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# TREE DIVERSITY AND REGENERATION OF A MID-HILL COMMUNITY MANAGED MIXED-FOREST OF SINDHUPALCHOWK, NEPAL

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## ABSTRACT

Community forests indeed play a crucial role in the management and conservation of biodiversity, especially in developing countries where poverty can create challenges for enforcing strict rules and regulations. This study focused on analyzing the tree diversity and regeneration in the Anterpu Sallyani Ghaari Community Forest located in the Sindhupalchowk District, Nepal. Data were collected using 30 quadrats, each measuring 10m x 10m, and the sampling method used was random sampling. The study recorded a total of 22 tree species from 16 families. Tree diversity was assessed using the simpon index (D) and Shannon-Wiener index (H), and the evenness of the forest was also calculated. Based on the Importance Value Index (IVI), the most dominant tree species were identified as *Schima wallichi* (DC.) Korth., *Pinus roxhborghii* Sarg., *Castanopsis indica* Roxb.Miq., and *Lyonia ovalifolia* (Wall.) Drude. The overall tree density in the forest was 1080 stems per hectare. The study also reported that the forest has good seedling density (1310 stems/ha) but poor sapling density (253 stems/ha). The density-diameter (d-d) curve of adult plants indicated a reverse J-shaped pattern, which is a positive sign as it suggests that the forest is regenerating. However, the low number of small saplings and a slight deviation from the ideal reverse J-shape in the curve indicated unsustainable regeneration. The study suggests that poor management practices and anthropogenic disturbances in the past and present could be contributing factors to the poor regeneration of certain tree species, such as *P. roxhborghii.* The findings of this study provide insights on the current state of the community forest.

**Key words:** Community forest, Diversity indices, Regeneration, Tree diversity, Nepal

## INTRODUCTION

Biodiversity encompasses a wide-ranging concept, denoting the assortment of organisms, plants, and animals, spanning from the level of genes to entire ecosystems. Each living being exhibits its own distinct identity and uniqueness within its habitat and community (Chaudhary *et al.*, 2020). The forest, as a complete entity, comprises a rich diversity of flora and fauna. Notably, the variation in tree species goes beyond mere distinctions between one species and another; it is also influenced by multiple factors such as geography, habitat, topography, and disturbances (Rajbhandary *et al.*, 2020). Within the forest, the diversity of tree species assumes paramount importance, as it serves as a crucial resource and habitat for nearly all organisms (Jimoh and Lawal, 2016).

Forest regeneration refers to the inherent ability of a species to grow and survive. The presence of an ample number of young trees, seedlings, and saplings within the forest periphery indicates the regenerative potential of a specific species (Bhatta *et al.*, 2018; Hammond *et al.*, 2021). Natural regeneration sustains the integrity of the natural forest and facilitates the establishment and growth of indigenous species (Gebeyehu *et al.*, 2019). The occurrence frequency of seedlings varies due to several factors, including light availability, drought, and biotic factors such as competition, diseases, and herbivores (Sharma *et al.*, 2018).

The sustainability of forest species heavily relies on successful regeneration. When some dominant tree species show weak regeneration, and less dominant and rare species expand, it indicates a shift in species composition and distribution within that forest (Manral*et al.*, 2018; Shahi *et al.*, 2022). To maintain a balance between older trees and the number of younger trees/saplings and seedlings, favorable growth and sustainable regeneration are essential. The ability to produce seedlings, their resilience, and growth capacity significantly influences successful regeneration (Mishra *et al.*, 2013). Factors such as climate, topography, soil condition, and geographical distribution play pivotal roles in forest regeneration, particularly in mountain forests. Additionally, causes such as limited viable seed production, predation, overgrazing, habitat changes, and biological invasions also impact regeneration (Wentworth *et al.*, 2008; Hosseinzadeh *et al.*, 2016; Sharma *et al.*, 2020).

The attainment of diversity within forests can be realized through effective management and the sustainable utilization of forest products. However, the escalating global demand, coupled with socio-economic significance, has led to the exploitation of forests through logging and farming practices, resulting in the degradation of primary forests, especially in developing regions (Shrestha *et al.*, 2018; Yasin *et al.*, 2018; Hussein, 2021). Another contributing factor to forest degradation is the exclusion of local communities from conservation efforts surrounding protected areas (Joshi, 2003; Shrestha *et al.*, 2019).

The notion of community-managed forest schemes was introduced as a strategy for biodiversity conservation, aiming to engage local communities in the management, utilization, and preservation of forests to ensure their sustainability (Neupane *et al.*, 2020). In Nepal, community forests are defined as national forests entrusted to user groups for collective development, conservation, and utilization, thereby benefiting the community as a whole. This participatory forest management approach has gained widespread recognition (Anup, 2017). The community forestry program was initiated in the 1970s and legally implemented in 1993 in Nepal, with the primary goal of countering deforestation and forest degradation through protective measures and active involvement of local communities in forest preservation and management (Rijal *et al.*, 2021). Presently, there are 22,415 community forests in Nepal protecting more than 2.3 million hectares of forest. About 2.9 million households, accounting for about 50% of the country's total populations are actively participating in the community forest management program (Sharma *et al.*, 2014, FECOFUN, 2023).The main objective of this research was to establish baseline data on tree diversity and regeneration patterns in the context of prevalent community forestry management practices in the country.

## MATERIALS AND METHODS

### Study site

This research was conducted within the

Antarpu Sallyanighaari community forest, situated in Sunkoshi Rural Municipality-6, Sindhupalchowk, Nepal (Figure 1). The forest covers a total area of 20 hectares and is oriented towards the south-east, with coordinates of 27°42'49.31"N to 27°42'53.22"N and 85°50'47.68"E to 85°50'56.03"E. The altitude of the area ranges from 1200 meters to 1750 meters above sea level. The annual rainfall in the region measures 1924.5 mm, and the temperature fluctuates between 25°C and 13.30°C (based on data from the nearest weather station in Chautara) (DHM, 2021). The study forest is situated within the sub-tropical climate region characterized by a prevalence of tree species such as *Schima wallichi, Pinus roxhborghii, Castanopsis indica,* and *Lyonia ovalifolia*. The community forest has been managed by the local community since 1986.

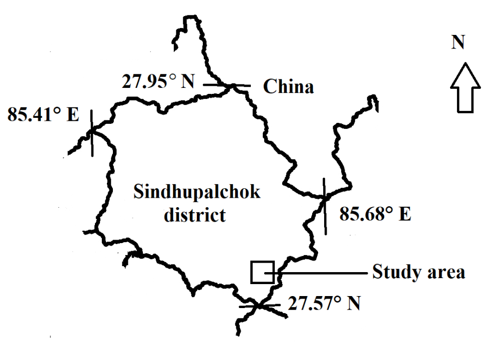


**Figure 1.** Map of the study area (Source: NSDI, 2023)

## Field sampling and Calculations

The study was conducted during October and November, 2021. A random sampling approach was employed for gathering vegetation data. A total of 30 quadrats, each measuring 10m x 10m, were utilized for vegetation sampling. Tree diameter was measured at breast height, 1.37 meters above the ground, using a diameter tape. The height of each individual tree was also measured using a clinometer. Based on criteria, trees were defined as having a diameter > 5cm and a height of 1.37m, saplings had a DBH less than 5cm and height less than 1.37m, while seedlings had a diameter less than 0.5cm and a height less than 20cm (Mandal and Joshi, 2014; Sharma *et al.*, 2020). The quantity and height of seedlings were also recorded. Woody plant species from each plot were collected for identification. Any unidentified plant species were recognized with the assistance of local individuals, teachers, and by referring to the herbarium in KATH. Vegetation characteristics were analyzed using the following formulas (Simpson, 1949; Nolan and Callahan, 2006; Mandal and Joshi, 2014; Redowan, 2015).

$$\text{Density (Stem/ha)} = \frac{\text{No. of individuals of species}}{\text{Total no. of plats studies} \times \text{area of each plot}} \times 10000$$

$$\text{Frequency (\%)} = \frac{\text{No. of plots in which the species occured}}{\text{Total no. of plots sampled}} \times 100\%$$

$$\text{Basal area} = \frac{(3.14) \times (dbh)^2}{4}$$

IVI = Relative Density+ Relative Frequency+Relative Basal Area

Shannon diversity index (H′) = $-\Sigma\,(n_i/N)\ln(n_i/N)$.

$= -\Sigma\, pi \ln pi$

Simpson's index of dominance (D) =1-[Σn(n-1)/N(N-1)]

$$\text{Evenness (e)} = \frac{H'}{\text{logs}} \text{ or } = \frac{\sum \text{pilnpi}}{\text{logs}}$$

## Statistical analysis

To assess the species dominance and diversity status of the forest, we calculated the Importance Value Index (IVI) and diversity indices. Additionally, the population of various life forms (seedlings, saplings, and adults) was determined to evaluate the regeneration pattern of the forest. To gain insights into the forest history, we analyzed the density-diameter (d-d) curve of the forest and the dominant tree species. Furthermore, scattered diagram was prepared between tree seedling and sapling density and tree basal area. All these analyses were performed using Microsoft Excel 2013 and SPSS (Statistical Package for the Social Sciences) version 27.0.1.

## RESULT AND DISCUSSION

### Plant diversity

In the study forest, a total of 22 tree species from 16 families were identified. Based on the Importance Value Index (IVI), *Schima wallichii* was found as the most dominant species (IVI = 93.19), followed by *Pinus roxburghii* (72.13), *Castanopsis indica* (33.67), *Lyonia ovalifolia* (21.83), *Engelhardia spicata* (15.64), and *Bridelia retusa* (11.23) (Table 1). Our findings align with previous research conducted in mid-hill community forests across the country (Gautam and Watanabe, 2005; Chhetri and Shrestha, 2019; Rajbhandary *et al.*, 2020), where multiple tree species were found to dominate the natural forest.

Usually, within natural forests, the dominant tree species tend to display higher IVI in comparison to species that are less dominant (Ismail *et al.*, 2021; Joshi *et al.*, 2021). Regarding family-wise diversity of tree species, Theaceae showed the highest density of 1010 stems per hectare with an IVI of 98.03, while Moraceae exhibited the lowest density of 3.33 stems per hectare with an IVI of 0.74. Moreover, research findings indicate that tree diversity and density are specific to different habitats and are influenced by climate and management practices (Sapkota *et al.*, 2009).

**Table 1:** Relative density, Relative frequency, Relative basal area and IVI of tree species

| S. N. | Scientific Name | Density (stem/ha) | RD | Frequency (%) | RF | BA ($m^2$/ha) | RBA | IVI |
|---|---|---|---|---|---|---|---|---|
| 1 | *Schima wallichii* (DC.) Korth. | 930 | 35.18 | 100 | 17.24 | 40.53 | 40.77 | 93.19 |
| 2 | *Pinus roxburghii* Sarg. | 347 | 13.11 | 76.67 | 13.22 | 45.53 | 45.80 | 72.13 |
| 3 | *Castanopsis indica* (Roxb.) Miq. | 433 | 16.4 | 73.33 | 12.64 | 4.6 | 4.63 | 33.67 |
| 4 | *Lyonia ovalifolia* (Wall.) Drude | 300 | 11.35 | 56.67 | 9.77 | 0.7 | 0.70 | 21.83 |
| 5 | *Engelhardia spicata* Lindl. ex Wall. | 163 | 6.18 | 50 | 8.62 | 0.83 | 0.83 | 15.64 |
| 6 | *Bridelia retusa* (L.) Spreng. | 110 | 4.16 | 40 | 6.90 | 0.17 | 0.17 | 11.23 |
| 7 | *Eurya acuminata* DC. | 80 | 3.03 | 23.3 | 4.02 | 0.53 | 0.53 | 7.58 |
| 8 | *Cleistocalyx operculatus* (Roxb.) Merr. and Perry | 60 | 2.27 | 30 | 5.17 | 0.17 | 0.17 | 7.61 |
| 9 | *Syzygium cumini* (L.) Skeels. | 30 | 1.13 | 20 | 3.45 | 1 | 1.01 | 5.58 |
| 10 | *Sapium insigne* (Royle) Benth. ex Hook. f. | 17 | 0.63 | 13.3 | 2.29 | 0.57 | 0.57 | 3.50 |
| 11 | *Phyllanthus emblica* L. | 7 | 0.25 | 6.67 | 1.15 | 1.4 | 1.41 | 2.81 |
| 12 | *Alnus nepalensis* D. Don | 7 | 0.25 | 3.33 | 0.57 | 1.53 | 1.54 | 2.36 |
| 13 | *Litsea monopetala* (Roxb.) Pers. | 30 | 1.13 | 6.67 | 1.15 | 0.01 | 0.01 | 2.29 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 14 | *Ficus hispida* L. f. | 3 | 0.13 | 3.33 | 0.57 | 1 | 1 | 1.70 |
| 15 | *Lindera pulcherima* (Nees) Benth. ex Hook. f. | 13 | 0.5 | 6.67 | 1.15 | 0.1 | 0.10 | 1.75 |
| 16 | *Fraxinus floribunda* Wall. | 17 | 0.63 | 13.33 | 2.30 | 0.77 | 0.77 | 3.70 |
| 17 | *Rhus wallichii* Hook. f. | 17 | 0.62 | 10 | 1.72 | 0.01 | 0.01 | 2.35 |
| 18 | *Prunus cerasoides* D. Don | 10 | 0.4 | 6.67 | 1.15 | 1 | 1 | 2.55 |
| 19 | *Myrica esculenta* Buch.-Ham. ex D. Don | 23 | 0.88 | 16.67 | 2.87 | 0.76 | 0.76 | 4.52 |
| 20 | *Choerospondias axillaris* (Roxb.) B. L. Burtt and A. W. Hill | 7 | 0.25 | 6.67 | 1.15 | 0.2 | 0.20 | 1.60 |
| 21 | *Persea odoratissima* (Nees) Kosterm. | 20 | 0.76 | 3.33 | 0.57 | 1 | 1 | 2.33 |
| 22 | *Shorea robusta* Gaertn. | 20 | 0.76 | 13.33 | 2.30 | 0.01 | 0.01 | 3.07 |
| | Total | 2644 | 100 | 579.94 | 100 | 102.42 | 100 | 300 |

**Table 2:** Relative density (RD), Relative frequency (RF), Relative basal area (RBA) and IVI of families of tree species

| S. N. | Family | Density (stem/ha) | RD | Frequency (%) | RF | Basal Area (m2/ha) | RBA | IVI |
|---|---|---|---|---|---|---|---|---|
| 1 | Theaceae | 1010 | 38.21 | 100.00 | 18.52 | 41.06 | 41.30 | 98.03 |
| 2 | Pinaceae | 347 | 13.11 | 76.67 | 14.20 | 45.53 | 45.80 | 73.11 |
| 3 | Fagaceae | 433 | 16.39 | 73.33 | 13.58 | 4.6 | 4.63 | 34.60 |
| 4 | Ericaceae | 300 | 11.35 | 56.67 | 10.49 | 0.7 | 0.70 | 22.55 |
| 5 | Sapotaceae | 163 | 6.18 | 50.00 | 9.26 | 0.83 | 0.83 | 16.27 |
| 6 | Euphorbiaceae | 127 | 4.79 | 46.67 | 8.64 | 0.74 | 0.74 | 14.18 |
| 7 | Myrtaceae | 90 | 3.40 | 43.33 | 8.02 | 1.17 | 1.18 | 12.61 |
| 8 | Phyllanthaceae | 7 | 0.25 | 6.67 | 1.23 | 1.4 | 1.41 | 2.89 |
| 9 | Betulaceae | 7 | 0.25 | 3.33 | 0.62 | 1.53 | 1.54 | 2.41 |
| 10 | Moraceae | 3 | 0.13 | 3.33 | 0.62 | 1 | 1 | 1.74 |
| 11 | Oleaceae | 17 | 0.63 | 13.33 | 2.47 | 0.77 | 0.77 | 3.87 |
| 12 | Roasaceae | 10 | 0.38 | 6.67 | 1.23 | 1 | 1 | 2.61 |
| 13 | Myricaceae | 23 | 0.88 | 16.67 | 3.09 | 0.76 | 0.76 | 4.73 |
| 14 | Anacardiaceae | 23 | 0.88 | 13.33 | 2.47 | 0.21 | 0.21 | 3.56 |
| 15 | Lauraceae | 63 | 2.40 | 16.67 | 3.09 | 0.11 | 0.11 | 5.59 |
| 16 | Dipterocarpaceae | 20 | 0.76 | 13.33 | 2.47 | 0.01 | 0.01 | 3.24 |
| | Total | 2643 | 100 | 540.00 | 100 | 102.42 | 100 | 300 |

## Diversity indices

The diversity of species is often quantified using the Shannon-Wiener index (Nolan and Callahan, 2006). In our study forest, the Shannon-Wiener index was determined to be 2.298. As species richness and evenness increase, the Shannon index also rises, starting from a value of 1.5. Additionally, we computed the index of dominance, known as Simpson's index, which was found to be 0.848 (Figure 2). Simpson's index provides a measure of diversity that considers both the number of species present and their relative abundance, with values ranging from 0 (indicating no diversity) to 1 (representing infinite diversity). Our study's results revealed that the Shannon-Wiener index is higher and Simpson's diversity index is lower in comparison to the Bhabar lowland and hill Sal forest, aligning with certain prior research findings (Sapkota *et al.*, 2009; Shrestha *et al.*, 2015; Sharma *et al.*, 2020). These findings suggest that the study forest exhibits relatively higher diversity.

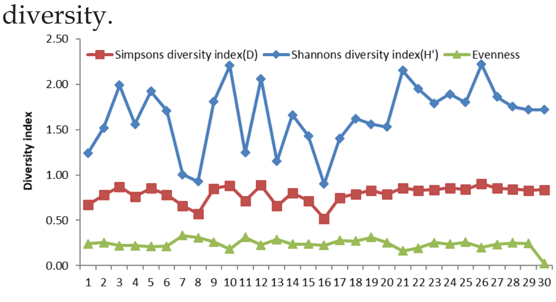


**Figure 2:** Plot wise diversity indices of tree species

Species richness pertains to the overall count of species existing in a given area. In our study forest, the tree species richness was determined to be 21 with highest richness (13) in plot 21 and lowest (3) in plots 7 and 8 (Figure 3). Likewise, evenness, which represents the species abundance in the forest, was calculated to be 0.697. A value close to 1 for species evenness indicates that the forest exhibits good tree diversity (Paudyal, 2013).

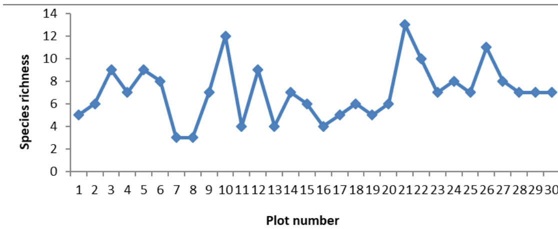


**Figure 3**: Plot wise richness of trees species in the study forest

## Population structure and regeneration

The population structure analysis of tree species reveals that both seedlings and mature trees contribute significantly more than saplings (Figure 4). The total density of seedlings, saplings, and mature trees was recorded as 1310 stems per hectare, 253 stems per hectare, and 1080 stems per hectare, respectively. This suggests that the forest is undergoing regeneration, but it is not yet stable. Despite *Schima wallichi*, *Pinus roxburghii*, and *Castanopsis indica* being dominant species in the forest, their sapling and seedling numbers are insufficient for proper regeneration. A forest is considered poorly regenerating if the number of saplings is significantly low (Chhetri and Shrestha, 2019; Sharma *et al.*, 2020). The density of plants in natural forests is influenced by various biotic and abiotic factors, such as disturbances, climate, and topography (Paudyal, 2013).

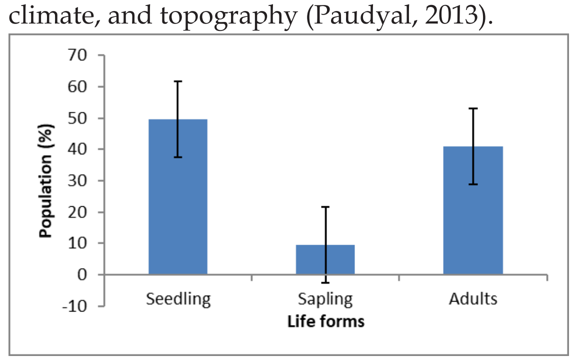


**Figure 4:** Population structure of different life forms of tree species in the study forest

**Table 5** : Density of Seedling, Sapling and Adult of tree species in the forest

| S.N. | Scientific Name | Density (stem/ha) | | |
|---|---|---|---|---|
| | | Seedling | Sapling | Adults |
| 1 | *Schima wallichii* | 384 | 50 | **496** |
| 2 | *Pinus roxburghii* | 7 | 0 | **340** |
| 3 | *Castanopsis indica* | 330 | 63 | 40 |
| 4 | *Lyonia ovalifolia* | 233 | 40 | **27** |
| 5 | *Engelhardia spicata* | 100 | 20 | **43** |
| 6 | *Bridelia retusa* | 86 | 30 | **0** |
| 7 | *Eurya acuminate* | 30 | 17 | 30 |
| 8 | *Cleistocalyx operculatus* | 37 | 13 | **10** |
| 9 | *Syzygium cumini* | 20 | 3 | **7** |
| 10 | *Sapium insigne* | 0 | 0 | **17** |
| 11 | *Phyllanthus emblica* | 0 | 0 | 7 |
| 12 | *Alnus nepalensis* | 0 | 0 | **7** |
| 13 | *Litsea monopetala* | 30 | 0 | **0** |
| 14 | *Ficus hispida* | 0 | 3 | **0** |
| 15 | *Lindera pulcherima* | 0 | 0 | 13 |
| 16 | *Fraxinus floribunda* | 0 | 0 | **17** |
| 17 | *Rhus wallichii* | 10 | 7 | **0** |
| 18 | *Prunus cerasoides* | 7 | 3 | **0** |
| 19 | *Myrica esculenta* | 3 | 3 | 17 |
| 20 | *Choerospondias axillaris* | 0 | 0 | **7** |
| 21 | *Persea odoratissima* | 20 | 0 | **0** |
| 22 | *Shorea robusta* | 20 | 0 | **3.33** |
| | Total | 1310 | 253 | 1080 |

## Relationship of tree basal area with seedling and sapling density

In natural forests, tree basal area is influenced by various factors such as altitude, species composition, tree age, and the level of disturbances (Gautam and Watanabe, 2005; Chhetri and Shrestha, 2019). Typically, different local and regional factors affect tree growth, but trees with a diameter of around 65 cm or those that have reached approximately 45 years of age tend to exhibit the highest growth rates (Ghimire and Lekhak, 2007; Sharma *et al.*, 2019). To examine the relationship between seedling and sapling density with the basal area of trees, a scattered diagram was employed (Figure 5). Both seedling and sapling density showed a negative correlation with basal area, although the relationship was not statistically significant. This suggests that as tree density increases, the canopy cover also increases, leading to reduced space for the growth of seedlings and saplings.

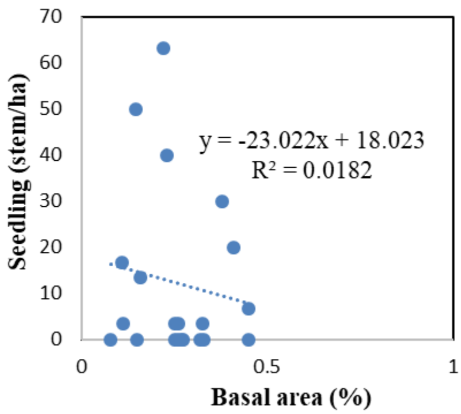


**Figure 5:** Relationship between seedlings, sapling density with tree basal area (n = 30)

The density-diameter (d-d) curve for adult trees exhibits a reverse J shape (Figure 6), indicating that the density of low diameter class individuals surpasses that of mature trees, which is a positive sign of sustainable regeneration (Ghimire and Lekhak, 2007; Joshi *et al.*, 2021). However, the low number of saplings suggests that the forest has recently experienced some anthropogenic disturbances, as evident from our field observations. Among the three dominant tree species, *S. wallichi* displays a relatively favorable d-d curve compared to others (Figure 7). This suggests that the forest habitat is more conducive to the growth of *S. wallichi* than to other tree species.

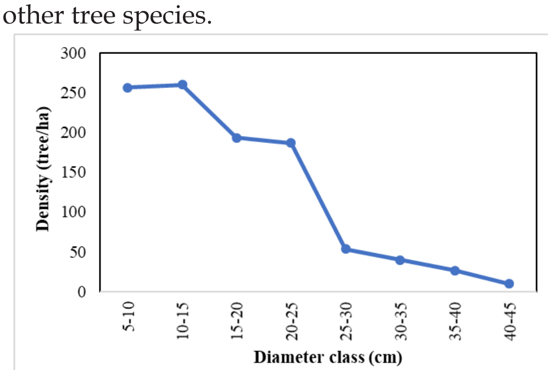


**Figure 6:** Density diameter (d-d) curve of tree species in the forest

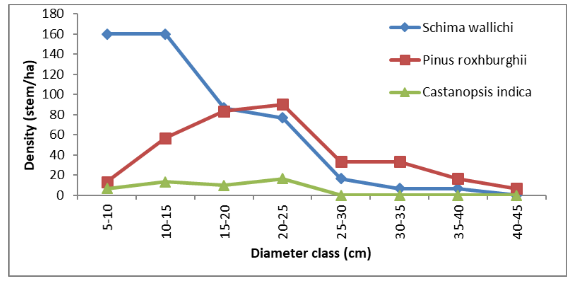


**Figure 7:** Density-diameter (d-d) curve of dominant tree species

## CONCLUSIONS

The study forest exhibits a good diversity of 22 tree species; however, diversity indices suggest that proper management is required to enhance species richness and evenness. Despite an overall positive forest regeneration indicated by the reverse J-shaped density-diameter (d-d) curve, the population structure of two dominant tree species, Pinus roxburghii and Castanopsis indica is unbalanced. Pinus roxburghii shows an unstable population structure, with hardly any saplings, while Castanopsis indica lacks stability, having a very low number of adult individuals. To ensure sustainable forest regeneration, it is crucial to balance the population structure of these dominant species. This can be achieved through measures like promoting natural regeneration, ensuring appropriate seed dispersal and germination, and managing disturbances that may impact their growth and recruitment. Further, effective forest management strategies are vital to preserve biodiversity and ensure the long-term health and resilience of the forest ecosystem.

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