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Woody species diversity and assemblage in different forest management stands of central Nepal

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Abstract

Various forest management strategies are in place for the conservation of forest ecosystems across the globe. Nepal is also implementing different forest management and restoration practices and has various impacts on vegetation characteristics. This study aims to compare the richness and diversity of woody plant species, and variability in abundance of woody species assemblages in different forest management stands, viz. restored stands inside Buffer Zone Community Forest (BZCF), natural stands of BZCF and core stands of Parsa National Park. Thirty sampling plots of 30 m × 30 m were laid on each stand, maintaining at least 50 m distance between the plots, where woody plant species having height 1.5 cm was identified and their DBH measured. Species composition was assessed comparing Importance Value Index (IVI) of woody plant species across the forests. Similarly, species diversity and structural diversity across stands were determined using Shannon Diversity index and basal areas of the plant species were calculated. The study showed *Shorea robusta* and *Lagerstroemia parviflora* with highest frequency (>80%) in all the sites, and the species diversity was highest in the core stands inside the national park followed by the natural stands of BZCF, and the restored stands of BZCF. Basal area of overall species and density of *S. robusta* were, however, highest on the restored stands of BZCF, whereas overall density was highest in the natural stands of the BZCF. The study revealed that the forest management practices need improvement in enhancing the plant species diversity of the ecosystems. We recommend to assess the functional attributes of the different forest management stands to evaluate the effectiveness of forest management strategies.

Keywords: *Buffer zone community forest, ecosystem, Restored forest stands, S. robusta*

Introduction

Forests are one of the most crucial natural resources, as they provide habitats for biodiversity, prevent desertification, sequester atmospheric carbon, regulate air, and produce wood (Baskent, 2021). Additionally, status of forests also provides information on forest regeneration and need of varying dimensions of restoration interventions (Chazdon et al., 2022). In rural Nepal, forests are a source of livelihood as people depend on timber, fodder, fuelwood, leaf litter, and other forest products that play a significant role in the livelihoods of communities situated nearby forest areas (Sapkota et al., 2009; Sapkota and Stahl, 2020). However, due to changes in biogeography and habitat, species diversity is not uniform (Whitmore, 1998). Tropical forests, in particular, experience high levels of anthropogenic disturbances due to timber harvesting (Dzulkritil, 2014), which can affect forest structure and composition, as well as its canopies, through top-down effects (Sapkota and Stahl, 2020). The density and size distribution of forests are determined by its structure (Huang et al., 2003), while species diversity and richness are used to assess ecological health (Davari et al., 2011). Various factors, such as environmental conditions, light levels, soil temperature, and air temperature under the canopy, can alter forest structural changes (Lebrija-Trejos et al., 2010).

Forest structure plays a crucial role in affecting different forest components, such as species diversity and composition, functional traits, and functional diversity (Whitfeld, 2014), and disturbances can also change forest structure. In forest habitats, species diversity, genetic flow, and biological interactions are all influenced by forest structure (Jafari et al., 2013). Forest also connotes to number of species, plant composition and tree size (Hui et al., 2019; Nowak et al., 2008). Forest structure provides reflection about habitat and species diversity, development of wildlife and plant species, ecosystem services and biomass production (Pommerening, 2002). Forest structure is also the driver for forest growth and ecological processes, which help to determine the past, present and future scenario of the forest (Hui et al., 2019).

Forest structure and diversity are crucial components in forest management (Jafari et al., 2013). *Shorea robusta* (Sal) is the dominant species in South and Southeast Asia (Whitmore, 1989; Ahmed et al., 2008). Forest management is carried with the main focus on integrating ecological complexity, socio-cultural, political and technological context (Torres-Rojo et al., 2016). It also varies as per the need such as forest conservation context, religious effect, ecosystem services and non-timber forest product (Torres-Rojo et al., 2016). Forest Act (2076) of Nepal has classified forests in terms of management regime government managed forest, forest protected area, community forest, partnership forest, leasehold forest and religious forest. This study focuses on analyzing the diversity, composition, and structure of different forest stands: restored stands inside Buffer Zone Community Forest (BZCF), natural stands of Buffer Zone Community Forest (BZCF) and core forest stands of Parsa National Park of central Nepal. While there are numerous studies on forest management, ecosystem services, invasive species, biomass, and carbon stock (Aryal et al., 2018; Smith et al., 2022; Uprety et al., 2023; Sharma et al., 2023), very few studies have focused on comparative studies on species structure and diversity (Jafari et al., 2013) in different forest management stands This study therefore attempts to fill gap by assessing the patterns of diversity, composition, and structure of the different forest management stands in and around Parsa National Park, Nepal.

Materials and Methods

Study Area

The study was conducted in and around Parsa National Park considering different forest management stands: restored stands inside Buffer Zone Community Forest (BZCF), natural stands of Buffer Zone Community Forest (BZCF) and core forest stands of Parsa National Park (Figure 1). Among the forest stands, BZCFs are managed by the forest user group, while the core forest is managed by the Government of Nepal. The study area lies on the sub-tropical elevation range of 100

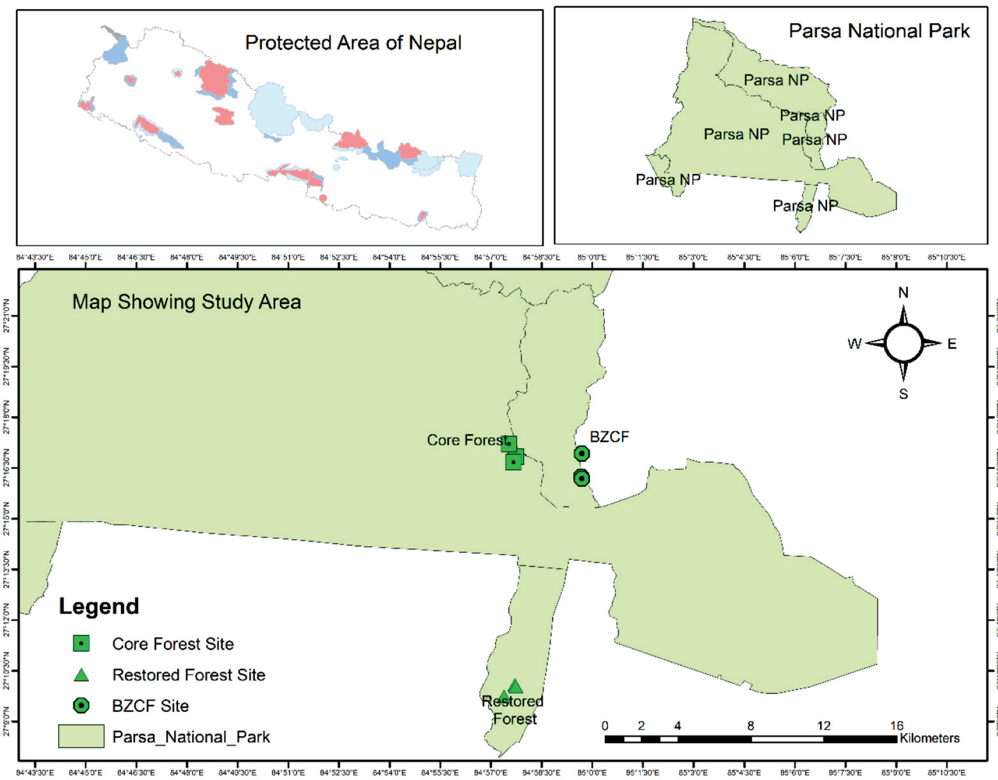

Figure 1: Study area map showing restored stands, natural stands of Buffer Zone Community Forest (BZCF) and core forest stands of Parsa National Park

m to 140 m, and vegetation is dominated by Sal (*Shorea robusta*) species. BZCF forests considered for the study were Radha Krishna BZCF, Janagaran BZCF and Musharni Mai BZCF while Churiya Mai BZCF was selected as the natural BZCF site. The restored stands at BZCFs were restored since about 20 years. Natural stands of BZCF and restored stands of BZCF are near from the human settlement, where human intervention is present. People collect forest resources for their subsistence needs *viz.* fodder, fuel wood, timber, etc. Core forest was inside Parsa National Park, where there is restricted access to the local community for the collection of forest resources.

Methods

Field data was collected on January, 2020. A total of 30 sampling plots for each forest management stands and each plot measuring 30 m x 30 m were established to survey the population structure of woody species in the study area. Tree/shrub was defined as woody species with height e” 1.5 m. In the plot, all the species were identified and their diameter at breast height (DBH) and height were measured. The local name of the species was recorded on site, while the scientific name was sourced from relevant literature. DBH was measured using a DBH tape, and height was estimated by using clinometer.

Data Analysis

This study focuses on analyzing the Shannon Diversity index, species composition, basal area, and species density across the different forest management stands. Species diversity was calculated by using the Shannon Diversity Index as:

$$H' = -\sum \text{pi} \ln \text{pi}$$

The Importance Value Index (IVI) was calculated as the summation of relative frequency, relative density and relative basal area of the species.

Relative frequency (RF %) =

$$\frac{\text{Frequency of a particular species}}{\text{Total frequency of all the species}} \times 100$$

Relative density (RD %) =

$$\frac{\text{Density of the particular species}}{\text{Total density of all the species}} \times 100$$

Relative basal area (RBA %) =

$$\frac{\text{Basal area of the particular species}}{\text{Total basal area of all the species}} \times 100$$

The data were analyzed using R (R Core Team, 2016) and RStudio (RStudio Team, 2015) using the packages “Plotrix” (Lemon, 2006) and “Sciplot” (Morales, 2017) for data handling and descriptive statistics, and “vegan” (Oksanen et al., 2020) for species diversity calculation. Shapiro-Wilk test was used for the normality test and analysis of variance (ANOVA) was used for comparing the mean values of structural attributes under the different management stands. A TukeyHSD test was applied for the pairwise comparisons of the different structural attributes.

Results and Discussion

This study examined structural attributes of different forest management stands in the sub-tropical lowland of Nepal, which consists of the study sites named as- core forest inside the Parsa National Park, natural stands of BZCF, and restored stands of BZCF. The restored stands are under restoration interventions for the past 20 years, while the core forest is protected under the management of Department of National Parks and Wildlife Conservation. The lowland forests are also facing threats from illegal collection and harvesting of forest products, including timber. Biodiversity conservation has emerged as a major concern in forest management over the past few decades, and forest management practices have significantly impacted the forest structure and diversity, as reported by Webb and Sah (2002) and Timilsina and Heinen (2008).

Species Composition

A total of 55 woody plant species were recorded across all sites, of which 15 woody species were common in all the forest management stands. The highest species diversity was observed in the core forest, followed by the natural stands of the BZCF

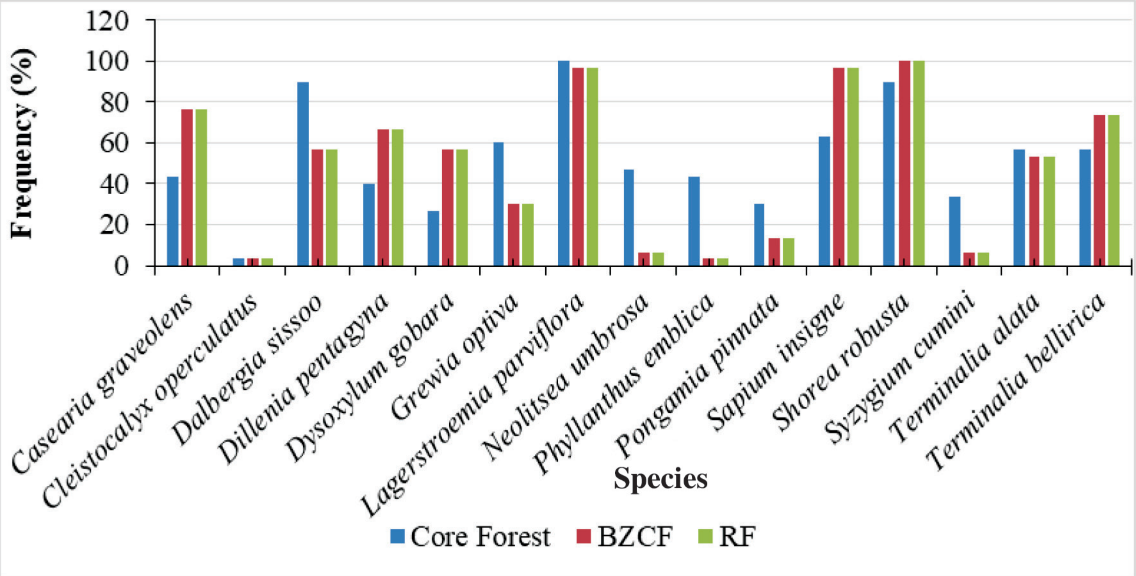

Figure 2: Frequency of 15 most abundant species in the studied forest stands

and the restored stands of the BZCF (Table 1). *S. robusta* and *L. parviflora* were found to have the highest frequency (>80%) in all the sites (Figure 2). Consistent with Terai Forest Inventory carried by DFRS, this study also observed one of the frequent species as *S. robusta* in all the management stands, which is similar with Khadka et al. (2023), Chapagain et al. (2021) and Sapkota et al. (2009).

Previous researchers have found variation was observed in species richness in mixed forests of Nepal. Sharma et al. (2020) found 27 tress species in central Terai Nepal, and Bhatta and Devkota (2020) found 42 species from 20 families in the hilly region of Nepal. The difference in the results might be due to consideration of different ecological zones. Similarly, variations in species richness are also altered by different environmental factors like climate, soil, geographical location, disturbance and management practices (Ram et al., 2004; Das et al., 2017; Bhatta & Devkota, 2020). This study found that the core forest had the highest species richness, consistent with the findings by Chauhan et al. (2010) and Awasti et al. (2020), who also observed higher species richness in their control blocks. Considering IVI, *S. robusta, P. pinnata, L. parviflora, B. ceiba,* and *M. philippensis* were the top three species across all types of forest management stands. The study also found that *S. robusta* had the highest IVI in the restored forest stands of BZCF and the natural stands of BZCF forests, but was comparatively lower in the core forest, which is consistent with findings by Khadka et al. (2023) for the IVI for *S. robusta*. In the core forest of the national park, natural stands of BZCF and the restored stands of the BZCF observed richness were found to be 41, 33, and 24, respectively (Table 1).

The natural forest stands of BZCF and restored forest stands of BZCF showed the highest IVI for

Table 1: Vegetation characteristics of the studied forest stands

Vegetation characteristics	Natural stands of BZCF	Restored stands of BZCF	Core Forest
No. of individuals ha^{-1}	736	489	441
No. of individuals of *Shorea robusta* ha^{-1}	272	381	73
Richness (No. of species observed in the sampling units)	33	24	41
Shannon Diversity Index (average per sampling unit)	1.7	1.1	2.1

Table 2: IVI of 15 most abundant species in the studied forest stands

Species Name	Restored Stands of BZCF				Core Forest				Natural Stands of BZCF			
	RF	RD	RBA	IVI	RF	RD	RBA	IVI	RF	RD	RBA	IVI
Casearia graveolens	9.45	3.48	1.05	13.98	5.53	2.36	2.10	9.99	7.35	2.97	0.93	11.25
Cleistocalyx operculatus	0.79	0.08	0.00	0.86	0.43	0.12	1.00	1.54	0.32	0.05	0.38	0.75
Dalbergia sissoo	1.57	0.61	0.77	2.95	11.49	8.62	3.52	23.63	5.43	1.61	3.42	10.47
Dillenia pentagyna	10.24	3.03	2.68	15.95	5.11	2.36	1.18	8.65	6.39	5.24	1.45	13.08
Dysoxylum gobara	3.94	1.14	2.53	7.61	3.40	4.25	2.00	9.65	5.43	2.82	1.36	9.61
Grewia optiva	2.36	0.68	0.40	3.44	7.66	8.97	2.72	19.35	2.88	0.65	0.18	3.71
Lagerstroemia parviflora	7.87	2.88	0.94	11.69	12.77	25.03	16.10	53.90	9.27	15.21	3.26	27.74
Neolitsea umbrosa	1.57	0.30	0.12	2.00	5.96	2.48	3.08	11.52	0.64	0.15	3.56	4.35
Phyllanthus emblica	2.36	0.38	0.22	2.96	5.53	3.07	1.50	10.10	0.32	0.05	2.10	2.47
Pongamia pinnata	4.72	0.61	4.84	10.17	3.83	1.18	27.84	32.85	1.28	0.25	27.08	28.61
Sapium insigne	1.57	0.38	1.06	3.01	8.09	6.14	8.76	22.98	9.27	9.77	1.37	20.41
Shorea robusta	23.62	77.82	2.21	103.65	11.49	22.55	13.98	48.02	9.58	41.34	1.13	52.06
Syzygium cumini	3.15	0.76	2.03	5.94	4.26	1.18	6.26	11.70	0.64	0.10	8.84	9.58
Terminalia alata	0.79	0.23	1.06	2.08	7.23	4.01	7.70	18.95	5.11	1.81	10.20	17.12
Terminalia bellirica	0.79	0.08	0.11	0.98	7.23	7.67	2.26	17.17	7.03	2.92	0.73	10.68

(RF: Relative Frequency; RD: Relative Density; RBA: Relative Basal Area; IVI: Importance Value Index; Values expressed in %)

S. robusta, while *L. parviflora* had the highest IVI value in the core forest (Table 2). Comparing the IVI of *S. robusta*, restored forest stands have the highest values (103.65%), followed by the natural stands of the BZCF forest (52.06%) and the core forests (48.02%).

Forest Structure

Basal area of tree species was found high in the restored stands of BZCF as compared to other type of forest management stands, since restored stands were managed for conservation of selective species. Likewise, the basal area of *S. robusta* found high in restored stands of BZCF, since there was high *S. robusta* found in the areas. This study found similar result with Whitfeld et al. (2014), who found high basal area in secondary forest like to that of restored forest, but Webb and Sah (2003) determined highest basal area in the natural than any other stands. Basal area may vary with different forest process like succession (Whitfeld et al., 2008), since it is dynamic process and can also vary with stand age, management intervention and regeneration survival.

Total basal area of trees was found 8.99±0.56 m^2/ha, 13.44±1.73 m^2/ha and 16.41±1.12 m^2/ha in natural stands of BZCF, core forest and restored forest stands of BZCF, respectively. There was significant difference in the mean basal area between the core forest and natural stands of BZCF (p=0.03), restored forest stands and natural forest stands of BZCF (p<0.001), but there was no significance difference in mean basal area between restored forest stands and core forest (p=0.21) (Figure 3). While the total basal area of *S. robusta* was found 3.77±0.45 m^2/ha, 3.24±0.56 m^2/ha and 14.24±1.11 m^2/ha in BZCF, core forest and restored forest, respectively. There was no significance difference between core forest and natural stands of BZCF (p=0.87), but significance difference was observed in restored stands and natural stands of BZCF (p<0.001) and restored stands and natural stands of BZCF (p<0.001).

The highest woody species density was found in natural stands of BZCF (735.56±59.11 ind./ha) followed by restored stands of BZCF (489.26±27.35 ind./ha) and the core forest (440.74±20.89 ind./ha), respectively (Figure 4). The TukeyHSD pairwise comparison shows that there was significant difference between core forest and natural stands of BZCF (p<0.001), and restored stands and natural stands of BZCF (p<0.001), but there was no significant difference between restored stands

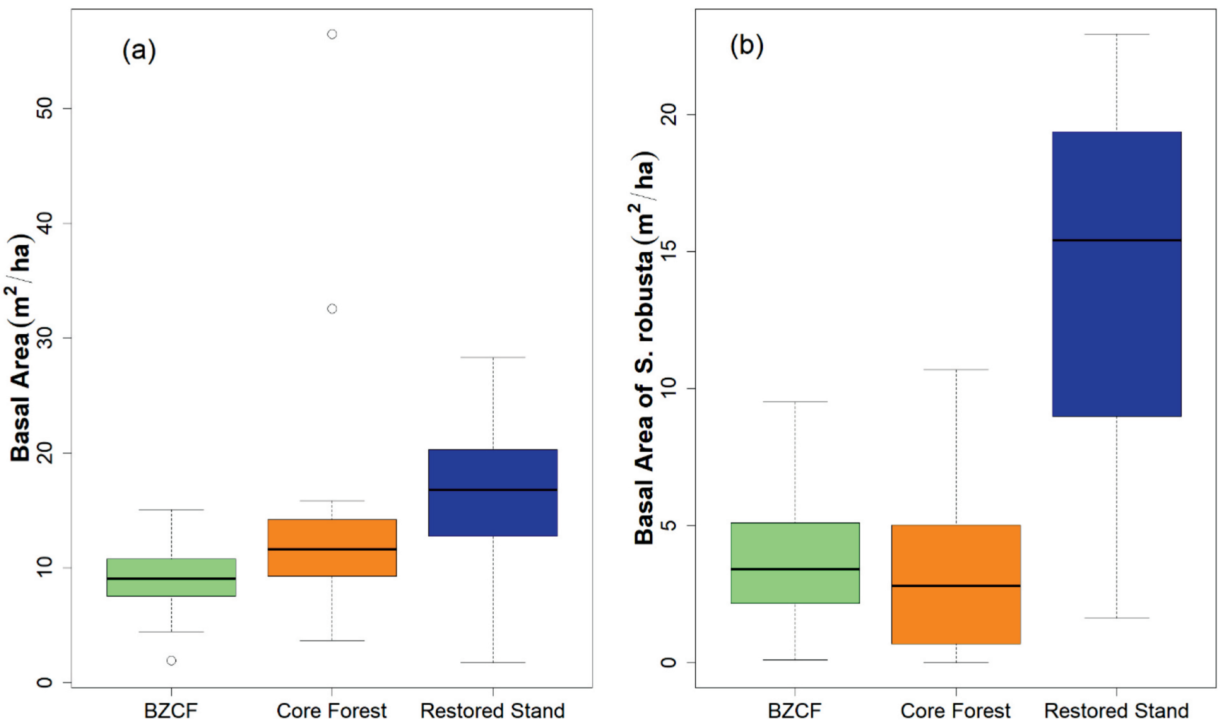

Figure 3: Basal area of overall species (a) and *Shorea robusta* (b)

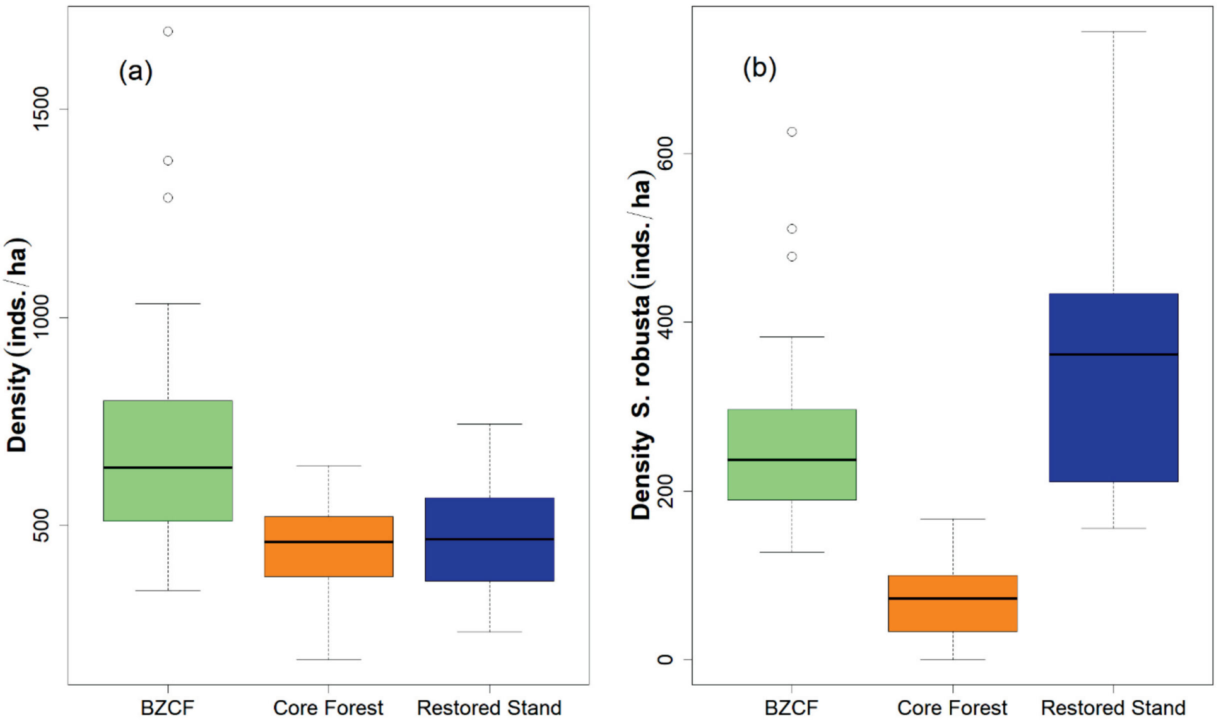

Figure 4: Density of overall species (a) and *Shorea robusta* (b)

and core forest (p=0.66). Similarly, highest *S. robusta* density was found in restored stands of BZCF (380.74±33.92 ind./ha) followed by natural stands of BZCF (272.43±21.89 ind./ha) and the core forest (73.33±8.43 ind./ha), respectively. The TukeyHSD pairwise comparison showed significant difference between all the forest management types. Chapagain et al. (2023) found highest species density in protected areas forest compared to BZCF, with significant difference between the studied sites. Likewise, Pandey et al. (2014) and Paudel and Sah (2015) also found high tree density inside national park as compared to the community forest. Poudyal et al. (2019) shows that selective harvesting support forest parameters, which might be the reason for this high density in the natural stands of BZCF compared to the core forest.

Forest Diversity

The Shannon diversity in natural stands of BZCF, core forest and restored stands of BZCF were 1.70±0.06, 2.12±0.06 and 1.12±0.06, respectively (Figure 5). Tukey HSD test showed significance difference in diversity between different management stands.

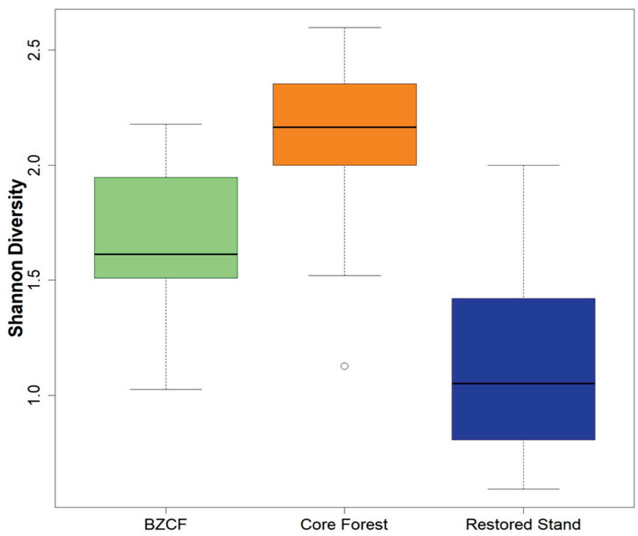

Figure 5: Plot level Shannon diversity of woody species in the studied forest stands

The species richness in core forest compared to other stands was higher which was similar with Awasti et al. (2015) and Chapagain et al. (2021), but they also found high species density in protected areas, while this study found high species densities in the restored stands of BZCF and natural stands of BZCF. Awasti at al. (2015) found low species richness in managed block and high species richness in unmanaged block, which was similar with this study. Whitfeld et al. (2008) found higher species richness on matured forest as compare to others, our study also correlates with their study, though they found more diversity in mature forest. But species diversity and richness were variable with functional habitat, biogeography, traits, grazing, social condition, disturbance and climatic variation (Whitmore, 1988; Tagle et al., 2008; Ratovonama et al., 2013; Jafari et al., 2013). Chapagain et al. (2017) found species richness changes with management practices.

Conclusion

This study has documented the woody species composition and diversity in different forest management stands in the sub-tropical forest ecosystems of Nepal. Our findings showed that the core forest had the highest species diversity, followed by the natural stands of BZCF and the restored stands of BZCF. *S. robusta* and *L. parviflora* with highest frequency (>80%) in all the forest management stands. Basal area of overall species and density of *S. robusta* were highest on the restored forest stands of BZCF, whereas overall species density was highest in the natural stands of the BZCF. Our findings emphasize the importance of considering forest structural attributes as indicators of health and integrity of the forest ecosystems. We recommend to assess the functional attributes of the different forest management stands to evaluate the effectiveness of forest management, and explore the interactions of different biotic and abiotic covariates in the future studies.

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