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Tree Regeneration Status in Community Forests of Mid Hills, Nepal

Dipak Khadka[1,2,3], Dinesh Raj Bhuju[4,5], Prakash Chandra Aryal[2,3] and Narendra Raj Khanal[7]
[1] Guangdong Key Laboratory for Innovative Development and Utilization of Forest Plant Germplasm, College of Forestry and Landscape Architecture, South China Agricultural University, Guangzhou, China
[2]GoldenGate International College, Tribhuvan University, Kathmandu, Nepal
[3]Environment Protection and Study Center (ENPROSC), Kathmandu, Nepal
[4]Nepal Academy of Science and Technology, Kathmandu, Nepal
[5]Resources Himalaya Foundation, Kathmandu, Nepal
[6]Central Department of Geography, Tribhuvan University, Kathmandu Nepal
*Correspondence: d.khadka@goldengate.edu.np

Abstract

Tree regeneration is one of the determinant factors for forest sustainability. We assessed the regeneration status of tree species in the four selected community forests of subtropical hills in Lamjung District, central Nepal. We laid 30 square plots (400 m^2, 50 m^2, and 4 m^2) to collect vegetation data and recorded 23 tree species, with seedlings 53,583 individuals/ha, saplings 3,273 individuals/ha and trees 892 individuals/ha. Among the studied community forests, Kirtipur Community Forest had the fairest regeneration with seedlings, i.e., 58,438 individuals/ha. Tree DBH showed the value of the shape parameter of Weibull (c) > 1, supporting 'mound-shaped' distribution, indicating a newly regenerated forests with a possibility of attaining sustainable regeneration. The proportion of seedlings showed a good response to medium grazing, trampling, and litter collection. Protecting adult trees with higher DBH is essential to maintain continuous regeneration.

Key words: *Community forest, himalaya, nepal, regeneration, seedling*

Introduction

The regeneration of trees has been a topic of discussion among researchers (Ceccon et al., 2004; García et al., 2020; Khurana & Singh, 2001). Regeneration in plants is a natural phenomenon of forming new generations in their communities (Wang et al., 2008) and forest regeneration pattern helps to understand the management and conservation status of the forests (Eilu & Obua, 2005; Vieira & Scariot, 2006; Wale et al., 2012). The assessment of phytosociological characters, plants' floristic composition, structure, development, and distribution (Poore, 1995), helps to understand the regeneration status of trees (Foster, 1980; Harper, 1977; Lykke, 1993; Saxena et al., 1984).

Plant regeneration depends on the survival and growth of seedlings and saplings (Good & Good, 1972; Mishra et al., 2013). Density, relative density, frequency, and important value index can provide insights of the phytosociological character of the forests (Sheikh, 2017). Similarly, number of seedlings, saplings, and adult trees also provide the idea on the status of the regeneration of trees (Ballabha, 2014; Pokhriyal et al., 2010). A diameter size class distribution diagram based on the survivorship curve is often used to assess the regeneration of mature trees (Leak, 1964; West et al., 1981), as Buchholz and Pickering (1978) reveal that population growth in plants is more dependent on DBH size than on age. Researchers have suggested a reverse J-shaped DBH size-class distribution for undisturbed forests with sustainable regeneration and a bell-shaped DBH size-class distribution for disturbed forests with poor regeneration (Bernadzki et al., 1998; Saxena et al., 1984). Environmental factors affect tree regeneration at local and regional scales (Sheil, 1999; Ramirez-Marcial et al., 2001). People near the community forests use forest areas for grazing their cattle and collect litter from the forests, creating disturbances like grazing, trampling, and litter, which in turn affect vegetation regeneration (Malik et al., 2016). Grazing pressure might cause failure of natural regeneration (Stern et al., 2002; Teich et al., 2005) and trampling affects the regeneration of plants directly through physical damage and soil erosion and indirectly through low seed production (Tonnesen & Ebersole, 1997).

There are several studies conducted in community forests of Nepal to present their status, including regeneration of trees, for instance, Oli & Subedi (2015), Paudyal (2012), and Sapkota et al. (2009). However, those studies were either species-focused (viz. *Shorea robusta*) or carried out in the Terai region of Nepal. We did this study in the community forests of sub-tropical mid-hills in Madhya, Nepal. We prepared the database on the regeneration of tree species in the four community forests at various levels of disturbances, and this work is expected to benefit forest user groups of studied CFs.

Materials and Methods

Study area

The study was conducted in four community forests of two villages, namely, Jita and Tandrang-Taksar, in Madhya Nepal Municipality of Lamjung District of central Nepal (Figure 1). Altogether, we sampled 30 plots (Table 1) dominated by *Shorea robusta*, except for one (Pisti CF). The average maximum temperature of this area is 26.67°C, and the average

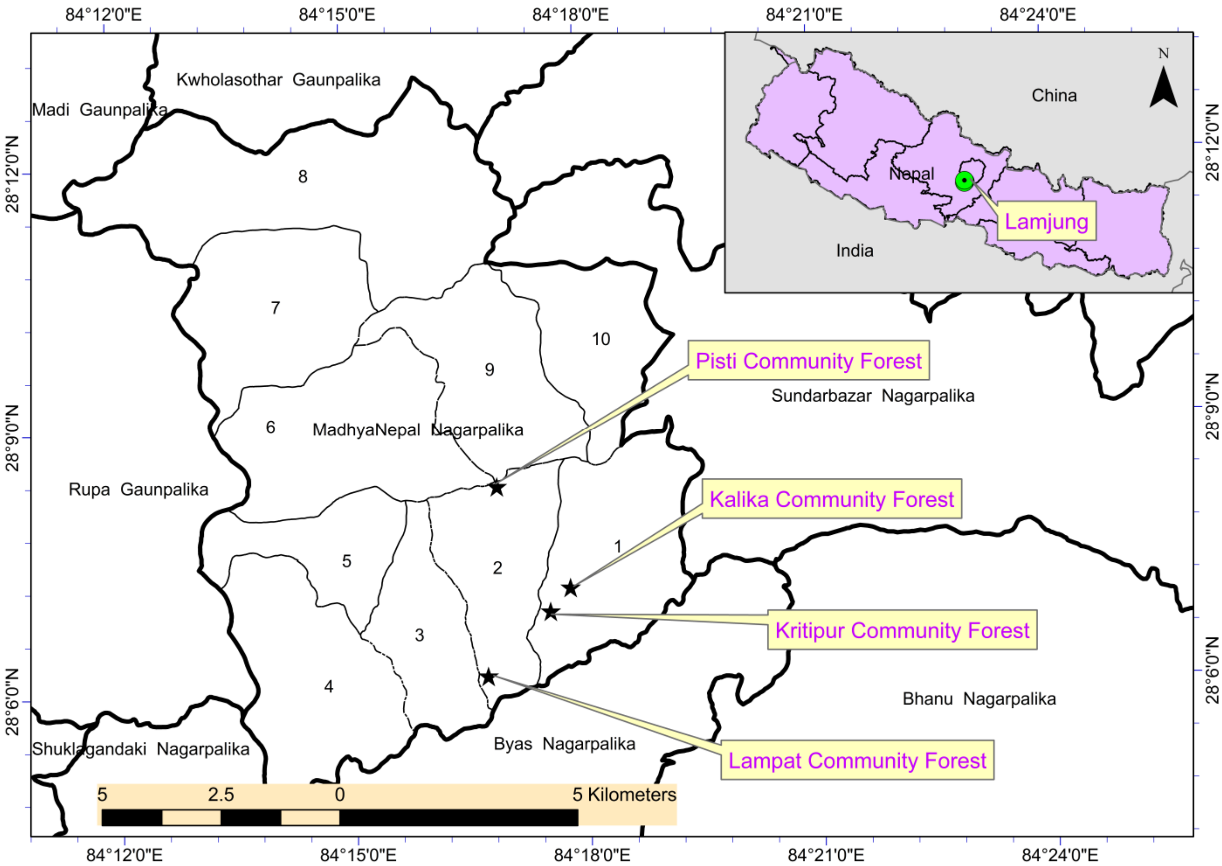

Figure1. Study sites, Lamjung, Nepal

Table 1: General characteristics of the studied community forests in Lamjung

Village	Community Forest	Area (ha)	Survey Plots	Altitude (masl)	Dominant Tree	Users (Hh)
Jita	Kalika	37.26	6	700 - 900	*Shorea robusta*	54
	Kirtipur	66.45	8	600 - 800	*Shorea robusta*	154
Tandrang-Taksar	Pisti	30.00	6	1050 - 1300	*Castanopsisindica*	38
	Lampat	84.27	10	500 - 650	*Shorea robusta*	260

minimum temperature is 14.08°C. The average annual rainfall is 2944.23mm (DFO, 2016).

A total of 30 stratified (based on community forest) random plots, each of size 400 m^2 that accounts for 0.56% of the total forest area (217.98 ha), were placed to sample the vegetation. Individuals of tree species, encountered in the sample plots, were divided into three growth stages: trees (DBH>5cm), saplings (DBH<5cm, height > 1.37 cm), and seedlings (height < 1.37cm), similar to Timilsina et al. (2007). In each plot all the individual trees were counted, the DBH (measured at 137 cm above the ground) and height were measured. Saplings were counted in two opposite corners (5m x 5m) of each plot (400m^2). Seedlings were counted in 1 m^2 quadrats at all four corners (1m x 1m plots= 4m^2). Tree DBH and height were measured using DBH tape (Keson, D18646) and clinometer (Suunto PM-5/360 PC Clinometer, accuracy 1/4°) respectively. The state of grazing, trampling, and litter cover were estimated visually and were categorized into high, medium, and low based on the sign presence percentages in the sample plots viz. (1-33.33% low, 33.33-66.66% medium, and 66.66-100% high).

Data analysis

The frequency, density, basal area, Importance Value Index (IVI) of adult trees was determined by adopting the methods described by Kent (2016). The Shannon index developed by Shannon and Weiner (1949) is employed for the estimation of species diversity.

Shannon diversity Index (H') = -Σ Pi. ln (Pi)

Where,
H' = Species Diversity Index
Pi = proportion of the species Pi = ni / N
N = total importance value of plants
ni = importance value of each species

The summary of the DBH of trees of each community forest was calculated by using R (R Core Team, 2018) . Skewness was calculated by using Bowley coefficient of skewness (Zar, 1999):

$$\text{Skewness} = \frac{(Q3 + Q1 - 2Q2)}{(Q3 - Q1)}$$

Where,
Q3: Third quartile
Q1: First quartile
Q2: Second quartile (median)

The DBH of adult trees was grouped into different size class starting from lower DBH size 5 cm with the interval 10 cm in successive classes. Two parameter Weibull distribution was fitted to the DBH of trees (Weibull, 1951).

$$f(D) = \frac{c}{b}\left(\frac{D}{b}\right)^{1/c} e^{-e\left(\frac{D}{b}\right)^{c}}$$

Where,
f (D) = probability density function
D = Weibull's variate (DBH with D1, D2, ……., Dn of sample size n)
b = Scale parameter of Weibull distribution
c = Shape parameter of Weibull distribution

Changing the shape parameter (c) Weibull distribution can model wide varieties of data (Bailey & Dell 1973; Nord & Cao, 2006) such as;

If,
c = 1, Exponential distribution
c < 1, Inverse J shaped distributions
c > 1, mound shaped distributions, in which if c = 2, Rayleigh distribution, c= 3.6, Equal to normal distributions and c = 1 to 3.6, Positively skewed (right skewed) and c > 3.6, Negatively skewed (left skewed)

We followed Shankar (2001) to assess the regeneration status of trees (Table 2)

Table 2: The criteria used for assigning the regeneration status of trees.

Description	Regeneration Status
Number of seedlings > saplings > adults regeneration	Good regeneration (GR)
If number of seedlings > or < saplings < adults	Fair regeneration (FR)
If the species occupied only as sapling life forms, there are no seedlings (Number of saplings may be more, less or equal that of adults)	Poor regeneration (PR)
If individuals of species were present only in adult form,	No regeneratio (NR)
New regeneration or not abundant (NA)	If individuals of species had no adults only occupy in seedlings or saplings.

The Shapiro test was performed to test the normality of the variables of interest. Kruskal-Wallis test was performed to test the differences of seedling presence in relation to the extent of disturbance.

Results and Discussions

Results

We recorded 23 species of trees (18 species at the adult stage, 14 species at the sapling stage, and 11 species at the seedling stage). *Shorea robusta, Schima wallichii,* and *Castonopsis indica* had higher densities than other species. The trees of *S. robusta* had higher population density, i.e., 413 ha^{-1}, basal area 6,009.52m^2, and relative basal area 73.8%, although *S. wallichii* had the higher frequency (30%). The other species, except *S. robusta, C. indica, and S. wallichii,* had lower population density, i.e., 61.67ha^{-1}, basal area of 44.99 m^2, and relative basal area of 0.56%. The IVI value of *S. robusta* was the highest (144.06) compared to other species (Table 2). The adult tree's Shanon diversity index (H') was 0.03.

Forest Wise Regeneration Status of Trees

The average number of seedlings, saplings, and adults in all four studied forests (in 30 plots) were 53,583 individuals/ha, 3,273 individuals/ha, and 892 individuals/ha with the coefficient of variation (C.V) 39.07%, 49.07%, and 45.5%, respectively. Among the four community forests, Kirtipur CF had the most number of adults (969 individuals/ha)), saplings (3,500 individuals/ha)) and seedlings (58,438 individuals/ha). The Pisti CF had the least number of adults (771 individuals/ha), saplings (2200 individuals/ha) and seedlings (41667 individuals/ha) (Figure 2).

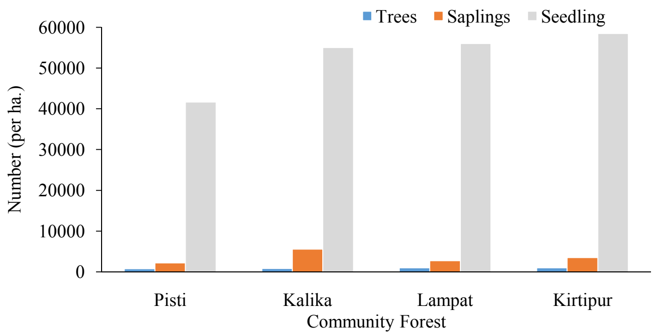

Figure 2. Comparison of tree regeneration in the studied community forests

The mean DBH of adults was higher in Kalika Forest compared to Kirtipur, Lampat, and Pisti, respectively (Table 3). The Bowely coefficient of skewness was observed more in adults of Lampat CF than in Kirtipur, Kalika, and Pisti. The DBH size class diagram showed a higher number of adults in size class 5-15 cm. The Weibull shape parameter for DBH was obtained between 1 and 2, showing a right-skewed diagram (Figure 3). The value of the Weibull shape parameter was higher in Kirtipur CF and lower in Lampat CF, whereas the value of the scale of Weibull was observed highest for Kalika CF and the lowest for Pisti CF (Table 5). The probabilities of densities in different sites were found to be different from each other (Figure 4).

Table 4: Summary Statistics of DBH (cm) of adults in different community forest

Parameters	Kalika	Kirtipur	Lampat	Pisti
Mean	17.76	16.84	15.53	13.53
Max.	68	65	113	74
Min	5	5	5	5
Q_1	6	8	6	6
Q_2	13	13	9	10.6
Q_3	25	21.75	22	15
Bowely coefficient of skewness	0.26	0.27	0.63	-0.02

Table 3: Phytosociological character of major adult tree species found in the studied community forests in Lamjung

Parameter/ Species	*Shorearobusta*	*Castanopsisindica*	*Schimawallichii*	Other species
Tree Density (ind.ha^{-1})	413	238	181	62
Relative Tree Density (%)	46	27	20	7
Tree Frequency	24	22	30	24
Basal Area of Tree (m^2) ha^{-1}	5008	667	1074	37
Relative Basal Area of Tree (%)	74	10	16	1
Importance Value Index IVI	144	58	66	31

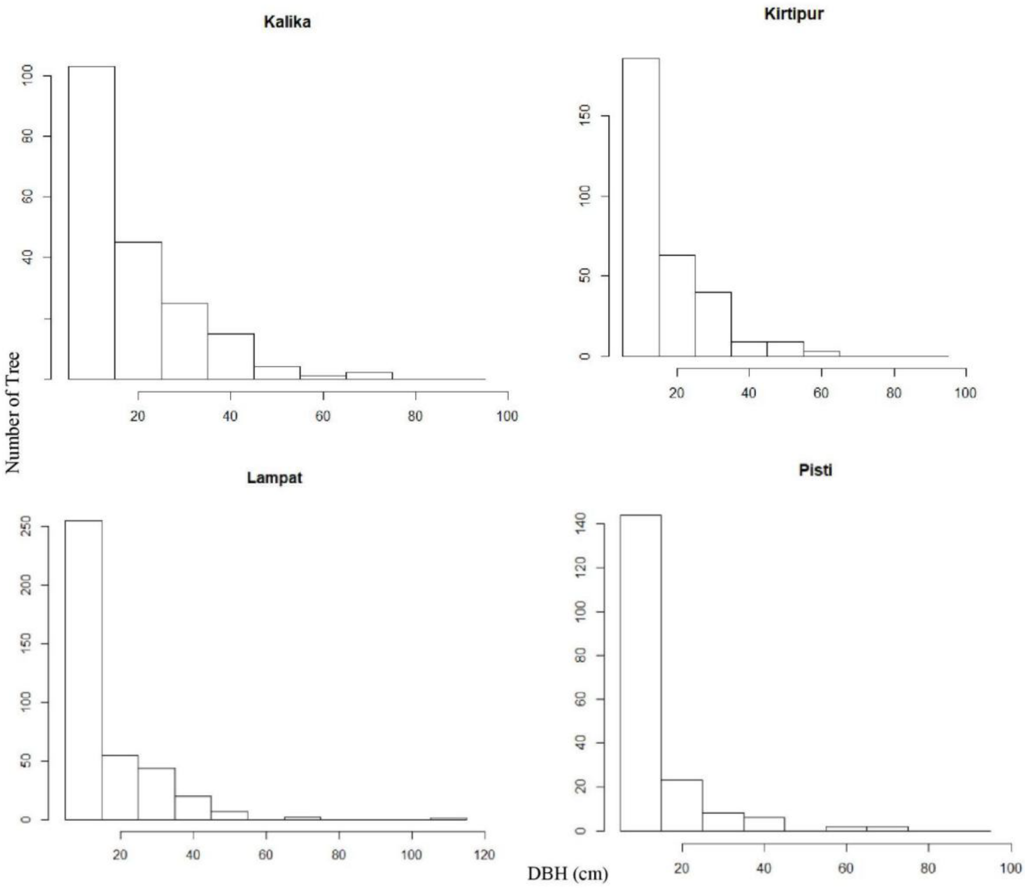

Figure3: Diameter at breast height (cm) size class of adults in the community forests of Lamjung.

Table 5: Shape and scale parameters (with standard errors) of Weibull distribution for different CFs.

Community Forest	Shape (c)	Scale
Kalika	1.38 (0.08)	19.59 (1.07)
Kirtipur	1.57 (0.07)	18.93 (0.73)
Lampat	1.31 (0.05)	16.81 (0.7)
Pisti	1.41 (0.07)	15.06 (0.84)

Species wise Regeneration

Out of the total species recorded (Table 3), only six species of the trees have all three stages, i.e., seedling, sapling, and adult; five species had no adult stage, nine species had no sapling stage, and 12 species had no seedling stage plants. Among the 23 tree species recorded, *S. robusta*, *S. wallichii*, and *C. indica* have fair regeneration status, whereas *Pinus roxburghii, Mucuna macrocarpa, Ajuga bracteosa,* and *Lagerstroemia parviflora* had no saplings and seedlings, i.e., no regeneration at all.

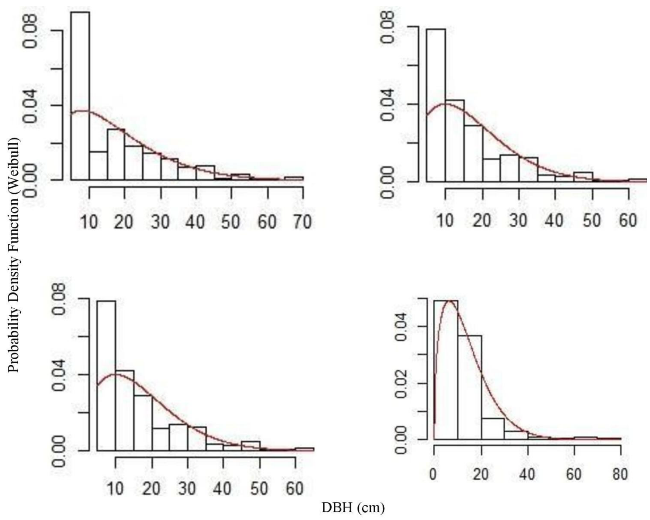

Figure 4: Probability Density Function for Weibull Distribution plotted with DBH classes (Kalika, Kirtipur , Lampat and Pisti respectively from top left side to down right)

Table 6: Regeneration status of the tree species found in the studied community forests in Lamjung.

Scientific Name	Local Name	Family	Adult ha-1	Sapling ha-1	Seedling ha-1	Regeneration Status
Shorea robusta C.F. Gaertn	Sal	Dipterocarpaceae	413	1367	28833	Good
Schima wallichii (DC.) Choisy	Chilaune	Theaceae	181	320	5667	Good
Castanopsis indica A.DC.	Kattus	Fagaceae	238	1253	15833	Good
Engelhardia spicata Lechen ex Blume	Mauwa	Juglandaceae	4	73	417	Good
Myrica esculenta Buch.-Ham. ex D.Don	Kafal	Myricaceae	1	27	333	Good
Mesua ferrea L.	Phalame	Clusiaceae	9	27	416	Good
Adina cordifolia (Roxb.) Brandis	Pakhale	Rubiaceae	16	7	None	Poor
Pinus roxburghii Sarg.	Salla	Pinaceae	12	None	None	No
Mucuna macrocarpa Wall.	Buldhangro	Fabaceae	1	None	None	No
Mallotus philippensis (Lam.) Müll.Arg.	Sindhure	Euphorbiaceae	2	None	None	No
Fraxinus floribunda Bunge ex A. DC.	Lakuri	Oleaceae	1	13	None	Poor
Morus indica L.	Simal	Moraceae	1	None	None	No
Neolamarckia cadamba (Roxb.)	Kadam	Rubiaceae	3	None	None	No
Falconeria insignis Royle	Khirro	Euphorbiaceae	8	7	None	Poor
Lagerstroemia parviflora Roxb.	Botdhangero	Lythraceae	2	None	None	No
Toona ciliata M.Roem.	Tuni	Meliaceae	1	None	83	Fair
Trichilia connaroides (Wight & Arn.) Bentv.	Aakhatare	Meliaceae	1	67	None	Poor
Ficus glaberrima Blume	Pakhuri	Moraceae	3	None	83	Fair
Rhus chinensis Mill.	Bhakimlo	Anacardiaceae	None	20	None	New
Diospyrosex sculpta Buch.-Ham.	Tendu	Ebenaceae	None	60	1583	New
Casearia graveolens Dalzell	Barkamle	Flacourtiaceae	None	None	250	New
Syzygium cumini (L.) Skeels	Jamun	Myrtaceae	None	27	83	New
Quercus lanata Sm.	Phalat	Fabaceae	None	7	None	New

Seedling and Disturbances

The plot level seedling numbers significantly differed for different disturbance intensities, grazing, and trampling (Table 5). Medium trampling, grazing, and litter presence have responded well to the number of seedlings. High grazing and trampling intensities have not shown a good response to the number of seedlings, whereas high litter has shown a good response to seedlings, but the response is less compared to medium grazing intensity. Low grazing, trampling, and litter have not shown a good response to a number of seedlings in comparison to medium grazing, trampling, and litter (Figure 5)

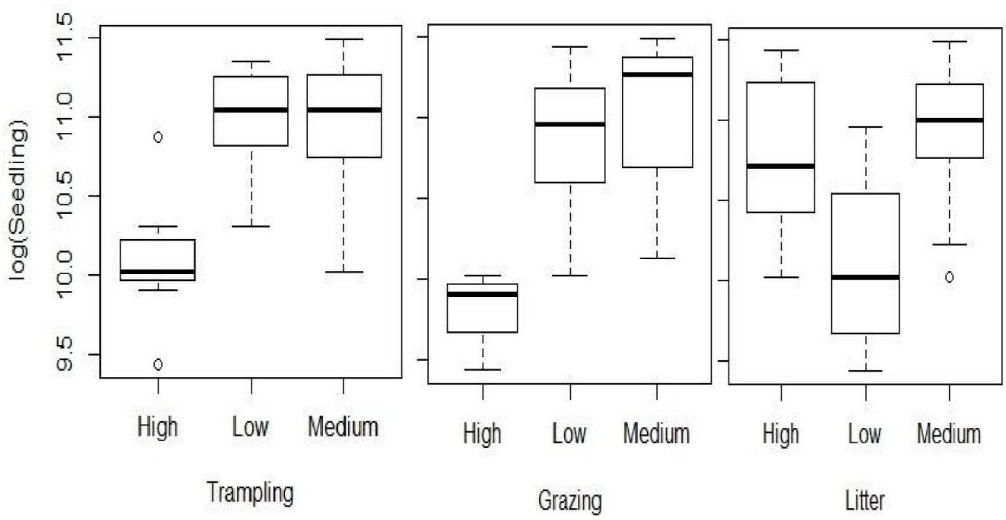

Figure5. Difference between seedling density and disturbance levels

Table 7: Seedling presence with respect to intensity of trampling, grazing and litter cover

Variable	x^2	d.f	P-value
Grazing	7.921	2	0.019
Litter	5.071	2	0.079
Trampling	11.812	2	0.003

Discussions

We found low tree richness and diversity similar to the other studies in *Shorea robusta*-dominated subtropical forests of Nepal (Chapagai et al. 2021;DFRS, 2015; Stainton, 1972). The *S. robusta*-dominated forests have acidic to neutral soils with a carbon content of 0.11 to 1.8%, which might limit the diverse tree species (Gangopadhyay, 1990). The management strategy plays a fundamental role in the composition of trees in Forests (Dhamala et al. 2023; Oli & Subedi, 2015). The *S. wallichii* and *Castonopsis indica* do not have good wood either, and the domestic animals do not prefer to eat their leaves, but their wood can be used for fuelwood; therefore, their densities are higher after *S. robusta*. Domestic animals prefer to eat the leaves of species like *Fraxinus floribunda* and *Ficus glaberrima,* leading to the low density of these species. In community forests, people also introduced some new species as a management strategy, such as *Toona ciliata, Neolamarckia cadamba,* and *Pinus roxburghii,* through different plantation programs. Besides the significant species *S. robusta*, *C. indica*, *S. wallichii,* and other species, *Fraxinus floribunda,* and *Ficus glaberrima,* have an essential role in improving the livelihood by providing fodder to the cattle and maintaining diversity. Therefore, CF management should focus on conserving these species and improving their densities to gain long-term benefits.

The seedling, sapling, and adult density indicated the overall regeneration is fair. This could be attributed to the spatial condition and *S. robusta* dominated forest properties (Mishra & Garkoti, 2016; Sapkota & Oden, 2009). The C.V. of the vegetation stages- adult, sapling, and seedling indicated that adult numbers are more consistently distributed than seedlings and saplings in the studied plots. This indicated that some sites need more care for growing seedlings and saplings to maintain stability in regeneration.

The community forests support livelihood by providing timber, fuelwood, fodder, and grasses in rural areas of Nepal. The livelihood and spatial arrangement of both forests and settlements, and local socio-economic conditions influence the forest resource utilization reflected by state of seedlings, saplings, and trees in community forests. Higher slope and altitude of the Pisti CF might have caused fewer adults, saplings, and seedlings than in the other forests (Bhandari et al., 2000; Sapkota & Oden, 2009). Moreover, Pisti CF is near the Gurung ethnic community, which uses diverse forest products compared to other local groups, resulting in a low number of adult status of trees in this forest. The concentration of people affects forest dependency (Illukpitiya, 2006), and disparities in socioeconomic conditions, values, beliefs, goals, and preferences have influence on the forest (Adhikari et al., 2004). This will change resource use conditions (Cavendish, 2000) and forest structure.

The Pisti CF does not have a population of *S. robusta* trees, whereas all the remaining 3 CFs have *S. robusta.* As a result, all forests have more seedlings and saplings than this forest. The Kalika CF is near the village with more disturbed sites, resulting in lower tree density. The Lampat CF is near the village, but some interventions like tree enrichment and forest management activities such as thinning and cleaning might have helped to support the number of trees. The Kirtipur CF is far from settlement compared to others; it has medium disturbances, which might have resulted in more standing trees (Cierjacks et al., 2008). Besides these, forest management practices might also have influenced the number of adult trees in the forest (Ujhazy et al., 2017).

This study found more tree in 5-15 cm DBH size class in all four CFs studied, indicating that forest user group activities have supported the regeneration of trees, similar to the other community forests of subtropical Nepal (Maharjan et al., 2006). There was a low number of large DBH-size classes, which might be due to the disturbances in the past before the formation of the community forestry program (Acharya, 2002). The value of the shape parameter of Weibull is (c) above one supported mound shape diameter distribution, and the Weibull's shape parameter estimate lower than 3.6 confirmed right skewness of diameter distribution curves (Husch et al., 2003; Nord-Larsen & Cao, 2006) for all the studied community forests. The shape of Weibull (c) distribution for DBH indicates that Lampat CF has a good regeneration status compared to Kalika CF, Pisti CF, and Kirtipur CF respectively. None of the studied forests have attained a reverse J-type curve, so the management should focus on managing population strata. This result indicates that the community forestry program in the studied area is on the path to success in improving the forest's population structure. Locals can use the information on the diameter distribution of adult trees to strengthen the forest management through different interventions (Sapkota et al., 2018) to ensure more trees reach larger size class.

The presence of seedlings and saplings compared to adults is fundamental to knowing the regeneration status of trees. Among the recorded species, 6 had good regeneration, 2 had fair, 4 had poor, 5 had new regeneration and 6 had no regeneration status. *S. robusta*, *S. wallichii*, and *C. indica* were naturally growing species; their seedling and saplings did not reflect high disturbance in the community forests. *S. robusta* is a tree protected in Nepal and might have experienced low disturbances, especially from cutting and felling, in the community forests (Paudyal, 2012). Some disturbance activities, such as selective logging introducing new species, were also evident in the study area and might have supported more seedlings of natural species like *S. robusta*. As no seedling or saplings of *P. roxburghii*, *M. macrocarpa*, *N. cadamba*, and *L. parviflora* were recorded, the regeneration of these species is bleak, at least for the next few years (Brendler & Carey, 1998).

The anthropogenic and ecological factors determine the forest structure and composition (Dolezol & struck 2008). Regeneration is one of the significant factors that is important to show forest structure and composition. Different natural and anthropogenic disturbances like fire, landslide, trampling, grazing, and litter collection occur in nature. Medium disturbances support the regeneration of trees, whereas low disturbances and high disturbances lower the regeneration, which is evident in a study in Bardia National Park of Nepal at elevation 153 m to 1,247 m (Napit & Paudel, 2015). We found a good response from seedlings with medium trampling, grazing, and litter, similar to other studies (Bhuju, 1998). It is also evident that intermediate disturbances support the regeneration of trees in tropical forests (Bongers et al., 2009; Mayor et al., 2012). The community forest groups and forest managers can maintain the intermediate disturbances in the forest through thinning, cutting of branches, and other interventions that will promote the regeneration status of the trees in the forest.

Conclusion

We recorded a total of 23 tree speices, with only 18 species at the adult stage, 14 at the sapling stage, and 11 at the seedling stage. *Shorea robusta*, *Castonopsis indica,* and *Schima wallichii* were the dominant species. The number of seedlings indicated a fair regeneration status of the trees. Kirtipur CF had the highest, and Pisti CF had the lowest tree regeneration. Tree species such as *Pinus roxburghii, Mucuna macrocarpa, Fraxinus floribunda, Morus indica, Neolamarckia cadamba, Lagerstroemia parviflora, Toona ciliata, Trichilia connaroides* and *Ficus glaberima* had neither saplings nor the seedlings. The poor regeneration of these species indicate either higher disturbances or simply a lack of care and inappropriateness of the forest conditions for healthy regeneration. Some species, such as *Casearia graveolens,* had only the seedlings, indicating that they were newly introduced species in the area. The diameter size class diagrams indicated that tree regeneration in all the forests is on the path to maintaining a good population structure of trees in the future, if present situation persists. New regeneration, namely, seedlings are seen to fare better in medium-level grazing, trampling, and litter cover. Therefore, a balanced intervention for growing the forest to ensure more adult-staged trees for a balanced population structure, and at the same time promoting the survival and growth of minor species to promote the tree diversity in the forest is recommended.

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