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Assessment of Forest Fire and Its Impact on Plant Biodiversity of Buffer Zone, Langtang National Park, Nepal

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ABSTRACT

The research work was focused on the study of forest fire and its impact assessment on plant biodiversity by vegetation assessment in the fire-affected and adjoining non-affected areas to identify the signals of severity and probable causes of fire. Data were collected by quadrate method, site survey, consultation and group discussion, mapping of the studied area, and questionnaire survey. The results show that there was a notable difference in tree and shrub diversity. The Shannon Wienner index (H) = 0.70 and 0.49, and Simpson's Divesity (D) = 0.64 and 0.51, for trees in adjoining and fire-affected areas respectively. Similarly, Shannon Wienner index (H) = 0.91 and 0.72, and Simpson's Divesity (D) = 0.84 and 0.68 for shrubs in adjoining and fire-affected areas respectively. Likewise, herb diversity did not differ significantly (H = 1.02 and 0.97; D = 0.87 and 0.88 in the adjacent to burned area and fire-affected area). *Gleichenia gigantea*, *Artemisia dubia*, *Rubus* spp., *Oxalis chodata*, and some medicinal plants such as *Butea minor* were found to be most affected by the fire. Mainly dried thickets of *Drepanostachyum intermedium* and *Saccharum spontaneum* act as fuel for the fire, which easily ignites and regenerates soon after a fire. Drought before monsoon was found to be the leading cause of forest fires, followed by electricity shooting (17%), ignorance and carelessness (38%), slash and burn practice (15%), other (7%), and unknown causes (23%). Hence the need to better address the drivers of resource extraction from the national park to mitigate this degradation.

INTRODUCTION

Fire is observed in every ecosystem of the world (Bond et al., 2005). It helps to maintain habitat, encourages reproduction, affects competition or association of plant species, and aids in increasing diversity (Marzluff and Ewing, 2008; Potts et al., 2010). Thus, fire may be either beneficial or detrimental to individual species, but it causes changes also (Pyke et al., 2010; Kunwar and Khaling, 2006). If only dry leaves, small saplings, or tree bark are burned, fire may be completely safe (Poorter, et al., 2014). Light surface fire helps to release the minerals embedded in the dead logs and removes the mat of leaf litter to encourage the germination of tree species like Chirpine (*Pinus roxburghii*), Blue Pine (*P. wallichiana*), and Hemlock (*Conium maculatum*) (Glasgow and Matlack, 2007).

Forest species change in composition after a fire (Moser et al., 2010). This may be good or bad, depending on the utility of the stand that follows or succeeds the fire (Stephens and Ruth, 2005). The semi-evergreen types of forest shed their leaves in the winter season. Coniferous forests of pine (*Pinus roxburgii and Pinus wallichiana*) trees, Spruce (*Piceasmithiana*), Dhupi (*Cryptomeria japonica),* and forests of Rhododendrons shed large amounts of litter on the ground. Vegetation like pine in higher altitudes (Sharma et al., 2008) and Sal (*Shorea robusta*) (Jaiswal et al., 2002) in the Terai are fire-adaptive species in Nepal. Fire in these plant communities is an important factor in breaking seed dormancy. However, repeated forest fires cause deterioration of site quality by changing soil moisture and soil nutrient regimes along with killing the regeneration (Johnstone et al., 2016).

The cause of a forest fire might be a topographical situation where vertical gradients affect the forest fire. According to Finney et al. (2010), when a fire burns uphill, fuel that is in close contact with the flame due to the steep slope angle increases the fire spread rate. For every 100 feet of upslope, the fire will double its forward rate of spread. Thus, the available topographic situation in Nepal favors forest fires. The higher temperature prolongs the drought which affects fuel temperature and increases the risk of fire (Littell et al., 2016). The amount of heat required to convert fuel to ignition temperature is 320^0 C (608^0 F) (Zafar et al., 2007). Similarly, relative humidity (RH) is 20% lower at lower altitudes (Terai and Churia) than at higher altitudes, and 30% RH is favorable for fire, while less than 30% makes it nearly impossible to extinguish the fire (Wicklein et al., 2015). Wind decreases the relative humidity in the air and increases the rate of fire spread (Moinuddin et al., 2021).

Anthropologically, it is caused by a lack of knowledge about forest fires, careless smoking, burned coal in vulnerable areas, honey collection (Butz, 2009), subsistence agricultural system, vision to avoid the incursion of wild pigs in farmland and slash and burn practice for soil fertility and grazing (Eastmond and Faust, 2006). Nepal is not devoid of such forest fires as observed in the Sacred Himalayan Landscape (SHL) in 2009. Mostly surface fires were found that affected understory vegetation in the study area. There is limited study of fire impacts on biodiversity and published research in Nepal. Therefore, the study was focused on the forest fire and its impact assessment on plant biodiversity in the Suryakunda Buffer zone (BZ) of Syafrubesi, Langtang National Park (NP) of Rasuwa. The study examines the differences in vegetation composition between the fire-affected and adjacent areas and employs signals to determine the severity of the fire. It also identifies major causes of forest fires.

MATERIALS AND METHODS

Study Area

The study was carried out in the Suryakunda BZ of Syafrabesi (approx. 500 ha). It lies in the BZ area (448 sq km) of the Langtang NP (1778 sq. km) at $85^o10.92$' to $85^o53.07$'E longitude and $27^o51.36$ to $28^023.1$'N latitude. The area is at a height of 1975 m above sea level (Figure 1). The annual Tmax/min temperature at nearby Dunche was $21.81/10.7^0$C in 1998 and $19.85/9.5^0$C in 2007. In March-May, the average Tmax ranges from 19^0C to 24^0C (DHM, 2008). Similarly, the rainfall in March, April, and May was 46.9, 68.7, and 104.2 mm, respectively. In the recorded data from 1998–2007, the average rainfall in winter and pre-monsoon was 25.25 mm and 73 mm, respectively, that dried out due to high temperatures. The average RH (%) (max/min) was lowest in March and April.

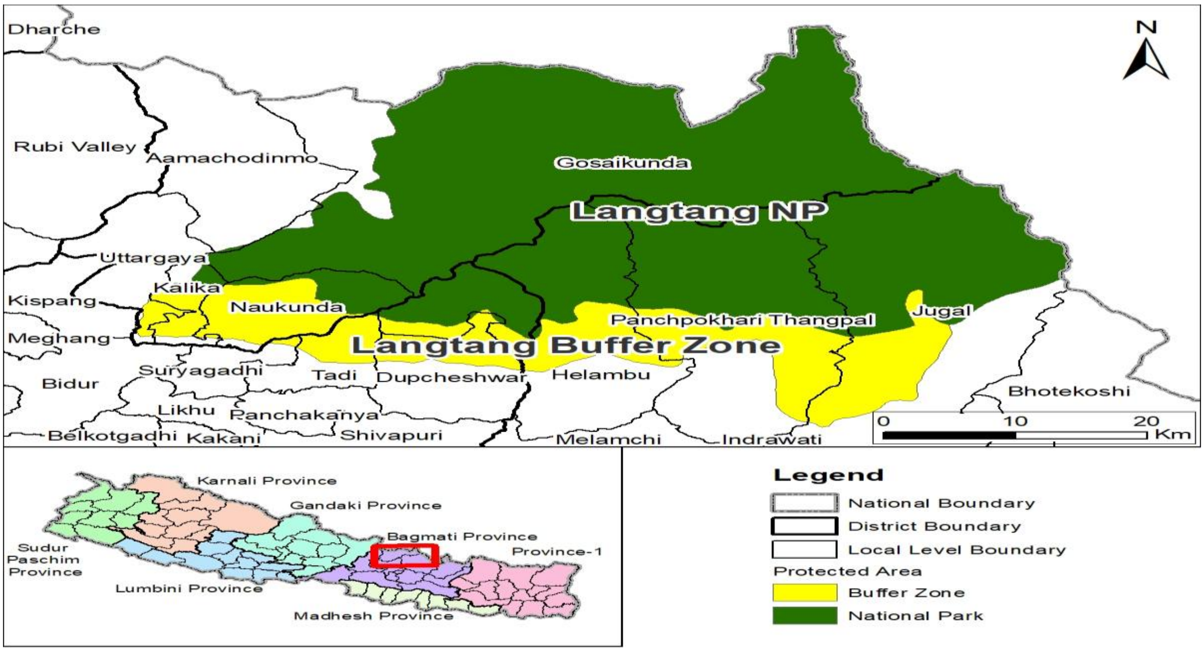

Figure 1. Map of the study area

Sample Design for Vegetation Analysis

The difference in species composition of the forest fire and adjoining area were compared and studied by the quadrate method (Parashar and Biswas, 2003). This method was used to estimate the population density and frequency of the trees, shrubs, and herbs. The nested quadrat method was used for sampling (Clark, 2009). Systematic sample plots of 10 m × 10 m for trees, 5m×5m for shrubs, and 1m × 1m for herbs were laid out at 10 m apart from each other along the estimated contour from base to uphill. The total number of quadrats studied was 20. The nomenclature of species was based on the *Dictionary of Nepalese Plant Names* published by the Natural History Museum (Shrestha, 1998).

Data Analysis

Data were analyzed by density, frequency, and diversity indices as follows:

1. Density = $\frac{\text{Total number of individuals of species in all quadrate}}{\text{Total number of quadrates laid down}}$ x Area of Quadrate

2. Frequency = $\frac{\text{Number of sampling unit in which species occurred}}{\text{Total number of sampling units studied}}$ x 100%

3. Regression analysis

It was used to calculate various plant and community-based indices of forest disturbance. Plant diversity was calculated from the information of the plant inventory. The difference in species composition of the forest fire and adjoining area was compared (Douglas and Ballard, 1971; Parashar and Biswas, 2003). The research was studied by the quadrate method and this method was used to estimate the population density and frequency of the trees, shrubs, and herbs. The Nested quadrat method was used for sampling (Clark, 2009). Systematic sample plots of 10 m × 10 m for trees, 5m × 5m for shrubs and 1m × 1m for herbs were laid out at 10 m apart from each other along the estimated contour from base to uphill. The total number of quadrats studied was 20. The nomenclature of species was based on the *Dictionary of Nepalese Plant Names* published by the Natural History Museum (Shrestha, 1998).

The Shannon Wiener Index was used as the index affected by both the number of species and the evenness of their population. Simpson's index was used as a dominance index for the common species and the probability of two individuals randomly selected from a sample. The following formulae were used to calculate the diversity indices (Odum, 1996):

Shannon Wienner index, $H = \sum_{i=1}^{s} p_i * \log p_i$ 1

dH = H(adjoining) – H(affected)

Simpson's Diversity, $D = 1 - \sum_{i=1}^{s} p_i^2$ 2

dD = D(adjoining) – D(affected)

Peilau's evenness, e = H/log (N) 3

Where, S = number of species, p_i = proportion of the i^{th} species in a community (=i/N), i = individual species and N = total number of species

Site Survey

A field visit to the forest fire and surrounding areas was conducted to gain a better understanding of the current situation. The destruction caused by fire (half/fully burned trees, dead and dry saplings, and mosses) and its severity was observed in the field. Thus, fire severity was analyzed by the observatory method.

Social Survey

A social survey was done to identify anthropological causes of a forest fire. Consultation and group discussions with governmental organizations, NGOs, community-based organizations, and district forest officers were conducted. A structured and semi-structured questionnaire survey was carried out with the help of Interviews taken with local people (above 18 years of age) and park staff.

RESULTS AND DISCUSSION

The adjacent area was covered by dense shrubs and herb species. Trees were mixed types in the non-burned area while Chir pine (*Pinus roxburghii*) was dominating in the fire-affected area.

Vegetation Analysis

1. Trees

The total number of individual trees in the adjoining and affected areas was found to be 227 and 221 respectively. Diversity was highest in the adjoining area. Chirpine (*P. roxburghii*) is a frequently occurring tree species in both adjoining and affected areas, i.e., 70% and 80% respectively (Table 1). *Rhododendron* spp*., Coriaria nepalensis*, *Bauhinia purpurea*, *Zizyphus incurve*, *Osyris* spp., *Bombax ceiba,* etc. (especially broad-leaved trees) were found in the lower elevation and Chirpine (*Proxburgii*) in the upper elevation. *Euphorbia royleana* in the adjoining area and *Z. incurve* in the affected area were both the least frequently occurring tree species (frequency: 10% and 5% respectively). Diversity was higher in the adjoining area than in the affected area. It was different by 0.21 and 0.13 in *d*H and *dD,* respectively. The dominance index for Pinus trees was 0.34 in the adjoining area and 0.51 in the affected area. The fire-affected area was mainly covered by Chirpine (*P. roxburghii*) while mixed types were found in the adjoining area.

Table1. Frequency and density in non-affected areas and fire-affected areas for trees

S. N.	Scientific names	Ad. Area		Af. Area	
		F (%)	D (ind/m$^{2)}$	F (%)	D (ind/m^2
1	*Aegle marmelos*			5	0.001
2	*Bauhinia pupurea*	30	0.003	25	0.0015
3	*Bombax ceiba*	25	0.0045	10	0.002
4	*Cororia nepalensis*	40	0.007	15	0.0025
5	*Euphorbia royleana*	10	0.001		
6	*Leguminaceae* spp.			15	0.0005
7	*Lyonia ovalifolia*	40	0.005	15	0.009
8	*Murraya koenigii*	20	0.006		
9	*Osyris* spp.	45	0.009	20	0.005
10	*Pinus roxburghii*	70	0.0655	80	0.0775
11	*Pinus wallichiana*			30	0.0035
12	*Rhododendron arboretum*	40	0.008	35	0.006
13	*Rhus javanica*	15	0.001	15	0.0015
14	*Zizyphus incurva*	15	0.002	5	0.0005
15	Unidentified	10	0.001		

Table 2. Diversity indices and evenness for trees

S. N.	Indices	Ad. Area	Af. Area
1	Shannon-Weiner Diversity Index (H)	0.7036	0.4902
2	Simpson's Diversity Index (D)	0.6416	0.5072
3	Pielou's Evenness Index (e)	0.2988	0.2091

Note: Ad. = adjacent to the burned area; Af. = fire affected area; F = frequency; D = Density; ind/m^2 = individual/m^2.

2. Shrubs

Shrubs and herbs are most likely killed by even low-intensity fires (Stephan, 2010). *Urtica dioica, Artemisia dubia*, *Berberies asiatica*, *Rubus* spp. in the adjoining area, and *Artemisia dubia, Cannavis sativa* and *Rhododendron* species in the affected area were the most abundant shrubs. *Ranunculous* spp. had the highest frequency (75%) of occurring shrubs in the adjoining area. *Artemisia dubia*is the most frequently occurring (75%) and

Rubus ellipticus, Micromeria biflora, Desmodium spp., *Blumea balsamifera* are frequently occurring shrubs in the affected area (Table 3). Total species were found comparatively higher (N = 1299) in the adjoining area than in the affected area (N = 1064). *d*H and *d*D in both areas show a small difference of 0.19 and 0.16, respectively. The adjacent area consisted of more species of shrubs. However, there was no difference in Simpson's diversity in both areas.

Table 3. Frequency and density in non-affected areas and fire affected areas for shrubs

S. N.	Species	Ad. Area		Af. Area	
		F(%)	D (ind/m^2)	F (%)	D (ind/m^2)
1	*Artemisia dubia*	25	0.55	75	0.536
2	*Woodfordia fruticosa*	25	0.06		
3	*Berberies asiatica*	50	0.32	40	0.024
4	*Blumia balsamifera*	20	0.03	15	0.04
5	*Eupatorium adenophorum*	35	0.06	35	0.046
6	*Rubus* spp.	40	0.1		
7	*Butea minor*	15	0.02		
8	*Vitis vinifera*	35	0.06		
9	*Rhododendron anthopogon*	15	0.028	10	0.05
10	*Urticadioica*	65	0.6	35	0.08
11	*Leucas lanata*	10	0.04		
12	*Desmodium* spp.	40	0.12	15	0.008
13	*Plumeria rubra*	35	0.03		
14	*Drepanostachyum intermedium*	80	0.5	85	.758
15	*Cannabis sativa*			25	0.516
16	*Rubus ellipticus*			5	0.014
17	*Codariocalyx motorius*			15	00.026
18	*Holarrhena pubescens*			20	0.03

Table 4. Diversity indices and evenness for shrubs

S. N.	Indices	Ad. Area	Af. Area
1	Shannon-Weiner Diversity Index (H)	0.91	0.72
2	Simpson's Diversity Index (D)	0.84	0. 68
3	Pielou's Evenness Index (e)	0.29	0.24

Note: Ad.=adjacent to burned area; Af.=fire affected area; F=frequency; D= Density; ind/m^2=individual/m^2.

3. Herbs

The most abundant herbs were *Saccharum spontaneum, Drepanostachyum intermedium*, and *Gleichinia gigantean* in the adjoining area and *Oxalis chodata*, *Saccharum spontaneum*, and *Drepanostachyum intermedium* in the affected area. *Saccharum spontaneum* had the highest (90%) and *Gleichinia gigantea* had the lowest (5%) frequency but a dense population in the adjoining lower-elevated moist area. It was nearly absent at higher elevations where the conditions were comparatively dry (Table 5). However, no major difference in diversity was found, despite the number of species (N = 1728) in the adjoining area outweighing the affected area (N = 801).

Table 5. Frequency and density in non-affected areas and fire affected areas for herbs

S. N.	Scientific name	Ad. Area		Af. Area	
		F (%)	D (ind/m^2)	F (%)	D(ind/m^2)
1	*Artemisia indica*	50	9.4		
2	*Elsholtzia fruticosa*			25	1.95
3	*Biden pilosa*			15	4.9
4	*Cyanodon dactylon*	25	2.5	25	2.2
5	*Cyperus rotundus*			30	3
6	*Drymaria* spp.			20	2.2
7	*Galinsuga parviflora*	10	1.4		
8	*Gingiberaceae* family spp.	35	0.4		
9	*Gleichenia gigantea*	5	25	15	0.1
10	Gramineae family spp.	20	1.25	60	0.6
11	*Hedychium spicatum*	20	1.2		
12	*Micromeria biflora*	10	0.044	15	0.02
13	*Oenothera ragio*	15	1.5		
14	*Oxalis chodata*			30	11.15
15	*Phyllanthus* spp.	25	3	25	0.078
16	*Piper* spp.	40	15		
17	*Pogonatherum incans*			45	2.6
18	*Polygonium hydropiper*	15	1.5		
19	*Polygonium* spp.	20	0.5		
20	*Ranunculus* spp.	75	0.156		
21	*Rubus peniculata*	70	0.3		
22	*Rubus* spp.	50	3		
23	*Saccharum spontaneum*	90	5.4	85	6.35
24	*Fragaria rubicola*			35	0.85
25	*Trifolium* spp.	30	1.95		
26	*Larix nepalensis*	30	2.5		
27	Umbellifers	20	1		
28	Unidentified 1			20	0.7
29	Unidentified 2			10	0.45
30	Unidentified 3			20	0.5

Table 6. Diversity indices and evenness for herbs

S. N.	Indices	Ad. Area	Af. Area
1	Shannon-Weiner Diversity Index (H)	1.0565	0.9349
2	Simpson's Diversity Index (D)	0.937	0.8963
3	Pielou's Evenness Index (e)	0.3271	0.3801

Note: Ad. = adjacent to burned area; Af. = fire affected area; F = frequency; D = Density; ind/m^2 = individual/m^2.

Impacts of Forest Fire

Fire is a major influencing factor in shaping plant diversity and the ecosystem (Joernand Laws, 2013). Fire-adaptive plants are categorized into those that require fire (e.g., pine for regeneration), plants that tolerate fire (e.g., Kans), plants that are not affected by fire (e.g., aquatic plants), and plants that are adversely affected by fire (seeder plants)

(Hoecker, 2021). According to Parasar and Biswas (2003), low-intensity or ground fire is less detrimental to tree species like *Shorea robusta*, *Pinus roxburghii,* and *Tectona grandis,* but shrubs and herbs are mostly affected. The area is dominated by *Pinus roxburghii*, and a few *Pinus wallichiana* among the trees. It is similar to the *Pinus ponderosa* in western North America (Brown et al., 2011). These plants have thick chambered bark (> 3 cm), fire adaptive traits, well off from the ground (Brown et al., 2011), serotinous cone (Parasar and Biswas, 2003), wax coating, narrow-pointed leaf clusters that slow down heat loss and evaporation during cold and long winters, re-sprouting capability, and seed characteristics (Miller, 2001). Other fire-adapted species included *Saccharum spontaneum* and *D. intermedium* (Jaiswal, 2002). These were top-killed by fire and sprouted soon after burning. They were enough in number, even after the fire. Grasses like *Oxalis chodata*, *Cyanodon dactylon*, *Gleichinia gigantea*, *Biden pilosa,* etc. in lower elevations dry before the monsoon very severely and easily catch fire from ignition sources nearby settlements. It was found that fire had altered the frequency of these herb species.

Literature shows that seed species (those species which have fire-sensitive adults) are mainly affected by the fire. The immediate fire effect on the plant was to kill the above-ground shoot part. The study area was found to be rich in medicinal plant diversity. Fire-adaptive plants dominate the community despite the frequent fire and eliminate other species slowly (Narendran, 2001), as studied by Narendran in Madhumalai Sanctuary in India, where *Shorea robusta* is dominating and eliminating other species. Similarly, perennial grasses can dominate annual grass. Low-severity but frequent surface fires lead to a mono-specific forest with a high density of fire-tolerant trees only. It can also cause the extinction of rare plant species. This situation was also observed in the study area where pine was dominating with very few other tree species. Vegetation regeneration is another impact of the forest fire. Ignition temperature from the flame of fire, i.e., 320 ^{0}C, can impact the mortality of sprouting sites that are above the ground surface (Miller, 2001). According to Jackson et al. (1994), frequently occurring fires harm small saplings in the case of Nepal, where a fire is not similar in other parts of the world.

The Severity of Forest Fire

Field observation showed that the surface fire had occurred and reached up to the tops of small trees. The bark of the trees and foliage, twigs, duff, rotten wood, and litter layer were blackened by fire. Trees (height = 1-2 m) lose all their leaves, leaving only their main stem or the basal part of the main stem only. Though the sign of crown fire was not seen, locals assume that the forest is frequently affected by the fire. Dead logs were charred. Small succession plants (mosses, lichen, ferns, etc.) on the rock were turned into ash. The leaves of pine trees were severely dried from top to bottom. Shrubs and herbs were sprouting from the deeper soil layer. However, the large-diameter trees and dead logs were not fully consumed. Based on sprouting and burn severity relations, such a fire is a moderate-severity surface fire (Miller and Findley, 2001). These fires can kill seedlings and small trees (Miller, 2001).

Some ecosystems are adapted to natural fire and benefit from the species' aftermath of a fire (Rodríguez-Trejo and Fulé, 2003). With increasing altitude, the forest is dominated by pine trees, and trees shed dry leaves. The most important property of fuel for increased fire susceptibility is the production or retention of dead material on the ground and in aerial structures (Bond, 1996). Similarly, Burgan and Rothermal (1984) expressed the fuel in packing ratio. A very porous fuel bed with sufficient oxygen content and heat transfer ignites quickly. A very compact fuel bed has less oxygen and burns slowly. Thus, sparse forests are more sensitive to fire. In the studied area, the ground was covered with loose leaf litter of pine, dry bushes of Himalayan bamboo, and thatch grass, which act as a major fuel for a fire.

Fire in Pastureland (Gumba Ban)

A forest fire in 2009 destroyed many places in the LNP and its area. According to DNPWC (2008/09), approximately 200 ha of land was targeted. About 185 ha. of the area of Barkhu, Khopangbhir, 55 ha. of Lauribina, 44 ha. of Brabal, 15 ha. each of Dhunche and Yarsa, 11 ha. of Grang, 6 ha. of Ramche, and 3 ha. of Timure of the Lantang area were destroyed by fire. Most grasses have generally deep and complex root systems that help to extract underground water and withstand drought and fire. If all or most of the metabolic reserve of the plant is destroyed, the plant is weakened and can die. The disappearance of native plants gradually decreases the nutritional value of the forage (Miller, 2001). Pastureland was dominated by *Saccharum spontaneum* and *Drepanostachyum intermedium* species (Table 7). These were found in the two main native plants of grassland. Grasses were dry and very susceptible to fire. The fire-affected area was blackened, showing bare rock, leaving only the basal root of the grass. It is not only fire but also animal grazing that affects plant loss over the pastureland.

Table 7. Trees, shrubs and herbs in pastureland (Gumba Ban)

S. N.	Plant species	Local name	Habit	Total individuals
1	*Pinus roxburghii*	Khotesalla	Tree	1
2	*Bombax ceiba*	Simal	Tree	4
3	*Artemisia dubia*	Titepati	Shrub	22
4	*Woodfordia fruticosa*	Dhanero	Shrub	17
5	*Butia minor*	Bhulethro	Shrub	7
6	*Berberies asiatica*	Chutro	Shrub	4
7	*Blumia balsamifera*	Gaitihare	Shrub	1
8	*Eupatorium adenophorum*	Banmasa	Shrub	20
9	*Saccharum spontaneum*	Kans	Herb	38
10	*Drepanostachyum intermedium*	Nigalo	Shrub	25
11	Unidentified 1	Khanai	Tree	1
12	Unidentified 1	Dhusuni	Shrub	18
13	Unidentified 1	Tyapte	Herb	9
14	Unidentified 1	Langta	Herb	8
	Total			175

Major Causes of Forest Fires

The natural causes of forest fires are long periods of drought before the monsoon and high-speed upslope wind. It is more intense over pastureland with no wind break as forest and promotes fire spread**.** The major anthropological causes of forest fire in the studied area were (Table 8). Ignorance and careless throwing of cigarettes, and burning faggot (coal) after cooking in nearby pastureland and forest areas in dry conditions, all contribute to forest fires. The electricity line that passes through the forest area and pasture land was found to be one of the main causes of forest fires in the area. Such forest fires were observed in 2012in Syafru-1 and Bridim under the LNP area in dry grassland (DNPWC, 2009). Slash and burn practices for grazing animals on the grassland and kitchen garden for making soil fertile might spread the fire to the forest. According to the CBD report (2003), the major causes of fire in tropical forests are commercial exploitation of forests, use of fire for agricultural expansion, and plantation. An intentional fire (other 7%) was set by charcoal traders, an enemy ship with the park officers, and a management group. However, some are unaware of the causes of forest fires (23.3%).

Table 8. Anthropological causes of forest fire

S. N.	Anthropological causes of forest fire	
	Causes	No. of people (%)
1	Ignorance and carelessness	38
2	Electricity shot	17
3	Slash and burn practice	15
4	Don’t know	23
5	Other	7

Forest Fire Control Measures

Based on a survey, villagers (survey in 30 HHs) favor strict rules and regulations to be implemented at the governmental level. Awareness among people and community involvement is another important factor that can prevent forest fires caused by humans (Table 9). Forest fires are mainly controlled by throwing green fronds of tree leaves and separating burned and non-fired areas by digging channels and running water through them. Fire in an elevated area is controlled by snow or rainfall. A forest fire hasn't been raised as a major problem by local people because it hasn't destroyed human lives and properties directly. Most people are illiterate and unaware of modern techniques like helicopter rain.

Table 9. Fire control by different bodies

S. N.	Governmental level		Community level	User groups	NGO/INGOs
1	Strict rules and regulation	Alternate of firewood	Awareness program	Afforestation activities	Focus on wildlife protection than fire
2	40%	12%	27%	18%	3%

Main Effect of Forest Fires on Local People

About 40 % of the people are dependent on grassland and nearby forest for their animal grazing; 38% depend on it for their firewood supply. Of these houses, hotels and restaurants depend on LPG and firewood for cooking. A huge stack of firewood could be seen in almost all the houses. Houses were made up of wooden floors, furniture, and roofs. Some 12% of surveyed houses (especially hotels) demand the necessary supply of alternate firewood. They depend on the hotel, business, and tourist management. According to an agreement between the local people and the governmental sector, the use of firewood in hotels should be replaced by LPG, kerosene, and heaters. Local people can collect firewood on Friday and Saturday, which has decreased firewood by 50% since then.

CONCLUSION

Differences in diversity and evenness indices between adjoining and affected areas indicated that the changes in vegetation had occurred after the forest fire that might be temporary. However, no major difference in diversity was found in herbs except the number of species (N = 1728) in the adjoining area outweighed the affected area (N = 801). Moderate to moderate fires were observed depending on the burn severity and sprout relationship. Drought before monsoon was found to be the leading cause of forest fires, followed by electricity shooting (17%), ignorance and carelessness (38%), slash and burn practice (15%), other (7%), and unknown causes (23%). Our research brings forth the need to better address the drivers of resource extraction from the national park to mitigate this degradation. It also brings forth the need to contribute to the development of appropriate participatory management programs outside areas of formal protection to sustain both biodiversity and ecosystem service delivery from these forests for the future. Finally, we conclude that incorporating both social and ecological knowledge in management decisions is needed for managing forest biodiversity and ecosystem service delivery sustainably.

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