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Variation in Species Composition and Diversity of Burnt and Unburnt Forest of *Shorea robusta*

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ABSTRACT

Forest fire is a critical ecological process that influences species composition, diversity, and regeneration dynamics. This study analyzes the impact of forest fire on the species composition and diversity of *Shorea robusta* forests in the Chure region of Butwal, Nepal, by comparing burnt and unburnt sites. Burnt areas were identified using historical fire data from ICIMOD and the Department of Forests and Environment. Vegetation was sampled using a systematic random method with 60 circular plots of 10 m, 5 m, and 1 m radii for trees, shrubs, and herbs, respectively. The burnt forest was co-dominated by *Shorea robusta* and *Lagerstroemia parviflora*, with associates including *Terminalia alata* and *Careya arborea*. In contrast, the unburnt forest was dominated by *S. robusta* and *Anogeissus latifolia*, associated with species like *Tectona grandis* and *Mallotus philippensis*. The Shannon-Wiener diversity and Margalef's richness indices were higher in the unburnt forest. However, the average density of *S. robusta* was significantly greater in the burnt forest. The findings suggest that fire plays an essential role in shaping species composition and promoting the density of *Shorea* in these forests, despite a reduction in overall diversity.

Keywords: Chure, disturbance, ecology, regeneration, species composition

INTRODUCTION

Fire is a fundamental ecological process that shapes terrestrial ecosystems worldwide (Cochrane et al., 2009). In South Asia, anthropogenic fires are frequently used as a

management tool to control vegetation growth, promote succession of certain species, and reduce wildfire risk (Bond and Van Wilgen, 1996). These fires significantly alter ecosystem functions including nutrient cycling, grass productivity, and tree recruitment (Bond and Keeley, 2005; Prior et al., 2009). Fire-induced changes in species composition represent a key ecological transformation, with burnt areas typically supporting more herbaceous vegetation due to reduced competition for resources (Keith et al., 2010). This shift reflects the replacement of fire-sensitive species by more tolerant ones through processes such as resprouting, which has been observed to be more prevalent in burnt forests (Marrinan et al., 2005).
The regeneration dynamics following fire are complex and influenced by multiple factors including grazing pressure, trampling, and tree clustering patterns (West et al., 1981). While fires release nutrients that can stimulate seedling establishment and ecosystem development (Pausas et al., 2005), they also create ecological trade-offs. High-intensity fires may damage soil tissues and reduce resprouting capacity, while heat-sensitive seeds in the soil bank may be destroyed (Keeley, 1991). Furthermore, uncontrolled fires can disrupt soil micro-flora and micro-fauna, potentially compromising decomposition processes and soil fertility (Kodandapani, 2001). The relationship between fire and forest dynamics is particularly relevant in tropical regions where tree species diversity shows substantial spatial variation (Pitman et al., 2002). Understanding how fire affects species composition and diversity in these ecosystems remains crucial for effective forest management and conservation.

Shorea robusta is deciduous timber tree endemic to South Asia, occupying about 12 million hectares and in Nepal, it primarily occupies subtropical forest zones of the Terai, Bhabar, and Dun regions, as well as the outer foothills, usually forming extensive, dominant stands (Tewari,1995). This species exhibits high ecological adaptability, occupying deciduous, semi-evergreen, and evergreen forests, influenced by local microclimate, geology, and soil conditions (Mishra et al., 2021). Widely recognized for ecological and economic value in South Asia, *S. robusta* is listed as endangered by the IUCN that supports livelihoods through timber, medicinal products, fodder, fuelwood, leaf-plates, edible seeds, and cultural uses (Kumar and Saikia, 2021). The ICIMOD fire data illustrates Chure forest of Nepal burns yearly although the frequency and intensity of fire varies with years. Therefore, this study was conducted to provide a comparative analysis of burnt and unburnt *Shorea robusta* forests in the Chure region of Butwal, Nepal. The specific objectives were to quantify and compare the species composition and diversity of trees, shrubs, and herbs between the forest stands; to assess the impact of fire on the population structure, density, and basal area of *S. robusta* and its major associated species; and to identify fire-tolerant and fire-intolerant species to inform future forest management and conservation strategies in this critical ecosystem.

MATERIALS AND METHODS

Study area

This study was conducted in the Chure range of Rupandehi district, Nepal. The area lies at an altitude of 500–800 m above sea level, between 27°42'–27°44' N and 83°23'–83°30' E. Two distinct forest sites were selected for comparison: a burnt site, consisting of *Shorea robusta* forest affected by seasonal fires, and an unburnt site located to the north of the burnt area, separated by natural streams. The burnt site was identified based on historical fire data provided by ICIMOD (2020), which documented frequent fire incidents in the region during dry seasons.

Vegetation sampling A systematic random sampling approach was employed to assess vegetation composition and structure. A total of 60 circular quadrats were established across both sites with 30 for each site and approximately 30 m distance between two quadrants. Each quadrat consisted of a 10 m radius plot for trees, nested with a 5 m radius sub-plot for shrubs, and a 1 m radius sub-plot for herbs. Total studied area of brunt and unburnt forest was 188,568 sq meters and 113,140.8 sq meters respectively. Sampling was conducted in October 2020. October months is suitable for post-fire recovery, seedlings growth and sprouts which are easily visible. For all trees and saplings within the quadrats, diameter at breast height (DBH, measured at 1.37 m above ground) was recorded using a DBH tape. Plant species were identified through local names, photographic documentation, and standard taxonomic references (Polunin & Stainton, 1997).

Vegetation analysis

Field data were used to compute frequency, density, basal area, and Importance Value Index (IVI) for tree species following Zobel et al. (1987). Several diversity indices were calculated to compare community structure between sites, including the Shannon-Wiener diversity index, Simpson's dominance index, Berger-Parker dominance index, Margalef's species richness index, Pielou's equitability index, and Beta diversity (Whittaker, 1962).

Statistical analysis

Independent sample t-tests were performed using IBM SPSS Statistics (Version 25) to

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evaluate significant differences in vegetation parameters—including diameter, basal area, height, and DBH—between burnt and unburnt forests. A significance level of α = 0.05 was used for all statistical tests.

RESULTS AND DISCUSSION

Species composition across forest layers

A total of 71 plant species were recorded across the study sites. In the unburnt forest, we documented 22 tree, 19 shrub, and 30 herb species. The burnt forest supported a slightly different composition, with 19 tree, 18 shrub, and 32 herb species. The herb layer in the burnt forest was dominated by *Imperata cylindrica* and *Eranthemum pulchellum*, whereas the unburnt forest was characterized by species such as *Boehmeria platyphylla* and *Dryopteris filix-mas* (Figure 1A).

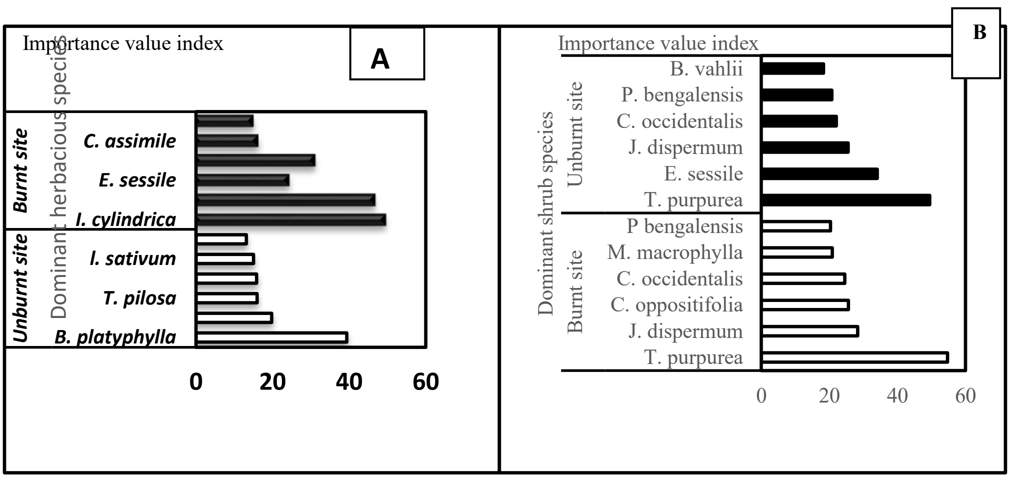

Figure 1. Importance value index of dominant herbaceous (A) and shrub species (B)

Importance Value Index (IVI) in both forest types. Four of the six dominant shrub species were common to both sites (Figure 2). The tree community showed a clear distinction between the forest types. Species such as *Mallotus philippensis*, *Tectona grandis*, and *Ficus semicordata* were recorded exclusively in the unburnt forest. Despite this, *Shorea robusta* was the dominant tree species in both forests, exhibiting the highest IVI (Figure 3).

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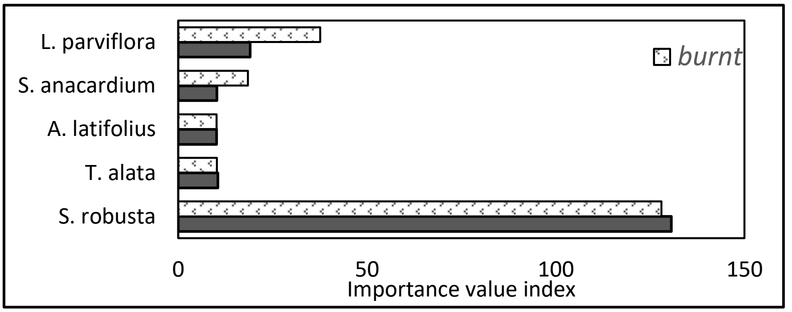

Figure 2. Importance value index of dominant tree species of both burnt and unburnt forest

Forest structure and population characteristics

The structural parameters of dominant tree species differed significantly between the burnt and unburnt forests. The average density of *S. robusta* was substantially higher in the burnt forest (1439.71 individuals/ha) compared to the unburnt forest (504.01 individuals/ha) (Figure 3A). Conversely, the basal area of *S. robusta* was greater in the unburnt forest (2.28 m^2/ha) than in the burnt forest (0.80 m^2/ha) (Figure 3B). Morphologically, *S. robusta* trees in the unburnt forest were taller (19.16 ± 0.24 m) and had a larger mean DBH (0.41 ± 0.11 m) compared to those in the burnt forest (height: 16.29 ± 0.21 m; DBH: 0.37 ± 0.16 m).

Diversity indices

Analysis of diversity indices revealed notable differences between the two forest conditions. The Shannon-Wiener diversity index was higher in the unburnt forest for both the tree (H = 1.80) and herb (H = 3.11) layers, indicating greater species diversity and evenness. In contrast, the shrub layer exhibited higher diversity in the burnt forest (H = 2.62) (Table 1). A similar pattern was observed for species richness. Margalef's index was higher in the unburnt forest for trees (2.94 vs. 2.34) but was comparable for shrubs and herbs across both sites. The Berger-Parker dominance index was highest for trees in the burnt forest (0.64), reflecting the strong dominance of a few species post-fire. Beta diversity, measuring the turnover of species between the sites, was highest for the tree layer (β = 0.078) and lowest for shrubs (β = 0.027), suggesting that fire had the most pronounced effect on tree species composition.

Statistical significance of fire impact

Independent sample t-tests confirmed that fire had a significant effect on key vegetation parameters. The basal area and density of ecologically important species, including *S. robusta*, *Lagerstroemia parviflora*, and *Semecarpus anacardium*, showed highly significant differences ($p < 0.05$) between the burnt and unburnt forests. Furthermore, the DBH and height of *S. robusta* were significantly greater in the unburnt forest ($p < 0.05$) (Table 2).

Table 1. Diversity indices of trees, shrubs and herbs of both burnt and unburnt forests

Life form	Shannon-Wienerindex		Equitability		Concentrationof Dominance		Margalef's Species richness		Berger-Parker	
	Burnt	Unburnt	Burnt	Unburnt	Burnt	Unburnt	Burnt	Unburnt	Burnt	Unburnt
Trees	1.43	1.80	0.49	1.80	0.44	0.38	2.34	2.94	0.64	0.61
Shrubs	2.62	2.35	0.90	2.35	0.08	0.08	2.44	2.45	0.17	0.18
Herbs	2.41	3.11	0.69	3.11	0.13	0.05	3.81	3.76	0.24	0.09

Table 2. Statistical comparison of structural parameters between burnt and unburnt forests

Parameters	T-value	p-value
Basal Area of *S. robusta*	6.290	0.04
Density of *S. robusta*	6.389	0.03
Basal Area of *L. parviflora*	6.489	0.01
Density of *L. parviflora*	11.41	0.00
Basal Area of *S. anacardium*	6.554	0.00
Density of *S. anacardium*	8.720	0.00
DBH of *S. robusta*	2.68	0.03
Height of *S. robusta*	8.78	0.02

Forest structure and population parameters

Significant structural differences were observed in dominant tree species between the burnt and unburnt forests. The density of *S. robusta* was nearly three times higher in the burnt forest (1439.71 individuals/ha) compared to the unburnt forest (504.01 individuals/ha) (Figure 3A). In contrast, the basal area of *S. robusta* was substantially greater in the unburnt forest (2.28 m^2/ha) than in the burnt forest (0.80 m^2/ha) (Figure 3B). Morphological measurements further revealed significant differences between sites. Trees in the unburnt forest were notably taller (19.16 ± 0.24 m) with larger DBH

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(0.41 ± 0.11 m) compared to those in the burnt forest (height: 16.29 ± 0.21 m; DBH: 0.37 ± 0.16 m). Statistical analysis confirmed the significant impact of fire on these structural parameters (Table 2). Independent sample t-tests revealed highly significant differences ($p < 0.05$) in both basal area and density for three key species: *S. robusta*, *L. parviflora*, and *S. anacardium*. Additionally, both DBH and height of *S. robusta* showed statistically significant differences between the burnt and unburnt forests,

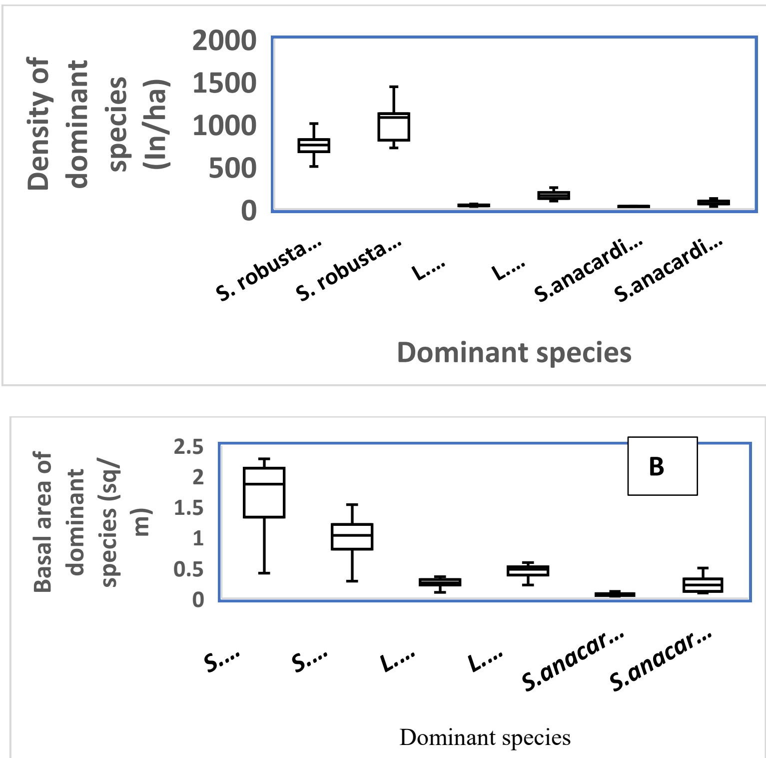

Figure 3. Comparison of densities (A) and basal area (B) of dominant tree species of burnt and unburnt forest. The box plots show the median, and 25 to 75 percentiles. Whiskers indicate maximum and minimum values.

Fire-induced changes in species composition

Results showed distinct shifts in species composition between burnt and unburnt *Shorea robusta* forests. In burnt areas, the tree layer was dominated by *S. robusta*, *Lagerstroemia parviflora*, *Semecarpus anacardium*, and *Cassia fistula*, with *Terminalia alata*, *Careya arborea*, and *Dalbergia sissoo* as common associates. This pattern aligns with previous studies indicating that mature Sal trees exhibit considerable fire resistance once they surpass the sapling stage (Bakshi, 1957; Kumar & Thakur, 2008). The persistence of *S. robusta* following fire events supports the traditional practice of controlled burning to maintain pure Sal stands and prevent succession toward mixed broadleaved forests (Suman, 1984).

The success of *L. parviflora* in burnt areas can be attributed to its ecological adaptations as a light-demanding, drought-tolerant, and fire-resistant species (Orwa et al., 2009). In the herbaceous layer, the dominance of *Imperata cylindrica* represents a classic fire-climax community, consistent with findings from Brook (1989) and Seth (1970). The species' extensive rhizome system and high root-to-shoot ratio facilitate rapid regeneration following disturbance (Ramakrishnan et al., 1983), explaining its proliferation in frequently burnt areas.

In contrast, unburnt forests supported a more diverse tree community including *Anogeissus latifolia*, *Tectona grandis*, *Mallotus philippensis*, and *Ficus semicordata* alongside *S. robusta*. The herb layer in these undisturbed sites was characterized by moisture-preferring species such as *Boehmeria platyphylla* (Maithani et al., 1986), reflecting the more stable microclimatic conditions.

Impacts on diversity patterns

Results demonstrated reduced overall diversity in burnt forests compared to unburnt areas, particularly evident in tree and herb layers. This finding corroborates studies from various ecosystems including tropical deciduous forests in Thailand (Kafle, 2006), mixed conifer forests in California (Collins & Stephens, 2010), and juniper forests in Mexico (Harner & Harper, 1976). The observed Shannon diversity indices (1.43-3.76) fall within the range reported for similar tropical dry forests (Reddy et al., 2008; Pandey, 1992).What was their range?- Exact range was not mentioned in paper

The reduction in species richness following fire disturbance can be attributed to the elimination of early successional species that become shaded out by rapidly growing woody resprouts (Miller, 2000). However, the higher shrub diversity in burnt areas suggests variable responses across life forms, possibly due to reduced competition and increased light availability (Keith et al., 2010). This pattern of differential response across vegetation layers underscores the complex nature of fire impacts on forest ecosystems.

Structural modifications and population dynamics

Significant structural differences were observed between treatment areas, with unburnt forests supporting taller trees (19.16 ± 0.24 m) with greater DBH (0.41 ± 0.11 m) compared to burnt forests (16.29 ± 0.21 m height; 0.37 ± 0.16 m DBH). These findings support previous research by Trapnell (1959), Strang (1974), and Gandiwa (2006), indicating that repeated burning negatively affects woody plant development through top-kill and subsequent resp routing (Enslin et al., 2000; Gandiwa & Kativu, 2009).

The differential response of species to fire was particularly evident in density patterns. While fire-intolerant species like *M. philippensis* and *F. semicordata* were absent from burnt areas, fire-adapted species including *L. parviflora* and *S. anacardium* showed increased abundance. This species replacement phenomenon illustrates the filtering effect of fire on community assembly, favoring traits such as resp routing capacity and heat-resistant bark.

The significantly higher basal area in unburnt forests (2.28 m^2/ha vs 0.80 m^2/ha for *S. robusta*) reflects the cumulative impact of fire-free growth periods. The reduction in basal area in frequently burnt areas results from the conversion of large-stemmed individuals to multi-stemmed coppices following top-kill events (Enslin et al., 2000).

CONCLUSION

In conclusion, burnt Forest acts as an important role in management of densities *Shorea* forests. Fire is one of the major disturbances causes unbelievable loss of forest, however, fire has been considered to play positive role to stimulate fire tolerate species. Therefore, regular monitoring of this forest is necessary to manage *Shorea* and maintaining species diversity of the area as well.

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