DOI: https://doi.org/10.3126/forestry.v18i01.41751

Forestry: Journal of Institute of Forestry, Nepal

journal homepage: www.nepjol.info/index.php/forestry

Regeneration status and diversity under irregular shelterwood system: A study from Panchkanya Community Forest, Sunsari, Nepal

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KEYWORDS

Irregular shelterwood system
Plant diversity
Regeneration
Shorea robusta

ABSTRACT

The present study is the outcome of vegetation sampling conducted in the managed and unmanaged forest patch under the irregular shelterwood system to analyze community structure and plant diversity in a degraded mixed forest in Eastern Terai, Nepal. Systematic random sampling was followed by laying out 15 quadrates sized $4m^2$ with uniform spacing of 50 meters in both managed and unmanaged blocks, respectively. This study revealed that the first and second-year regeneration felling subsisted the *Shorea robusta* in the managed forest patch. There was observed a remarkable increase in regeneration but a decrease in plant diversity in the managed area in comparison to the unmanaged one. Simpson's index of diversity was 0.760 and 0.890 and Shannon-Wiener indexes were 1.82 and 2.43 in managed and unmanaged forest blocks, respectively. Independent sample t-test showed a significant difference in the total number of regenerations between managed and unmanaged forest blocks since P-value <0.05 (P=0.0166) i.e., managed blocks with opened canopy had higher regeneration but a lower diversity. This study concludes that the irregular shelterwood system is deemed pivotal for increased regeneration of *Shorea robusta* particularly in the eastern lowland of Nepal.

Introduction

Biodiversity provides opportunities to adapt our production systems to emerging challenges and is significant for efforts to meet the Sustainable Development Goals (SDGs) of the 2030 Agenda (FAO 2019). Forests cover over 30 percent of global land and consist of more than 60000 different tree species while providing habitats for 80 percent of amphibian species, 75 percent of bird species and 68 percent of mammal species (FAO and UNEP 2020). Globally reversing the loss of forest cover through sustainable forest management is incorporated as one of the

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Received 13 July 2021 Accepted 29 November 2021

goals of the United Nations strategic plan for forests (2017–2030). Nepal, despite occupying only about 0.9 percent of the global land, has always been exemplified as a biodiversity-rich country (Bhuju et al. 2007). Community forests have been widely acclaimed as a successful approach in terms of participatory forest management and governance (Ghimire and Lamichhane 2020) in the country where forests occupy 40.36 percent of its total land (DFRS 2015). However, the Forest Policy (2015) and the Forestry Sector Strategy (2016-2025) have also now emphasized sustainable forest management based on silvicultural systems to enhance forest productivity in Nepal. Similarly, several endeavors towards integrating silvicultural system-based management have been enacted with the principal target of improving the quality and productivity of forests in Nepal (DOF 2017).

Irregular shelterwood system which is the most commonly prescribed silvicultural system in the Terai (Awasthi et al. 2015) focuses on establishing desirable species with a prolonged regeneration period than a regular system (Smith 1986; Hannah 1988). Irregular shelterwood system is a type of silviculture system in which the trees, except few mother/ shelter trees, are removed in felling operations and regeneration and poles are retained as the advanced crops for the future, thus resulting in an irregular crop composition (Khanal and Adhikari 2018). Irregular shelterwood is possibly the foremost way to create complexity into managed forests (Raymond et al. 2009; Burrascano et al. 2013) as the unpredictability of outcomes of harvest gaps makes regulating natural processes simultaneously alongside timber harvest a difficult task (Kern et al. 2013). So the issues related to the pattern of felling and its visible effects on regeneration and species composition can be investigated given its major technical significance for the preliminary assessment and eventual development of a sustainable forest management plan (Shamsul 2001; Kushwaha and Nandy 2012; Duguid and Ashton 2013; Nguyen & Baker 2016).

Forest regeneration, in terms of ecosystem dynamics, is a biological phenomenon of forest resource restoration (Wang and Chen 2008) which includes asexual and sexual reproduction, dispersal and establishment corresponding to ecological aspects (Barnes et al. 1997). Regeneration is essential for the conservation and maintenance of biodiversity in natural forests (Hossain et al. 2004; Rahman et al. 2011) as well as maintaining the composition and stocking of the coveted species after several disturbances (Khumbongmayum et al. 2005). Successful regeneration is the most significant factor in achieving long-term sustainability of forests (Saikia & Khan 2013), so the knowledge of plant regeneration status assists in preparing management alternatives and setting priorities (Zegeye et al. 2011; Haider et al. 2017). The reliable data on regeneration trends is necessary for the meaningful management and conservation of natural forests (Eilu & Obua 2005). Species is one of the key analytical components of the plant community (Odum 1959), so the information of its composition and diversity is of pivotal significance to comprehend the structure, prepare planning and executing the conservation strategy for the community (Malik 2014; Malik & Bhatt 2018). Comprehension of forest structure is a foremost basis to describe various ecological processes and also to model the functioning and dynamics of forest (Elouard et al. 1997).

Shorea robusta forests of Nepal are shrinking with poor regeneration alongside changes in species composition but the studies elucidating the influence of disturbances on stand structure, species composition and regeneration of tree species are very limited (Sapkota et al. 2009). A study reported increased species richness and promotion of threatened species in the regeneration layer as the effect of irregular shelterwood system (Shrestha et al. 2019). Some other studies have also focused on regeneration status (Khanal & Adhikari 2018), regeneration dynamics (Awasthi et al. 2020) and species diversity (Awasthi et al. 2015) but mostly in the *Shorea robusta* dominated forests of Nepal.

However, the study was confined in a degraded forest predominantly composed of economically inferior species like *Adina cordifolia, Trewia nudiflora and Albizia lebbeck*. In such a forest, the major objective of applying shelterwood system focused on the reintroduction of economically valuable species including *Shorea robusta* through regeneration. Thus, this study was conducted for a comparative study on regeneration performance and plant species diversity after the implementation of the irregular shelterwood system in eastern Terai of Nepal.

Materials and Methods

Study Area

The study was carried out in the Panchkanya community forest located in Dharan Municipality of Sunsari district of Eastern Nepal. The community forest covers an area of 340.77 ha out of which 312.8 ha was allocated for the implementation of intensive management applying irregular shelterwood system. The compartment allocated for intensive management was further divided into 10 periodic blocks. Two coupes in periodic block I had implemented the irregular shelterwood system that was regarded as managed blocks and ones without implementation of regeneration felling were considered as unmanaged blocks. The regeneration felling was conducted in the first and second felling coupes in the year 2017 and 2018 respectively. Coupe-I (First year felling coupe) wasn't included in the study as that coupe was enriched by artificial regeneration of *Shorea robusta*. General information on the study site has been described in Table 1.

Data collection

Vegetation sampling was conducted by the quadrat sampling method following Mishra (1968); Shrestha (1996); Cunningham (2001); Shrestha et al. (2007). Systematic random sampling was followed for data collection. The plots were laid out in both managed as well as unmanaged blocks. The plots were laid out through the Arc Gis software (version 10.2.2) with a uniform plot distance of 50 meters (m). Total 15 sample plots of $4m^2$ (Size=2 m × 2 m) were laid in the managed block. Similarly, an equal-area (3.91 ha) was surveyed in the unmanaged block by allocating a total of 15 sample plots of the same size.

Data Analysis

The plant community composition both in the managed and unmanaged blocks was studied. The regeneration data in both disturbed and undisturbed blocks were quantitatively analyzed for frequency, density and abundance by using the expressions following Zobel et. al.

Table 1: General Information of the study site

Name of community forest	Panchkanya Community Forest
Address	Dharan Municipality, Ward no 4, Sunsari
Forest Type	Mixed broadleaved softwood forest
Major vegetation types	*Adina cordifolia, Albizia lebbeck and Trewia nudiflora.*
Area	Total forest area: 340.77 ha Total compartments: 2 (Intensive management area and reserved area). Intensive management area: 312.8 ha. Sub-compartment (Periodic Blocks): 8 (each with an area of 39.1 ha). Reserved Area : 27.97 ha.
Silvicultural system	Irregular shelterwood system Applied since: 2017
Felling coupes	10 (each with an area of 3.91 ha), felling has been carried out in Coupe-I and II (first and second-year felling coupes).

(1987)

$$\text{Frequency (\%)} = \frac{\text{Number of quadrats in which and individual species occurred}}{\text{Total number of quadrats sampled}} \text{ X } 100$$

$$\text{Density (stem/Ha)} = \frac{\text{Total number of individuals of a species in all plots}}{\text{Total number of plot studied X Size of th eplot}(m^2)} \text{ X } 100$$

$$\text{Abundance} = \frac{\text{Total number of induviduals of the species}}{\text{Total number of quadrats in which the species has occurred}} \text{ X } 100$$

$$\text{Relative Frequency (RF, \%)} = \frac{\text{Frequency of individual species}}{\text{Sum of the frequencies for all species}} \text{ X } 100$$

$$\text{Relative Density (RD, \%)} = \frac{\text{Density of individual species}}{\text{Total density of all species}} \text{ X } 100$$

$$\text{Relative Abundance (RA, \%)} = \frac{\text{Abundance of individual species}}{\text{Total abundance of all species}} \text{ X } 100$$

Importance value index (IVI) = RF + RD + RA

Independent-samples t-test was conducted to compare the mean number of regeneration between the plots in managed and unmanaged areas through IBM Statistics SPSS version 22.

Plant Regeneration diversity Analysis was conducted as below:

a) Concentration of dominance was measured by Simpson's index of dominance (D) (Simpson 1949). As,

$$(D) = \sum_{i=1}^{s} (P_i)^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{I}$$

Where,

S = total number of species

Pi = proportion of all individuals in the sample that belongs to species i

b) Shannon-Wiener Diversity Index (Shannon and Wiener 1963) was used for the calculation of species diversity as;

$$H' = -\sum_{i=1}^{s} P_i(ln \cdot P_i) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{II}$$

Where,

S = total number of species in the sample

Pi = proportion of all individuals that are of species

c) Species richness index or variety index (d) indicating the mean number of species per

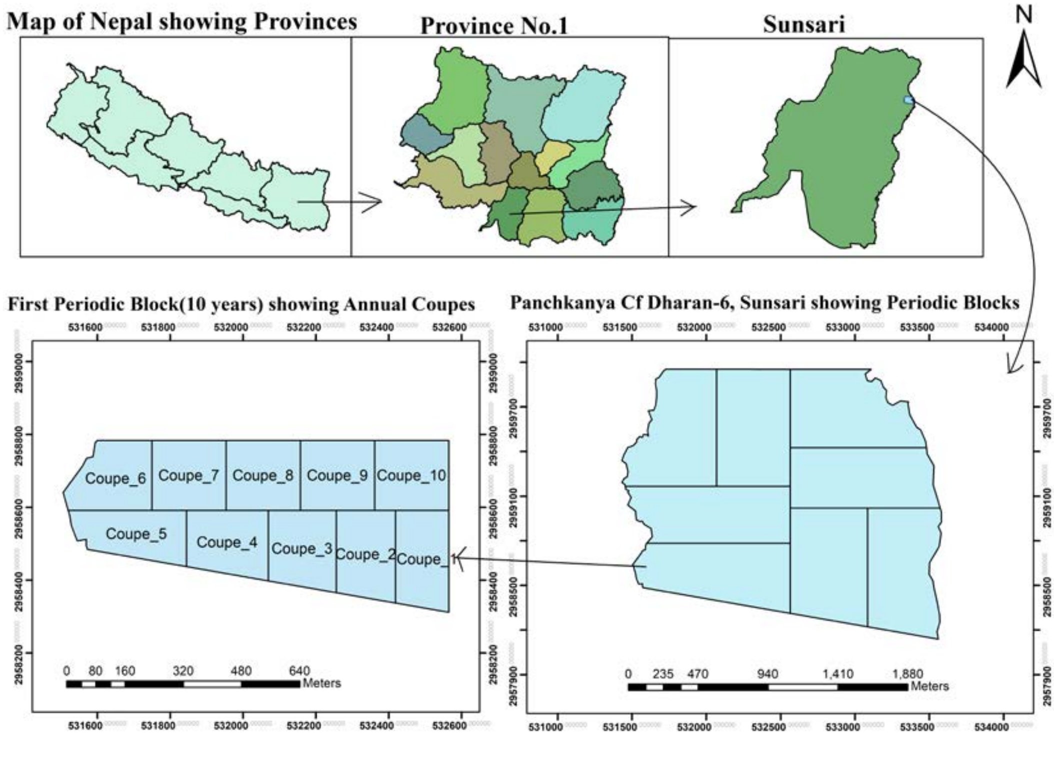

Figure 1: Map showing the location of the study site.

sample (Margalef 1958) was calculated as:

$$d = \frac{S-1}{ln \cdot N} \text{ ....III}$$

Where, $$e = \frac{H'}{ln \cdot S} \text{ ....IV}$$

d= species richness index
S =Number of species

N = number of individuals of all species

d) Equitability or evenness index (e) refers to the degree of relative dominance of each species in that area. Following Pielou (1966), equitability or evenness index was calculated as:

Where,
e = evenness

H'= Shannon-Wiener's diversity index

S = Number of species

The value of e ranges from 0 (not even) to 1 (completely even).

Results

Regeneration Status

The result depicted the status of regeneration in both managed and unmanaged blocks after the intervention of irregular shelterwood system. Regeneration of 12 plant species was recorded in managed and 16 species were listed in the unmanaged block.

In unmanaged block, *Adina cordifolia* had the highest regeneration density (2638.88 ha^{-1}) followed by *Albizia lebbeck* (994.44 ha^{-1}). Similarly, in the managed block the regeneration density was also highest for *Adina cordifolia* (9000 ha^{-1}) followed by *Anthocephalus cadamba* (4166.67 ha^{-1}). The regeneration density of *Shorea robusta* was

Table 2: Regeneration density and frequency for species in the managed and unmanaged forest block

S.N.	Species	Managed bock			Unmanaged Block		
		Density (ha-1)	Frequency (%)	IVI (%)	Density (ha-1)	Frequency (%)	IVI (%)
1	*Adina cordifolia*	9000	80	86.22	2638.89	44.44	44.91
2	*Albizia lebbeck*	1166.67	13.33	21.29	1944.44	38.89	36.17
3	*Anthocephalus cadamba*	4166.67	60	49.84	694.44	16.67	17.63
4	*Cassia fistula*	833.33	20	17.38	138.39	5.56	6.92
5	*Dalbergia latifolia*	500	13.33	13.10	N/A	N/A	N/A
6	*Dysoxylum gobara*	500	13.33	12.78	416.67	11.11	12.93
7	*Ehretia acuminate*	333.33	13.33	10.04	555.56	16.67	15.23
8	*Lagerstroemia parviflora*	500	20	13.10	416.67	16.67	12.84
9	*Mallotus philippensis*	333.33	13.33	10.04	N/A	N/A	N/A
10	*Schleichera oleosa*	N/A	N/A	N/A	138.89	5.56	6.92
11	*Shorea robusta*	2333.33	46.67	33.78	277.78	5.56	11.95
12	*Symplocos ramosissima*	N/A	N/A	N/A	277.78	11.11	9.88
13	*Syzygium cumini*	1500.00	26.67	25.13	1388.89	27.78	28.09
14	*Terminalia bellerica*	N/A	N/A	N/A	277.78	11.11	9.88
15	*Trewia nudiflora*	N/A	N/A	N/A	1250.00	22.22	26.12
16	*Unknown*	N/A	N/A	N/A	833.33	22.22	19.93
17	*Viburnum spp.*	N/A	N/A	N/A	1388.89	33.33	28.66
18	*Wrightia arborea*	166.67	6.67	7.30	138.89	5.56	11.95

Table 3: Diversity indices in managed and unmanaged block

Block Name	No. of Species	Shannon-Wiener Index (H')	Simpsons diversity index (1-D)	Simpson's index Dominance (D)	Species richness	Evenness index
Managed	12	1.82	0.76	0.239	2.26	0.73
Unmanaged	16	2.43	0.89	0.109	3.3	0.87

found higher (2333.34 ha^{-1}) in the managed block as compared to the unmanaged block (277.77 ha^{-1}).

Regeneration frequency for each species was also found different for managed and unmanaged blocks. The regeneration frequency of *Adina cordifolia* was highest in the unmanaged block (44.4%) followed by *Albizia lebbeck* (38.9%). *Shorea robusta* had the least frequency (5.6%) along with *Wrightia arborea* and *Cassia fistula* in the unmanaged block. The regeneration frequency of *Adina cordifolia* (80%) was also found highest for managed block however increased regeneration frequencies of *Anthocephalus cadamba* (49.84%) and *Shorea robusta* (46.67%) while *Wrightia arborea* had the lowest frequency of 6.67%. The frequency of *Shorea robusta, Anthocephalus cadamba* and *Adina cordifolia* was observed upsurge in the managed as compared to the unmanaged block due to canopy opening. The importance value index (IVI) of *Adina cordifolia* was found the highest in both the managed and unmanaged areas. It means that *Adina cordifolia* has the highest frequency, density and abundance in both the managed and unmanaged blocks. *Wrightia arborea* had the least IVI (7.29) in the managed area while in the unmanaged area *Cassia fistula* and *Schleichera oleosa* had the least IVI (6.91) each. Table 2 shows the regeneration density, relative frequency and Importance value index (IVI) for both managed and unmanaged forest block.

Plant Regeneration Species Diversity

Margalef richness index or variety index was higher in unmanaged block (3.30) than in managed block (2.26). Similarly, the evenness index was also found higher in the undisturbed (unmanaged) block (0.87) as compared to that of the disturbed block (0.73). Simpson's diversity index for the trees of the unmanaged block (0.89) was higher than of managed (0.76). Similarly, Simpson's index of dominance in the managed and unmanaged areas is 0.23 and 0.109 respectively. The value derived for the diversity indices is showcased in Table 3 above.

The total number of regenerations per sample plot in both managed and unmanaged was measured. The mean values of the two areas were compared by t-test. The number of sample plots for both managed and unmanaged areas was 15. Independent sample t-test showed a significant difference (p-value of 0.016693 i.e less than 0.05) between the total number of regeneration in between managed and unmanaged areas. The result of the statistical test is shown in Table 4 below.

Discussion

Regeneration density was found to be significantly increased on the managed block. The findings were similar to the study

Table 4: Independent sample t-test of regeneration in managed and unmanaged block

	Block	N	Total no. of regeneration	Average no. of regeneration	t-value	Df	p-value
Total no. of Regeneration	Managed	15	128	8.53			
	Unmanaged	15	93	5.17	2.611	20.095	0.016693

conducted by Awasthi et al. (2020) where seedling and sapling density were found to be increased in managed blocks, ensuring the sustainable productivity of forest stand. The results also support the argument that opening of the canopy through regeneration felling is significant in the establishment, promotion and growth of regeneration (Awasthi et al. 2020). The findings of Khanal & Adhikari, (2018) also showed 6.4 times increase in the number of seedlings and 3.4 times increase in the number of saplings after one year of regeneration felling. The present study also showed increased regeneration density of *Shorea robusta* in the managed block as compared to the unmanaged one. Present results also showed a profound increase in overall number, density, frequency and abundance of regeneration in managed areas as compared to the unmanaged area This study coincides with the conclusion of Shrestha et al. (2019) that the application of irregular shelterwood system have positive results in the case of regeneration. This study showed not only the increased regeneration but also increased the density, frequency and IVI of *Shorea robusta* in the managed area.

The regeneration diversity found in this study was similar to the previous study. Sapkota et al. (2009) and Ranabhat et al. (2016) had identified 14 to 23 species for different site conditions. We found species richness index or variety index was higher in the unmanaged block than in managed block. The higher species richness was found in the unmanaged block due to the presence of grasses, shrubs and other tree species. But in the managed block, only the desired species were allowed to grow due to regular interventions of weeding and removal of undesirable species.

The evenness index, as well as Simpson's diversity index, was found higher for the unmanaged block in comparison to managed block however Simpson's index of dominance was found higher in the managed block than in the unmanaged blocks. The most dominant species was *Adina cordifolia* which seems to be flourishing even more dominantly in the managed area as compared to the unmanaged area. *Anthocephalus cadamba* and *Shorea robusta* seem to be the other desired species that are flourishing more in the managed area than unmanaged. This could mean the canopy opening has positively influenced the regeneration of desired species in the managed area. Uniyal et al. (2010) reported Simpson's index of dominance to be 0.24 and 0.35 for managed and unmanaged forests respectively in Garhwal Himalaya. Tripathi et al. (2004) found Simpson's index of dominance for undisturbed forest between 0.041 to 0.126. This study also showed Simpson's index of dominance for the unmanaged block was 0.109 which is similar to the previous study however it was found higher for the managed blocks.

The Shannon-Wiener diversity index was found more in the unmanaged block than in the managed block. It indicates that, the possibility of decreased species diversity but increased regeneration of desired species. Baral et al. (2018) also noted that local communities preferred economically valuable species and thus focused protection of those particular species. Uniyal et al. (2010) reported the values of diversity index 1.4 for undisturbed forest and 0.7 for disturbed from Garhwal Himalaya. However, Shannon-Wiener indices were nearly equal for disturbed (3.5) and undisturbed (3.4) evergreen forests of Andaman Island (Rasingam and Parathasarathy 2009). In the protected (undisturbed) forest of the same island, Tripathi et al. (2004) reported the Shannon Wiener index from 2.63 to 3.58.

The overall results showed the increased regeneration of *Shorea robusta* in the managed area. Most of the desired species had silviculture characteristics that require more light for their growth. In the shelterwood silviculture system, large trees were cut down to allow regeneration by opening the tree canopy cover. However, the overall species richness and diversity are marginally low in the managed area as compared to the unmanaged. According to Smith et al. (2005), species diversity decreases at the initial stage after the regeneration felling followed by post harvesting in the managed stands under irregular shelterwood system and goes on to eventually increase with time. Awasthi et al. (2020) also found that plant diversity is significantly decreased but the concentration of dominance is significantly increased in managed forest blocks and thus suggested further researches to balance the species diversity along with intensive management approaches like the irregular shelterwood system.

Conclusion

Irregular shelterwood system decreased the species diversity of the stand however increased the density and frequencies of regeneration, particularly for desired tree species. The regeneration status of *Shorea robusta* was found to increase after the intervention. Similarly, irregular shelterwood system was deemed effective for the increased regeneration and even more effective for the regeneration of desired species including *Shorea robusta* in the lowland forest of Nepal. However due to the short time after implementation of the system, the impact on regeneration dynamics and established species diversity for ensuring sustainable productivity and forest regulation needs further study.

Acknowledgments

We would like to thank the team of Division Forest office, Sunsari and Panchkanya community forest user group, Sunsari for their kind support and collaboration. Similarly, we are also grateful to the Association of Family Forest Owners, Nepal (AFFON) for providing us with the funding and the logistics.

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