species) followed by Poaceae (5 species), Lamiaceae (4 species *A. lanceolatus* was dominating in hill base and hill slope, while *S. bryopteris* dominated at hill top while 22 to 25 herbs were reported for mixed oak forests of the region [41].

Natural as well as human disturbances influence forest dynamics and plant diversity at local and regional scales [42]. Nearly all studies of fire effects have revealed that the cover and/or abundance of herbaceous plants increased after fire [23,25,43,44]. For woody plant cover, the fire response may be more variable because of the variation in the sprouting response in different vegetation types [44-46]. Fire often has been shown to increase species richness and/or diversity in the herbaceous layer [25,44,45].

Herb-layer vegetation is affected indirectly when fire alters the forest floor and soil environments. Elevated soil temperatures likely affect the germination, establishment and growth of herb-layer vegetation. Leaf litter plays an important role in herb-layer plant communities [47]. In the short term, the consumption of leaf litter and humus during fires probably causes the greatest changes in herb-layer vegetation by reducing the mechanical barrier (accumulated litter and debris) and increasing light levels to seeds in the humus and mineral soil. The consumption of leaf litter in fires also releases nutrients that are then incorporated into the mineral soil, altering soil chemistry and likely affecting plant productivity, particularly on nutrient poor sites [48], as fire alters forest structure by killing of saplings and some trees, light levels increase to the forest floor. Fire also increases the amount of nitrate in soil, this could stimulate the germination of some seed bank [49].

The total density of herbs varied from 19.60 to 33.7 ind.m^{-2} with hill top having highest density (Table 5). However, herb density ranged from 100.80 to 135.6 ind.m^{-2} in earlier studies [40]. In the present study site, the total biomass fall between 212.57 gm^{-2} (at hill base) and 116.22 (at hill slope), while Karki et al. [40] reported the total biomass from 174.71 gm^{-2} to 352.52 gm^{-2} at the same site before fire. Perhaps, the major difference of density and biomass values may be due to increase in anthropological pressures (accidental fire) with development of time.

Herb species	**Density (ind.m^{-2})**	
	After fire (Present study)	**Before fire (Karki et al. 2016)**
Hill base		
Achyranthes bidentata	0.8	12
Ainsliaea aptera	-	14.4
Artemisia annua	1	3.2
Arthraxon lanceolatus	9.3	18
Bidens alba	0.1	-
Cardamine amara	0.1	-
Clematis buchaniana	-	0.4
Conyza agerotoides	0.5	-
Creniotome versicolor	-	14.8
Cynodon dactylon	0.1	2.4
Dicliptera bupleuroides	4.4	-
Dioscorea deltoidea	-	1.6
Erigeron bellidiodes	0.1	44.4
Eupatorium adenophorum	1	9.6
Fragaria vesca	0.1	0.8
Galium aparina	-	1.6
Goldfussia dalhousianus	-	1.6
Melaxis acuminate	-	0.4
Roylea cinerea	0.6	-
Salvia officinalis	0.1	-
Seigesbeckia orientalis	0.8	-
Selaginella spp.	-	11.2
Verbascum Thapsus	0.6	-
Viola canescens	-	2.8
Vitis Himalayana	-	3.2
Hill slope		
Achyranthes bidentata	0.5	9.2
Ageratum conyzoides	0.9	-
Ainsliaea aptera	0.8	8.4
Arthraxon lanceolatus.	7	24
Carex hirta	0.3	-
Clematis buchaniana	0.2	-
Dicliptera bupleuroides	0.2	13.6
Justicia simplex	1	-
Poa annua	0.4	-
Randia densiflora	0.7	-
Selaginella spp.	8	27.6
Strobilanthes callosa	0.7	-
Thalictrum foliolosum	0.5	-
Vitis himalayana	0.6	0.8
Cypress rotundus	-	45.6
Creniotome versicolor	-	14.8
Stellaria media	-	2.4
Galium rotundifolium	-	10
C. dactylon	-	4
G. dalhousianus	-	2.8
G. gossypina	-	2.8
Onychium cryptogrammoides	-	8
Hill Top		
A. aptera	-	17.2
A. bidentata	-	8
Artemisia annua	1	-
Arthraxon lanceolatus	3.6	24.8
C. rotundus	-	12
Cassia occidentalis	0.1	-

Clematis buchaniana	1.2	0.4
Craniotome versicolor	2.7	-
Crysopogon zizanioides	2.3	-
Cyanotis axillaris	1.1	-
Cynodon dactylon	0.8	-
Cynoglossum officinale	0.2	-
D. bupleuroids	-	8.4
Eupatorium adenophorum	1.8	-
Fragaria vesca	1.1	-
G. dalhousianus	-	17.2
G. gossypina	-	3.2
G. rotundifolium	-	4.4
Gallium aparina	1.5	-
Hedychium spicatum	-	1.2
Micromeria	1.7	-
Parietaria officinalis	2.1	-
Paspalum conjugatum	0.5	-
Selaginella spp.	11.4	62
Stellaria media	0.3	-
Thalictrum foliolosum	-	0.8
Tragopogon gracilis	-	2.8
V. himalyana	-	2.0
Verbascum Thapsus	0.3	-
Viola serpens	-	0.4

Table 5: Comparative study of densities of herb species across the stand position before fire and after fire.

In the present study, two types of distributional patterns, viz. random and contagious were observed. Random distribution was rare whereas, contagious distribution was common. Earlier studies [50] also support the fact that clumped (contagious) distribution is the commonest pattern in nature, random distribution is found purely in very uniform environment and the regular distribution occurs when severe competition exists between individuals. On the basis of percent similarity, Hill base and Hill slope were 20.68% similar, the Hill slope and Hill top were 18.75% similar and the maximum similarity existed between Hill Top and Hill base (48.48%). However, earlier studies [40] revealed that Hill slope and Hill top showed 68.97% similarity, hill base and hill slope showed 51.61% similarity and hill base and hill top showed 43.75% similarity (Table 2).

Cluster Analysis

Cluster analysis is a way of grouping cases of data. In the present study, 2 groups were formed on the basis of different parameters (Density, Diversity and Biomass) before and after fire. Across the sub-sites (Hill base, Hill slope, Hill top), group 1, 2 and 3 (before fire) join together to form a cluster with homogenous combination followed by group 4, 5 and 6 group (after fire) which showed heterogeneous combination with group 1,2 and 3. On the basis of different parameters, group 1, 2, 3 form a single cluster that means hill base, hill slope and hill top of before fire showed similarity whereas group 4, 5, 6 also form a single cluster i.e. hill base, hill slope, hill top after fire also showed similarity but as the clusters formed before fire and after fire showed a wide gap in between i.e. they were strongly dissimilar with respect to the parameters studied (Figure 3).

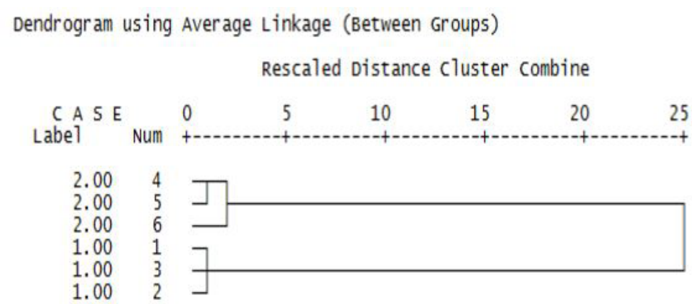

Figure 3: Cluster analysis for different parameters

1=Hill base 2=Hill slope 3= Hill top (1.00=Before fire)

4=Hill base 5=Hill slope 6=Hill top (2.00=After fire)

Correlation Matrix

The correlation matrix of different parameters with study sites (Before and after fire) is indicated in Table 6. Density (-0.988) and biomass (-0.977) showed strong negative correlation with study sites i.e. density and biomass of herbs decreased after fire in the studied site. Biomass (0.953) showed positive correlation with density i.e. biomass increased with increasing density. Diversity showed least significance with site and position.

	Site	Position	D	H	B
Site	1	0.000	-0.988**	-0.418	-0.977**
Position		1	-0.109	-0.373	0.067
D			1	0.462	0.953**
H				1	0.313
B					1

Table 6: Pearson Correlation matrix for the study site before and after fire.

Herb species	Family	Present study(After fire)			Karki et al. 2016 (Before fire)		
		Hill base	Hill slope	Hill top	Hill base	Hill slope	Hill top
Achyranthes bidentata Blume	Amaranthaceae	+	+	+	+	+	+
Ageratum conyzoides L.	Asteraceae	-	+	-	-	-	-
Ainsliaea aptera DC.	Asteraceae	-	+	-	+	+	+
Artemisia annua Linn.	Asteraceae	+	-	+	+	-	-
*Arthraxon lanceolatus.*Thunb	Poaceae	-	-	-	+	+	+
Bidens alba (L) DC.	Asteraceae	+	-	-	-	-	-
Cardamine amara L.	Brassicaceae	+	-	-	-	-	-
Carex hirta L.	Cyperaceae	-	+	-	-	-	-
Cassia occidentalis L.	Fabaceae	-	-	+	-	-	-
Clematis buchaniana DC.	Ranunculaceae	-	+	+	+	-	+
Conyza agerotoides DC.	Asteraceae	+	-	-	-	-	-
Craniotome versicolor. Reichb.	Lamiaceae	-	-	+	+	+	-
Crysopogon zizanioides (L.)Roberty	Poaceae	-	-	+	-	-	-
Cyanotis axillaris (L.)D.Don ex Sweet	Commelinaceae	-	-	+	-	-	-
Cynodon dactylon (L.)Pers.	Poaceae	+	-	+	+	+	-
Cynoglossum officinale L.	Boraginaceae	-	-	+	-	-	-
Cyperus rotundus L.	Cyperaceae	-	-	-	-	+	+
Dicliptera bupleuroides Nees	Acanthaceae	+	+	-	-	+	+
Dioscorea deltoidea Kunth.	Dioscoreaceae	-	-	-	+	-	-
Erigeron bellidiodes L.	Asteraceae	+	-	-	+	-	-
Eupatorium adenophorum Spreng	Asteraceae	+	-	+	+	-	-
Fragaria vesca Linn.	Rosaceae	+	-	+	+	-	-
Gallium aparina L.	Rubiaceae	-	-	+	+	-	-
Gallium rotundifolium L.	Rubiaceae	-	-	-	-	+	+
Gebera gossypina (Royle) Beauv.	Asteraceae	-	-	-	-	+	+
Goldfussia dalhousianus Clarke.	Acanthaceae	-	-	-	+	+	+

Hedychium spicatum BuchHam.ex J.E.Smith	Zingiberaceae	-	-	-	-	-	+
Justicia simplex D. Don	Acanthaceae	-	+	-	-	-	-
Malaxis acuminate D.Don.Roxb.	Orchidaceae	-	-	-	+	-	-
Micromeria biflora (Don)Benth.	Lamiaceae	-	-	+	-	-	-
Onychychium cryptogrammoides C. Chr	Cryptogrammaceae	-	-	-	-	+	-
Parietaria officinalis L.	Urticaceae	-	-	+	-	-	-
Paspalum conjugatum Hochst.ex Steud.	Poaceae	-	-	+	-	-	-
Poa annua L.	Poaceae	-	+	-	-	-	-
Randia densiflora L.	Rubiaceae	-	+	-	-	-	-
Roylea cinerea (D. Don) Baill.	Lamiaceae	+	-	-	-	-	-
Salvia officinalis L.	Lamiaceae	+	-	-	-	-	-
Seigesbeckia orientalis L.	Asteraceae	+	-	-	-	-	-
Selaginella spp	Selaginellaceae	-	+	+	+	+	+
Stellaria media (L)Vill	Caryophyllaceae	-	-	+	-	+	-
Strobilanthes callosa (Nees) Bremek	Acanthaceae	-	+	-	-	-	-
Thalictrum foliolosum DC.	Ranunculaceae	-	+	-	-	-	+
Tragopogon gracilis D. Don	Asteraceae	-	-	-	-	-	+
Verbascum thapsus L.	Scrophulariaceae	+	-	+	-	-	-
Viola serpens Wall.	Violaceae	-	-	-	-	-	+
Vitis himalayana Brandis	Vitaceae	-	+	-	+	+	+
Voila canescens Wall. ex Roxb.	Voilaceae	-	-	-	+	-	-

Table 7: A list of herb species encountered in the studied area before and after fire (+ sign indicates the presence of species and -sign indicates its absence).

Conclusion

The present study is an attempt to investigate the role of fire in shaping ecosystem with emphasis on long and short term impact of fire and other biotic/ abiotic factors in combination with fire which cause biodiversity loss. The species composition and richness were significantly affected by fire but the magnitude of effects was generally small. Overall species composition became different in burned areas than in unburned areas. Certain burned areas also developed greater small-scale species richness than that of unburned areas. A group of perennial herbs, primarily grasses exhibited significant changes in their frequencies after fire that may result in long term changes in composition and richness.

From conservation prospective for successful rehabilitation of burnt sites a detailed study of all the vegetation layers and physico-chemical properties of soil could be helpful to conclude the effect of fire in vegetation and soil nutrient pool. Plantations could be established in accessible sites by using fast-growing native species in order to speed up the gap filling and carbon sequestration potential.

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