An Assessment of Forest Structure, Regeneration Status and the Impact of Human Disturbance in Panchase Protected Forest, Nepal

Roshan Chikanbanjar[1*], Binod Baniya[2,3], Man Kumar Dhamala[1]

Abstract: Vegetation study is crucial for the biophysical environment and ecosystem balance. Both qualitative and quantitative assessments of the vegetation can give complete picture of the forest ecosystem. In this study, quantitative characteristics of Panchase Protected Forest in Kaski district were analyzed. The study was focused on the structural characteristics of forest stand, its regeneration pattern along altitudinal gradients, and human impacts on vegetation structure. Density, basal area, frequency, and Importance Value Index (IVI) were used to assess the structural characteristics of forest; Density-Diameter (DD) curve and seedling/sapling/tree density relation were used to assess the regeneration status. Counting the number of lopping and cut stumps and quantifying fuelwood consumption pattern of the village were used to assess human disturbance. The vegetation survey showed 21, 17 and 14 species of trees, saplings, and seedlings, respectively. *Daphniphyllum himalense* was the most dominant species followed by *Quercus lamellosa*. DD curve showed reverse J-shaped structure indicating sustainable regeneration. *Daphniphyllum himalense* and *Alnus nepalensis* were major species of trees consumed as fuelwood and average annual fuelwood consumption was 2083.79 tons. Density of lopped trees and cut stump was in decreasing trend along with elevation. Species richness was higher in moderately disturbed sites. This study has significant implications for protected forest management and biodiversity conservation in Nepal.

Keywords: *Forest, human disturbance, altitudinal gradient, species richness, forest management*

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Introduction

Nepal has rich biodiversity, especially in plant species, because of variability in topography, climate variations and vertical dissimilarities. In Nepal, 118 types of ecosystems have been identified in different physiographic zones with 52 and 38 ecosystems in the middle mountains and the highlands respectively (Maskey 1995). MFSC/GoN 2014 enumerated 6,973 species of angiosperm and 26 species of gymnosperm in Nepal. The Panchase area is rich in biodiversity and has high biodiversity values. By recognizing the rich biodiversity, forest resources, cultural and spiritual values of the area, it was gazetted as a 'Protected Forest', under the article 23 of the Forest Act 2002 (DOF 2016). Forest structure comprises trees, shrubs, and ground covers including vegetation and dead woody materials. Based on diameter class, structure can be small, medium, and large trees (Bennett 2010). Vegetation structure is the organization of individuals in space that constitutes a stand of plants.

The regeneration patterns and factors governing them determine the forest structure and composition (Wangda 2003). Successful regeneration requires adequate seedlings and their survival, which is controlled by the microclimate of the site and anthropogenic stimuli. Indeed, even high starting seedling densities can't ensure successful regenerations in the zones with higher interference levels like grazing and tree felling (Rooney and Waller 1998). The recruitment, survival, and growth of seedlings and/or sprouts in a given area determine the regeneration of the woody plants (Lalfakawma 2010). Development of trees from seeds that fall and germinate in-situ is known as regeneration (Harmer 2001). The natural regeneration of forests in the forest ecosystem is fundamental for evolution (Ackzel 1994). However, plants regenerate not only from seeds but also from the vegetative parts, i.e., stumps (Evans 1992) or rootstocks (Whitmore 1982). Initiation, distribution and diversity of regeneration depend upon various variables. The light environment is one of the factors, which affects natural regeneration and the germination of seeds (Denslow 1987). Generally, regeneration involves both the physiological and developmental mechanisms inherent in plant biology as well as external ecological factors, including interactions with other biotas, climate, and disturbances (Price et al. 2001).

The forest environment and the dynamic nature of forest canopies provide many different regeneration niches to which different species have become specialized. Forest regeneration begins with the dispersal of seeds to sites suitable for germination. The dispersed seeds must be viable, escape predators, and encounter the light, moisture, and temperature required for germination. Subsequently, the fruitful fulfillment of a few occasions in the vegetation cycle, for example, coppicing (growing) capacity (Bellingham and Sparrow 2000; Evans 1992), seed production, dispersal to safe locales, germination and seedling rise, seedling foundation and forward development, decides the achievement of woody plant regeneration in forest (Barik et al. 1996). However, ecological factors may affect all these events negatively or positively. Therefore, understanding the patterns of regeneration enables us to undertake a proper forest management plan. Although, natural regeneration is a very slow process, it is an important process to maintain the stable age structure in the species of plants in a community. A reverse J-shaped size class distribution is attributed to undisturbed old-growth forest with sustainable regeneration (West et al. 1981) whereas disturbed forest shows a bell-shaped size class distribution (Saxena et al. 1984).

Cutting and removal of forest cover in an area is done usually for its conversion into pastures, plantations areas, croplands or urbanized settlements (Kricher 1997). For most people in rural mountain regions, fuelwood is the most important energy source for cooking and heating (Broadhead et al. 2001; International Energy Agency 2002). In 2011, annual wood removals amounted to 3.0 billion MT globally, of which 49% were for fuelwood (FAO 2016). Chhetri et al. (2002) reported firewood and fodder resources are extracted from the forests which are accessible to the local people mostly by chopping of trees and lopping of branches in the open canopy, however this practice significantly deformed the canopy structure.

Fuelwood consumption levels are accelerating because of exponential increase in population. As a consequence of poor socioeconomic conditions of various ethnic groups and growing population, firewood consumption is increasing especially in remote areas (Bhatt et al. 2010). Although various governmental as well as non-governmental agencies are engaged in energy plantations in hills to address the problems, there is still lack of scientific expertise for firewood farming (Bhatt et al. 2010). There is decrease in forest cover as a result of anthropogenic activities (Todaria et al. 2008). Most common reasons for deforestation include direct factors like lumbering, logging, cattle grazing and trampling as well as indirect factors like overpopulation, urbanization, dams, and roads construction. Secondary reasons include natural forest disturbances as earthquakes, land sliding, and fires (Decker 1994). Unsustainable collection of dry season fodder by the locals through heavy and indiscriminate foliage lopping is another reason for forest destruction (Shrestha and Paudel 1996). Due to heavy lopping practices trees are reduced to naked poles with devastated seed and flower production leaving the forest unable to regenerate itself (Singh and Singh 1992). The vegetation can also be influenced by factors like topography and other human disturbances (Chhetri et al. 2017), moisture limitation, land use practices and ecological restoration such as afforestation and agricultural practices in Nepal (Baniya et al. 2019).

The forest assumes a powerful part in securing the delicate environments and keeping up different and complex biological systems. The ecological study of the forest ecosystem is very necessary. It is a habitat for many plants and animals as tree trunks and branches are usually densely covered with epiphytic plants, including ferns and orchids. Moreover, it is crucial for watershed protection and biodiversity conservation and it brings rich animal diversity (Tashi 2004). Lopping of trees is a common practice among the mid-hill farmers for fodder. Heavy lopping results pole like the appearance of the trees with scanty leaves (Jackson 1994; Shrestha and

Paudel 1996). Grazing and litter collection are other disturbance factors in the Panchase forest (Maren et al. 2014). The improvement in the potential of forest regeneration and sustainable forest management has become a matter of concern to mitigate disturbed forest. The lack of natural regeneration becomes a serious issue in many areas of the world, including Nepal (Vetaas 2000; Shrestha 2003). In this context, our study findings help to determine the factors affecting vegetation structure and regeneration of the forest. Moreover, it delivers quantifiable evidences on the community structure and regeneration status of certain recorded species of the site. Literature review suggested that there are very few studies on structure and regeneration along with the altitudinal gradient in the Panchase area (Maren et al. 2014; Bhatta et al. 2018; Bhandari et al. 2018). The study aimed to assess general floristic features and prepare vegetation structure of forest along the altitudinal gradient, examine regeneration status of the forest along the altitudinal gradients, and study the impacts of human activities on vegetation structure. This study stands as an additional contribution to the Panchase forest and is helpful to understand the effect of altitude and other environmental and anthropogenic factors on vegetation composition and regeneration of forest in mid-hill.

Materials and Methods

Study Area

The study was conducted in BhadaureTamagi (now Annapurna Rural Municipality, ward number 4 and Pokhara Lekhnath Metropolitan City, ward number 23) which is located in Kaski district, Gandaki Province, Nepal at latitudes between 28°12'35" and 28°16'34" and longitudes between 83°48'14" and 83°52'52" (Figure 1). The altitude of the study area (Annapurna Rural Municipality, ward number 4 and Pokhara Lekhnath Metropolitan City, ward number 23) ranges from 815 m at the Harpan River flood plains to 2484 above mean sea level (AMSL) at the peak of Panchase hill. The study area has upper tropical to moist temperate (UNDP 2012) and annual average precipitation is 3355 mm.

The major part of the Panchase forest lies in BhadaureTamagi. The lower and middle parts of the study area are dominated by the *Schima-Castanopsis* forest while the upper part is dominated by the *Daphniphyllum* forest. The major part of the forest is north, east, or north-east facing and thus there are plenty of possibilities for NTFPs and MAPs (Sharma et al. 2013).

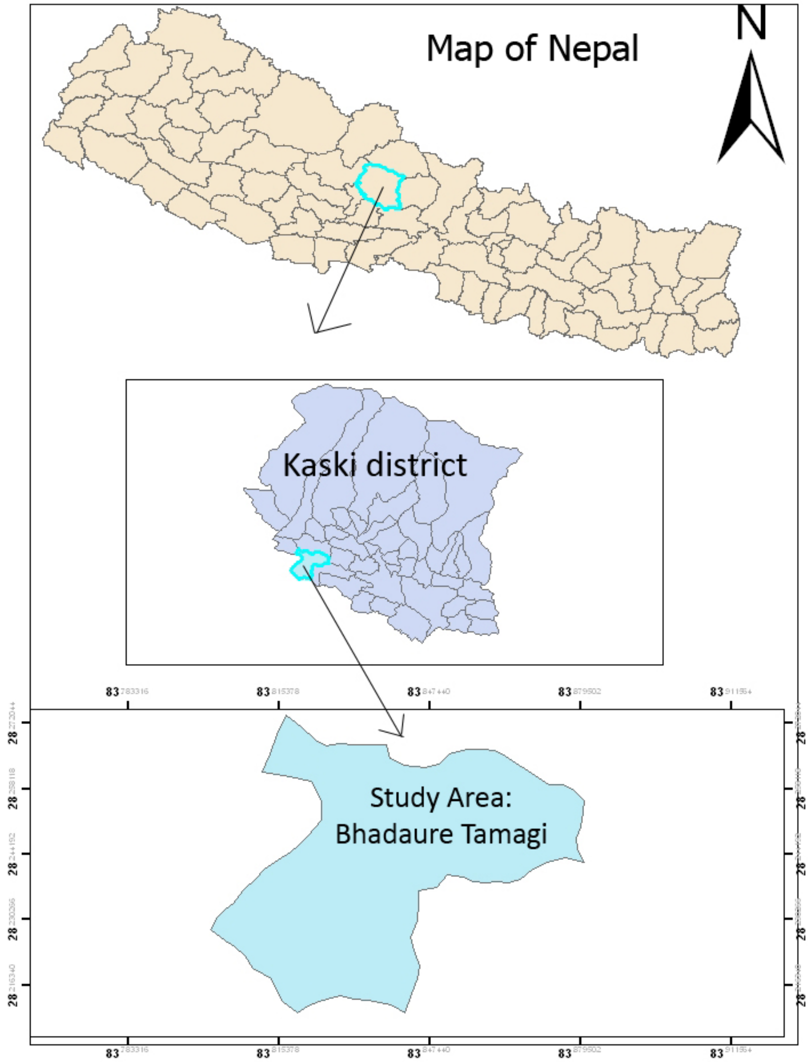

Figure 1: Location map of the study area

Data Collection

The whole forest was divided into five altitudinal bands of 200m vertical difference in terms of topographic map. Each band of the forests was stratified into three vertical strata - tree, under canopy, and ground (Table 1). Circular sampling plots as recommended by Carbon Measurement Guideline for community forests, 2010 were used (Subedi et al. 2010). The default radius of each plot for moderately dense vegetation is 8.92m. Altogether, 40 large circular sample plots of area 250 m², 40 medium circular sample plots of area 100 m² for saplings, and 40 small circular plots of area 3.14 m² for seedlings were selected for the primary data collection (Figure 2).

Table 1: Detail of elevation range of five bands

SN	Altitudinal bands	Band code	Elevation range (m AMSL)	No. of circular plots
1	Band 1	B1	1500-1700	8 (for trees) +8 (for saplings) +8 (for seedlings)
2	Band 2	B2	1700-1900	8 (for trees) +8 (for saplings) +8 (for seedlings)
3	Band 3	B3	1900-2100	8 (for trees) +8 (for saplings) +8 (for seedlings)
4	Band 4	B4	2100-2300	8 (for trees) +8 (for saplings) +8 (for seedlings)
5	Band 5	B5	2300-2500	8 (for trees) +8 (for saplings) +8 (for seedlings)

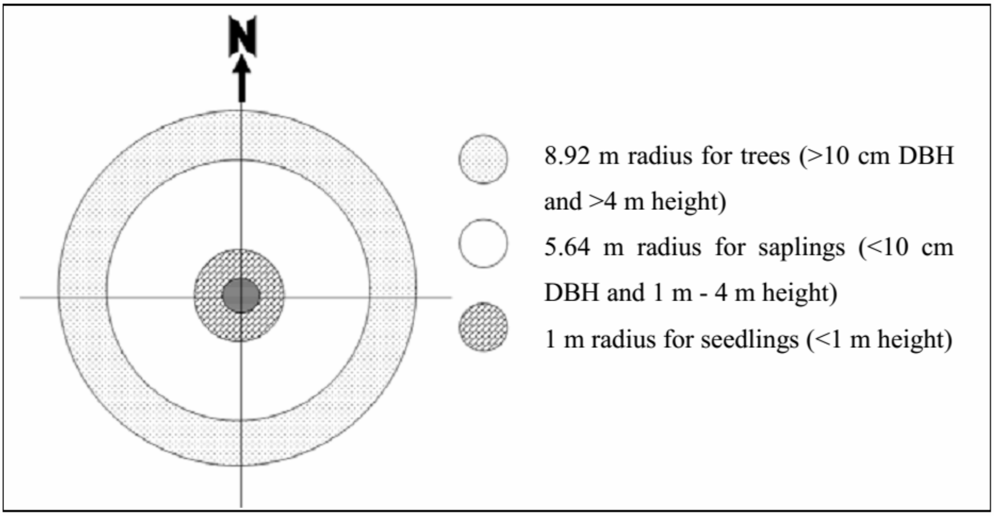

Figure 2: Sampling design of circular plot

The height, diameter at breast height (DBH), canopy coverage and frequency were collected in the field and density and basal area were calculated at desk. Similarly, altitude, aspect, slope, distance from water source, distance from the village, exposed rock and any disturbance present were also noted for each plot. The height of the tree was measured by using Haglof Vertex IV Hypsometer. The DBH was measured using DBH tape and the canopy coverage was measured by using Densitometer. The frequency of trees, seedlings and saplings were measured by direct counting in the respective plots.

The impacts of human activities on vegetation structure were assessed through counting of cut stumps of trees and the number of lopping in each tree species wise. Similarly, the impacts were also quantified through fuelwood consumption pattern by weighing the each bharis of fuelwood (species wise) in 20 different households.

Data Analysis

Vegetation Structure

There are some important parameters for describing vegetation structure in precise quantitative terms. These are frequency, height, density, basal area and abundance. These parameters were calculated by the following formula (Curtis and Mclntosh 1951).

"In an association several species thrive at the cost of the rest, thus producing at one extreme a class with comparatively few species but a great number of individuals, and at the other extreme another class with a very small number of individuals representing rare and sporadic species" (Raunkiaer 1934). Raunkiaer categorized his structure into five recurrence classes as follows: A) including those species happening in 1-20% of the sample zone; B) in 21-40 %; C) in 41-60%; D) in 61-80%; and E) in 81-100%. He found that the classes were identified with one another regarding the quantity of species each contained by accompanying formula; A>B>C>=<D<E (Raunkiaer1934).

Frequency indicates the number of sampling units in which a given species occurs (Mishra 1968). Frequency indicates the dispersion of species in a community. It is the percentage of sampling units in which a particular species occurs. Relative frequency is the frequency of a particular species in relation to total frequency of all the species present in the community. Density refers to the number of individual trees per unit area and it indicates the numerical strength of a species in a community. The proportion of density of species with respect to total density of all the species within an area is referred to as relative density.

Basal area refers to the ground actually penetrated by the stems. It is one of the characters that determine the dominance. Basal area of a species in each sampling plot was obtained by the summation of Basal area of all individuals of a species.

$$\text{Basal Area } (m^2) = \frac{\pi(DBH)^2}{4} \quad .$$

Relative basal area is the basal area of individual species divided by total basal area of all species multiplied by 100.

Abundance is the study of the number of individuals of different species in the community per unit area. The samplings were made randomly at several places and the number of individuals of each species was summed up for all the plots divided by the total number of plots in which species occurred. Relative abundance (%) is the abundance of individual species divided by total abundance of all species multiplied by 100. In this study, relative abundance had been used to obtain the IVI of seedlings and saplings.

Importance Value Index (IVI)

The term Importance Value Index was introduced by Curtis and Mclntosh (1951) as an index of vegetation importance of a tree within a stand. Importance Value Index gives the overall importance of each species in the community. It was calculated as the sum of relative values of density, frequency and basal area for trees. Similarly, IVI was calculated as the sum of relative values of density, frequency and abundance for saplings and seedlings.

Shannon's Species Diversity Index

Species diversity is the combination of species richness and species evenness. Species richness is the number of species per sampling unit. Species evenness is the distribution of individuals among the species. Shannon's Index is a measure of the amount of information needed to describe every member of the community. Species diversity was calculated by using the following formula:

Shannon's Index (H') $= -\sum_{i=1}^{s}(pi)\ (\ln pi)$

Where, s = total number of species

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

Simpson's Index or Simpson's Dominance Index (D) measures the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species).

Simpson's Dominance Index (D) $=\sum(\frac{n}{N})^2$

Where, n= the total number of organisms of a particular species

N= the total number of organisms of all species

Species Richness and Evenness

Species richness is simply the number of species present in the study area. Species evenness (j) stated by Magurran (1988) as another component of diversity was calculated using diversity index.

Species Evenness $= \frac{H'}{H_{max}}$,

Where, H′ = Shannon's Index and H_{max} = lnS

S is the number of species present.

The Evenness Index ranges from zero (when one species is dominant) to one (when all species are equally abundant).

Regeneration Status

The Density-Diameter (D-D) curve, tree canopy coverage, and seedling/sapling/tree density relation was used for predicting the regeneration status of trees. All the trees were divided into different size classes based on Diameter at Breast Height (DBH) of 10 cm intervals. Altogether ten size classes were recognized at different altitudinal zones. The D-D curve was plotted for all individuals of the tree based on the DBH class. The following criteria were used to ascertain the status of regeneration (Shankar 2001): a) 'good', if seedling > sapling > trees, b) 'fair', if seedling > sapling ≤ trees, c) 'poor', if a species survives in only sapling stage but not as seedlings, d) 'none', if a species is absent in both sapling and seedling stages, e) 'new' if a species has no adults, but only saplings or seedlings or both. The density of seedlings and saplings per hectare was also assessed and compared with the community forestry inventory guideline to determine the regeneration status of the forest. The regeneration is good if seedlings density is above 5000 per hectare, fair if between 2000 and 5000 per hectare and poor if less than 2000 per hectare. Similarly, the regeneration is good if sapling density is above 2000 per hectare, fair if between 800 and 2000 per hectare and poor if less than 800 per hectare (MFSC 2002).

Human Impacts on Vegetation Structure

Human disturbance on forest was also analyzed through primary investigation. People utilize forests for their well-being. This may bring about changes in the density and composition due to uncontrolled lopping and felling of trees for fuelwood, fodder, timber, and grazing affecting the regeneration. The disturbance parameters such as grazing, trampling, distance from human settlement, exposed ground, etc. were also noted for analyzing the human impacts on vegetation structure. The change in species richness and average basal area along with change in elevation was analyzed to measure the human impacts on vegetation structure. Similarly, this species fuelwood consumption by the local was quantified; the increase or decrease in the number of lopping and cut stumps along change in elevation and distance from human settlement was compared to document the human influence on vegetation structure.

Data Interpretation and Presentation

All the data from the field were entered and analyzed in Microsoft Word 2010 and Microsoft Excel 2010 and results were presented in the form of tables, graphs and charts. The maps of study area were prepared using Arc GIS 9.3.

Results and Discussion

Floristic Composition and Vegetation Structure

The vegetation survey showed a total of 21 species of trees, 17 species of saplings, and 14 species of seedlings. The number of species for overall seedlings, saplings and trees was also 21. The tree species richness varied along the altitudinal gradient but did not show any linear trend. But if we exclude band 5, the species richness gradually decreased along with an increase in elevation. It could be due to an increase in canopy cover in higher elevation. It could also be because of a decrease in temperature and moisture content and unfavorable environmental conditions for some species of the plants. The differences in the microclimate, aspect, and altitude greatly influence vegetation within a forest type (Ghimire et al. 2008). The floristic composition of the forest is much affected by island size, history, degree, and level of disturbance (Maharjan et al. 2006). The altitude and physiographic factors largely control distribution and species richness patterns of different species. (Sharma et al. 2009a, 2009b). The altitudinal band of 1500-1700m AMSL (B1) and 2300-2500m AMSL (B5) had the maximum species richness of 12 whereas the altitudinal band of 2100-2300m AMSL (B4) had the least species richness of eight (Table 2). The higher species richness in band 1 and 5 could be because of the moderate disturbance of the human activities. Based on the average density, basal area and canopy cover, band 1 and 5 were the bands with moderate human influence whereas band 4 was the least disturbed and band 2 was the most disturbed one among the five bands. According to the intermediate disturbance hypothesis, a moderately disturbed area comprises the highest species richness than the highly disturbed and least disturbed area (Connell 1978; Bongers et al. 2009). In this study, Shannon's Index ranged between 1.125 and 2.152 in different forests and elevations (Table 2). Tree diversity values have been reported 2.69-3.82 from low to high elevation (Tripathi et al. 1991). Giri et al. (2008) had reported tree diversity between 0.88 and 2.11.

Table 2: Phyto-sociological parameters

S. No.	Parameters	Band 1	Band 2	Band 3	Band 4	Band 5	Overall
1	Species richness	12	10	9	8	12	21
2	Average tree density (stems/ha)	505	440	570	820	675	602
3	Average basal area (m^2/ha)	23.04	14.18	30.77	55.73	48.53	34.45
4	Shannon's Index	2.152	1.208	1.125	1.501	2.074	2.246
5	Species evenness	0.866	0.524	0.512	0.722	0.835	0.738
6	Simpson's Dominance Index	0.138	0.468	0.522	0.275	0.156	0.182
7	Simpson's Index of Diversity	0.862	0.532	0.478	0.725	0.844	0.818
8	Sapling density (stems/ha)	1288	1113	1050	1563	1188	1240
9	Seedling density (stems/ha)	33821	19895	28648	32627	27454	28489

Note: *ha means hectare; m^2/ha means square meter per hectare*

The species diversity, species evenness did not show any specific trend along the altitudinal gradient but the moderately disturbed bands i.e. band 1 and band 5 had higher species diversity, species richness, and species evenness. Hernandez et al. (2012) suggested that low species richness seems to be associated with the dominance of one or a few species. In the present study, Simpson's dominance index for trees ranged between 0.138 and 0.522 in different forests. Whittaker (1965) and Risser and Rice (1971) reported a dominance index for tree layer in the range of 0.10-0.99 for temperate forests. Likewise, some investigations have reported similar value in the range of 0.25-1.00 (Saxena and Singh 1982; Ralhan et al. 1982). Total tree density ranged from 440 stems/ha in band 2 to 820 stems/ha in band 4 and the average tree density of the whole forest was found to be 602 stems/ha (Table 2). Koirala (2004) reported the density of Tamafok forest and Madimulkharka forests in Tinjure-Milke region Nepal to be 756 stems/ha and 346 stems/ha respectively. The average basal area at the canopy layer was found to be 34.48 m^2/ha. The total basal area ranged from 14.18 m^2/ha in band 2 to 48.53 m^2/ha in band 4 which indicated that band 2 was the most disturbed part of the forest and band 4 was the least disturbed part (Table 2). A similar study in mid hill villages of central Nepal, Namjung forest of Gorkha district and Khari forest of Dhading district, reported tree density of 1227 stems/ha and 251 stems/ha respectively and basal area 45.56m^2/ha and 15.48 m^2/ha (Shrestha 2005). The basal area of Tamafok forest and Madimulkharka forests in Tinjure-Milke region Nepal were reported to be 69.8 m^2/ha and 58.9m^2/ha respectively (Koirala 2004).

The IVI varied from 0.81 to 88.91. *Daphniphyllum himalense* (88.91) stood as the most dominant species based on IVI which was followed by *Quercus lamellosa* (51.18) and *Symplocos ramosissima* (28.22) and they were associated with *Lyonia ovalifolia, Schimawallichii, Alnus nepalensis, Rhododendron arboreum, Quercus semecarpifolia, Neolitsea pallens, Eurya acuminata, Eurya cerasifolia, Cinnamomum tamala, Castanopsis indica,* etc. These species represented the major species occupying most of the tree canopy in the forest. *Rhus* species, *Litsea cubeba* and *Choerospondias axillaris* were the species with low values of the Importance Value Index (Table 3).

Table 3: Composition of woody vegetation at canopy level for the whole forest

S.N.	Name of plant species	BA (m^2/ha)	RBA (%)	Density (stems/ha)	RD (%)	Freq. (%)	RF (%)	I.V.I.
1	*Daphniphyllum himalense*	11.31	32.80	227	37.71	75	18.40	88.91
2	*Quercus lamellosa*	10.62	30.80	71	11.79	35	8.59	51.18
3	*Symplocos ramosissima*	2.20	6.38	65	10.80	45	11.04	28.22
4	*Lyonia ovalifolia*	1.47	4.26	23	3.82	30	7.36	15.45
5	*Schima wallichii*	1.13	3.28	36	5.98	25	6.13	15.39
6	*Alnus nepalensis*	2.02	5.86	23	3.82	22.5	5.52	15.20
7	*Rhododendron arboreum*	1.55	4.50	31	5.15	22.5	5.52	15.17
8	*Quercus semecarpifolia*	1.04	3.02	21	3.49	20	4.91	11.41
9	*Neolitsea pallens*	0.65	1.89	19	3.16	17.5	4.29	9.34
10	*Eurya acuminata*	0.32	0.93	14	2.33	20	4.91	8.16
11	*Eurya cerasifolia*	0.33	0.96	17	2.82	17.5	4.29	8.08

12	*Cinnamomum tamala*	0.48	1.39	14	2.33	17.5	4.29	8.01
13	*Macaranga pustulata*	0.59	1.71	11	1.83	12.5	3.07	6.61
14	*Engelhardia spicata*	0.37	1.07	11	1.83	10	2.45	5.35
15	*Castanopsis indica*	0.08	0.23	4	0.66	12.5	3.07	3.96
16	*Semecarpus anacardium*	0.07	0.20	3	0.50	7.5	1.84	2.54
17	*Myrica esculanta*	0.13	0.38	4	0.66	5	1.23	2.27
18	*Prunus* species	0.06	0.17	4	0.66	5	1.23	2.07
19	*Choerospondias axillaris*	0.04	0.12	2	0.33	2.5	0.61	1.06
20	*Litsea cubeba*	0.01	0.03	1	0.17	2.5	0.61	0.81
21	*Rhus* species	0.01	0.03	1	0.17	2.5	0.61	0.81
	Total	34.48		602				

Note: *BA-Basal area, RBA-Relative basal area, RD-Relative density, Freq.-Frequency, RF- Relative frequency, I.V.I.-Important Value Index*

Height Class Distribution

The number of trees of height class (5-10) m and (10-15) m was more but the height class of <5 m and (20-25) m had a lower number of trees in almost all the bands (Figure3). Band 5 had the maximum number of stems (i.e. 89) of height class (5-10) m. Only band 1 had the trees of height greater than 20 m height (Figure3). These data revealed that the forest of the study area was at the young and growing stage.

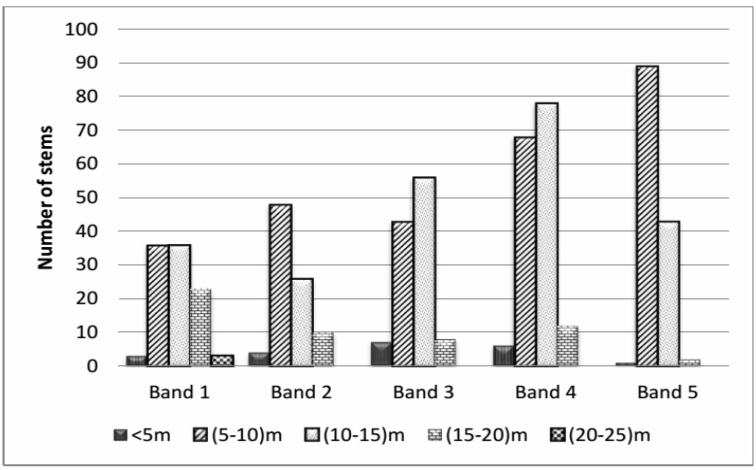

Figure 3: Height class distribution of the tree species in the forest

Frequency of Occurrence

The range of frequency was observed to be in the range of 2.5% to 75%. *Daphniphyllum himalense* possessed the highest frequency and was mixed with different communities. *Choerospondias axillaris, Litsea cubeba,* and *Rhus* species were the least frequent tree species and they also possessed lower density. *Daphniphyllum himalense* followed by *Symplocos ramosissima* (45%), *Quercus lamellose* (35%), and *Lyonia ovalifolia* (30%) were species with the greater frequency. When the frequency of occurrence of the plant species were grouped according to Raunkiaer's (1934) five frequency classes, it was found as A>B>C=D>E. The frequency diagram shows that the frequency class A has the highest number of species (Figure4).

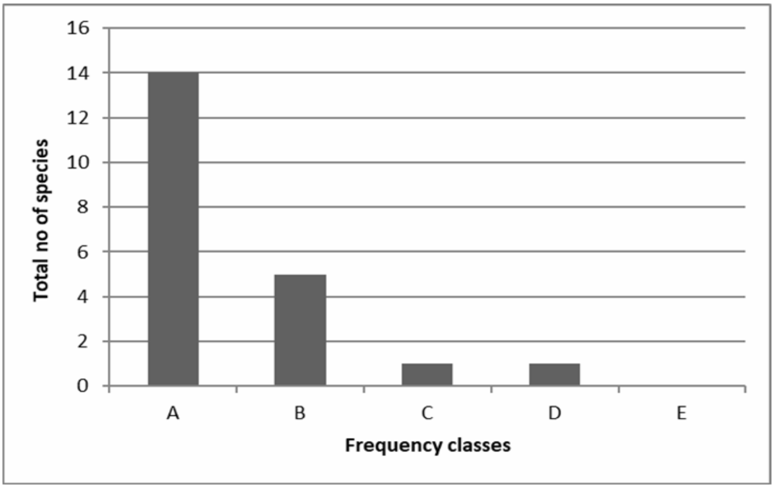

Figure 4: Number of species in frequency classes

Regeneration Status of Panchase Forest

The overall regeneration status of Panchase Forest can be considered good since 12 out of 21 species (57.14%) had achieved good regeneration status. Two species (9.52%) had fair regeneration whereas six species (28.57%) had possessed no regeneration and one species (4.76%) had poor regeneration (Table 4). But there were no new regenerating species of trees (Table 4). According to Community Forestry Inventory Guideline 2002, the regeneration status of the forest can be stated as good if the density of the seedlings is greater than 5000 per hectare (MFSC 2002). The density of seedlings in the present study was 28,489 per hectare which indicated that Panchase Forest has good regeneration (Table 4). But if we consider the density of saplings of 1240 per hectare in the present study which lies between 800 and 2000 saplings per hectare, the forest has fair regeneration capacity as per Community Forestry Inventory Guidelines (MFSC 2002). Paul et al. (2019) revealed that about 77% of the species demonstrated fair regeneration, 8% species indicated good regeneration while 15% of the species displayed no regeneration in a study of the population structure and regeneration status of Rhododendron tree species in temperate mixed broad-leaved woodlands in Tawang and West Kameng regions of western Arunachal Pradesh, India. A population with a sufficient number of seedlings, saplings and young trees depicts satisfactory regeneration behavior, while the deficient number of seedlings and saplings of the species in woodland demonstrates poor regeneration and the total non-attendance of seedlings and saplings of tree species in a forest shows no regeneration (Pokhriyal et al. 2010). The dominant species of the forest, *Daphniphyllum himalense* had fair regeneration whereas co-dominant species *Quercus lamellosa* and *Alnus nepalensis* had no regeneration and poor regeneration respectively.

Germination of seeds mostly depends on various environmental factors like temperature, moisture, and light and also on the viability of seeds. Seeds on the ground experience repeated desiccation and dehydration. It is important to assess the ability of seeds to germinate after being subjected to varying levels of desiccation (Singh and Singh 1992; Angelovici et al. 2010). On the other hand, seedling establishment is another important part of regeneration. It may be affected by environmental factors for the establishment and also the seedlings must compete with herbaceous flora for limited resources. In the present study area, the total seedlings that germinate from the seed did not develop into the saplings which were indicated by the higher density of seedlings than saplings (Table 4). The possible reason for this condition is that all seedlings cannot tolerate harsh environmental conditions and cannot compete with herbaceous flora. In different forest stands, seedling density varied from 19,895 to 33,821 stems/ha and sapling density from 1050 to 1563 stems/ha. In Nepal, the complacent number of seedlings per hectare reported in the hilly area of central development region in the altitude classes 1250 and 1750m, above sea level was between 10,460 and 18,190 stems/ha, respectively (FRSC/HMG 1996). The density of seedlings obtained in the studied forest was near to the expected value in the hill forests.

Table 4: Regeneration status of whole forest

S. No.	Name of species	Seedlings/ha	Saplings/ha	Trees/ha	Regeneration Status
1	*Alnus nepalensis*	0	13	23	P
2	*Castanopsis indica*	1273	23	4	G
3	*Choerospondias axillaris*	0	0	2	N
4	*Cinnamomum tamala*	1353	38	14	G
5	*Daphniphyllum himalense*	4058	203	227	F
6	*Engelhardia spicata*	716	13	11	G
7	*Eurya acuminata*	1273	43	14	G
8	*Eurya cerasifolia*	3501	95	17	G
9	*Litsea cubeba*	80	5	1	G
10	*Lyonia ovalifolia*	1910	105	23	G
11	*Macaranga pustulata*	637	50	11	G
12	*Myrica esculanta*	0	0	4	N
13	*Neolitsea pallens*	477	33	19	G
14	*Prunus* species	0	0	4	N

15	*Quercus lamellosa*	0	0	71	N
16	*Quercus semecarpifolia*	239	8	21	F
17	*Rhododendron arboreum*	159	33	31	G
18	*Rhus* species	0	8	1	N
19	*Schima wallichii*	1512	75	36	G
20	*Semecarpus anacardium*	0	10	3	N
21	*Symplocos ramosissima*	11300	490	65	G
	Total	28489	1240	602	

Note: *G - good regeneration; F - fair regeneration; P - poor regeneration; N - no regeneration*

Regeneration status of the forest in different altitudinal bands revealed that band 1 had the highest number of species with good regeneration (i.e. seven) and bands 2 and 3 had least species with good regeneration (three each) which showed that band 1 had good regeneration capability and band 2 and 3 had low regeneration capability. Band 4 and 5 had moderate regeneration capability (Table 5). The most dominant species of the forest *Daphniphyllum himalense* had good regeneration at band 1 and 2, fair regeneration at bands 3 and 4, but no regeneration at band 5.

Table 5: Regeneration status of the forest in different altitudinal bands

Regeneration Status	Number of species					
	Band 1	Band 2	Band 3	Band 4	Band 5	Overall
Good	7	3	3	4	4	12
Fair	2	0	2	1	1	2
Poor	1	2	2	0	1	1
No	2	5	2	3	6	6
New	0	1	0	0	0	0

The Density-Diameter (D-D) curve showed reverse J-shaped structure (Figure 5). The highest density of trees was found at the lower DBH class. The density of trees at the lowest two DBH class 10-20 cm and 20-30 cm had a very high-value density of 280 stems/ha and 160 stems/ha respectively. After these two classes, the density had been drastically decreased, resulting in a reverse J-shaped structure (Figure 5). The Density-Diameter distribution resembled a reverse J-shaped structure indicating sustainable regeneration (Vetaas 2000; Sujakhu el al. 2014). The domination of under canopy and ground strata by tree seedlings and saplings was an indication of good regeneration and self-maintenance of the forest. In the under-canopy stratum, the saplings of *Symplocos ramosissima* possessed the highest density as well as frequency among the entire tree saplings. So, the species *Symplocos ramosissima* has a good scope to maintain under canopy in the future due to its regeneration power and dispersion capability.

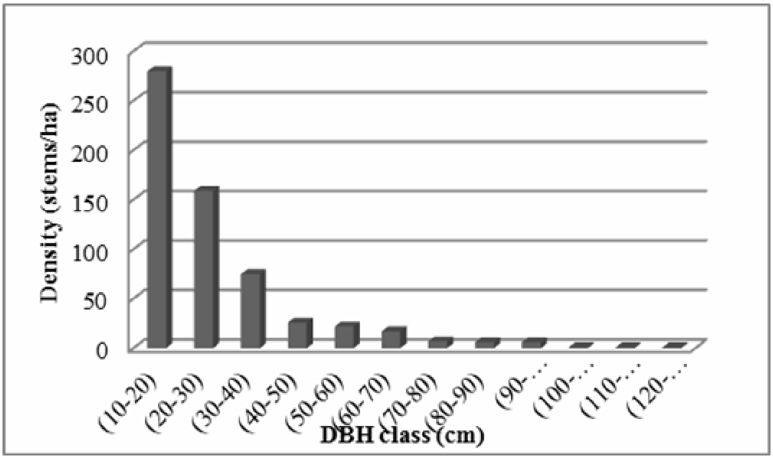

Figure 5: Density-Diameter curve for the regeneration of the whole forest

Human Impacts on Vegetation Structure

The graph plotted between the average basal area and species richness along x-axis and altitude in the y-axis revealed that band 2 was the most disturbed and band 4 was the least disturbed part of the forest. Bands 1 and 5 are moderately disturbed bands and have maximum species richness that is 12. The least density of trees in band 2 also revealed that it was the most disturbed band and the maximum density of trees in band 4 indicated that it was the least disturbed band (Figure6). Band 2 went through the highest human disturbance indicated by the low density and the basal area of trees, the low density of saplings and seedlings and low canopy cover. Similarly, bands 1 and 5 were the moderately disturbed and hence possess higher species richness and diversity. Along the environmental factors, human interference is the main factor affecting regeneration as well as the population structure of the forest.

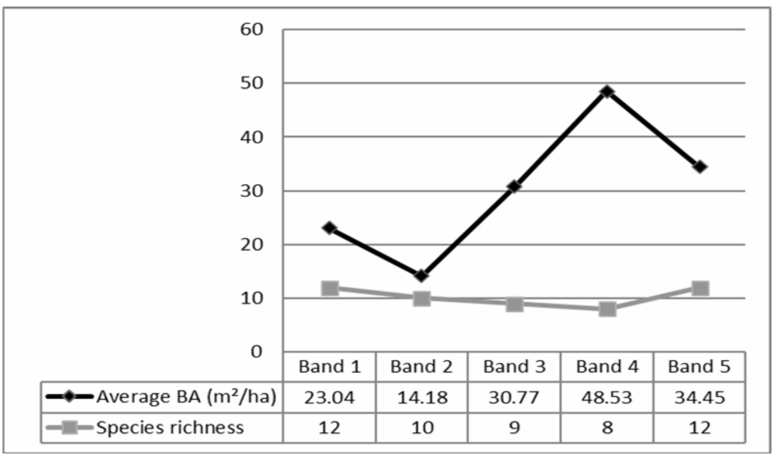

Figure 6: Average basal area and species richness versus altitudinal bands

The excessive and continuous grazing over the year has degraded these lands to such an extent that their productivity is very low (Chalise et al. 1993). It might be almost impossible to compete the whole successional cycle after disturbances such as fires, agriculture, urbanization, roads, and so forth (Guo 2003). The woody vegetation is severely impacted by anthropogenic disturbances (Yadav and Gupta 2006).

The density of lopping decreased along with the increase in elevation which indicated that the human disturbance gradually decreased from lower to higher elevation. Similarly, the density of cut stumps (cs) also showed a similar trend (Figure 7). People use the stumps of *Alnus nepalensis, Schimawallichii, Daphniphyllum himalense, Castanopsis indica*, etc. for constructing buildings and bridges. Based on the density of lopping and cut stumps, band 1 was the most disturbed and band 4 was the least disturbed among the five bands. Figure 7 shows the decreasing trend of the number of lopping per hectare along with the increase in elevation, whereas the number of cut stumps (cs) did not show any increasing or decreasing trend along with the altitude.

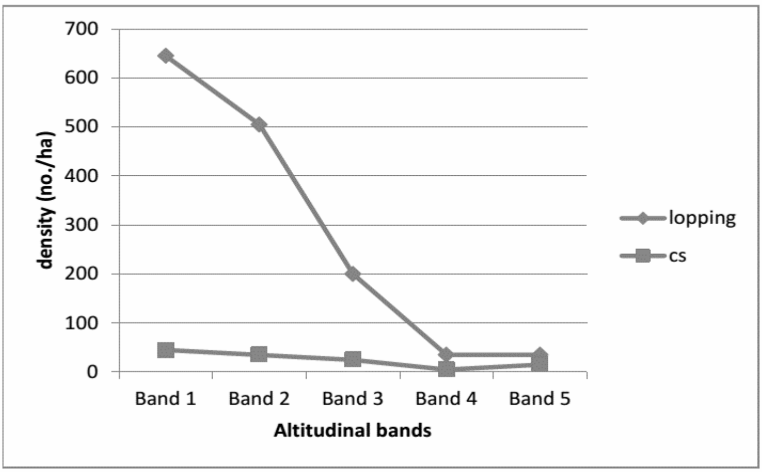

Figure 7: Number of cut stumps (cs) and lopped trees per hectare along the altitudinal gradient

The present study revealed that an average of 10315.8 kg (10.31 tons) of fuelwood is consumed annually by each household in BhadaureTamagi (now Annapurna Rural municipality ward no. 4). The annual consumption of the fuelwood by BhadaureTamagi was about 2083.79 tons (Figure 8). *Daphniphyllum himalense* (3879.6 kg/yr/house hold) was the most consumed tree species used for fuelwood. It could be because of the higher abundance of this species in the study site. *Alnus nepalensis, Schimawallichii* and *Castanopsis indica* were also among the major species used as fuelwood.

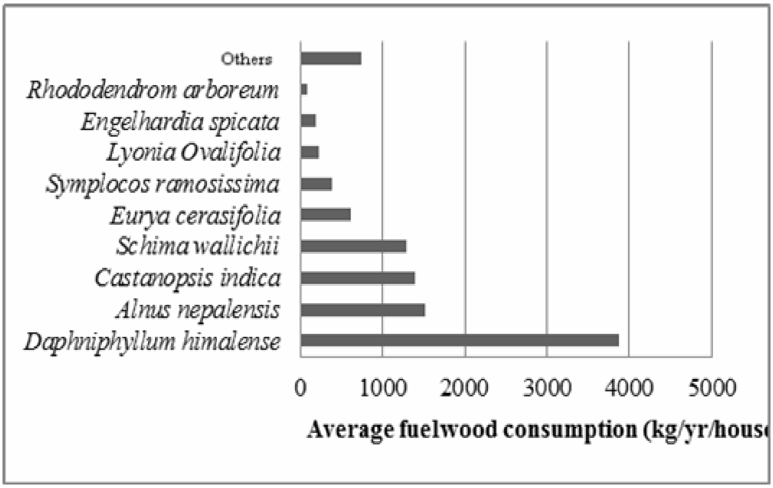

Figure 8: Annual average fuelwood consumption of each household

Altogether, 2083.79 tons of fuelwood was consumed annually by the people of BhadaureTamagi. *Daphniphyllum himalense, Alnus nepalensis, Castanopsis indica, Schimawallichii,* and *Eurya cerasifolia* were the major species of trees consumed as fuelwood by the villagers (Figure 9).

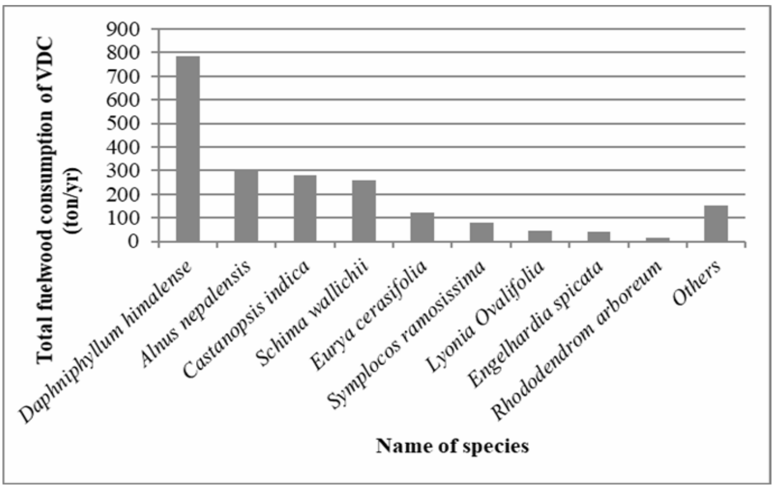

Figure 9: Total annual fuelwood consumption

A study in the western Himalayan communities of Bagh, Pakistan showed an annual fuelwood consumption of 10.2 metric tons per household. In terms of kg/capita/day, fuelwood consumption ranged from 2.19 in lower Bagh to 3.76 kg/capita/day in Upper Bagh with an average of 2.97 kg/capita/day (Shaheen 2010). In other studies, consumption level is 1.5 kg/capita/day in rural and tribal communities of the western Himalayas (Bhatt et al. 1994); 1.6-2.4 kg/capita/day in

South‐East Asia (Donovan 1981), and 1.24 kg/capita/day in trans‐Himalayan Nepali communities (Mahat et al. 1987).

The scatter diagram plotted between the density of trees and altitudinal bands revealed that more tree density had increased along with elevation, but because of the human disturbance band, 2 and band 5 tend to decrease the density of trees (Figure 10). The disturbance along the altitudinal gradients did not show any specific linear trend.

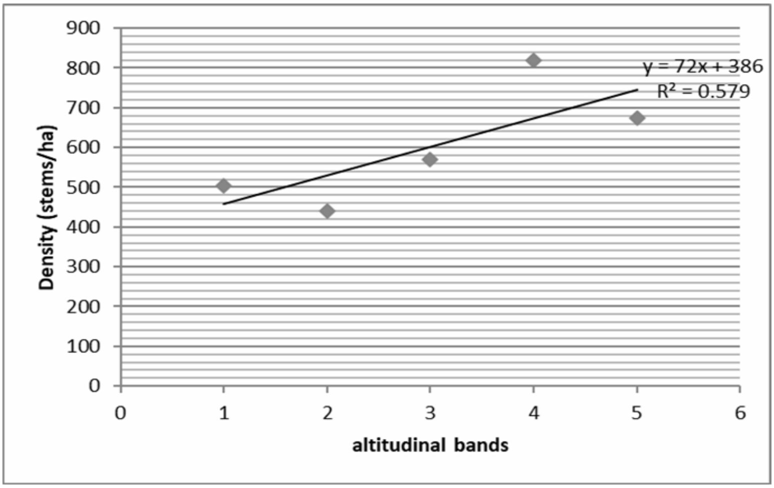

Figure 10: Tree density versus altitudinal bands

Since band 2 was nearest to human settlement, it was the most disturbed band based on tree density, basal area, and canopy cover of the forest. Band 4 was the least disturbed band, whereas bands 1 and 5 were moderately disturbed areas. Forest is most species rich when disruption is at a halfway power since it contains both pioneer and climax species (Connell 1978; Bongers et al. 2009). In the present study, the species richness was higher in moderately disturbed sites than in the least disturbed and highly disturbed ones. It has been suggested that when there is no disturbance, only a competitive dominant species can survive and when there is a high disturbance, only highly tolerant species can survive. Therefore, high diversity was observed when the disturbance was at a moderate level.

Conclusions

We have investigated the quantitative characteristics and regeneration status of the Panchase Protected forest in the western mid-hills of Nepal. The study revealed that the contribution of seedlings to the total population was highest followed by saplings and trees. It illustrates that the regeneration of tree species in the forest is good and the future communities may be sustained unless there is any major environmental stress or interference exerted by human activities. *Daphniphyllum himalense* was the most dominant species in the forest and it is hindering the growth of other trees. The dominance of *Daphniphyllum himalense* could be the main cause of lower species richness in the middle part of the forest. *Symplocos ramosissima* was found dominant in under canopy and ground stratum, indicating its good scope to maintain under canopy in the future due to its regeneration power and dispersal capability. However, considering the increasing anthropogenic pressure, there may be a spatial and temporal threat to the seedling establishment and growth of tree species in the study site. Quantitative analysis of diversity, population structure, and regeneration status of tree species recorded from the present study provide baseline information for formulating conservation and management strategies of the protected forest. However, thinking about the expanding anthropogenic pressure, there might be a spatial and temporal danger to the seedling foundation and development of tree species in the study site. Quantitative investigation of diversity, population structure, and regeneration status of tree species recorded from the current study give baseline data for detailing preservation and the executive's procedures to secure forest.

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