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# Vegetation structure and carbon stock potential in the community-managed forest of the Mid-Western Hilly Region, Nepal

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**Abstract.** *Rawal K, Subedi PB. 2022. Vegetation structure and carbon stock potential in the community-managed forest of the Mid-Western Hilly Region, Nepal. Asian J For 6: 15-21.* Community forests (CF) play a crucial role in sustainable development and accumulate carbon to mitigate global climate change. The objective of this study was to evaluate the plant diversity, regeneration status, and carbon stock potential of two community-managed *Shorea robusta*-dominated forests in Nepal's Dailekh District, namely Bayeldhunga Pahapu CF and Bayeldhunga CF. A total of 76 sample plots were studied using a systematic sampling intensity of 0.5%. The density of species in the developmental phase was used to determine the forest's regeneration condition. Allometric equations were used to calculate the aboveground carbon store of tree species. *Shorea robusta* Gaertn. was the foremost species regarding regeneration and carbon storage in the studied forest areas, with high regeneration conditions. The seedlings, saplings, and trees in the Bayeldhunga Pahapu CF exceeded those in the Bayeldhunga CF. In both study areas, J-shaped reverse population curves were observed. This study provided details on tree species' regeneration condition, structure, proportions, and carbon sequestration capacity, which is critical for community forest management and conservation. The analysis showed that by altering the structure and proportions of community forests, community management has boosted the carbon storage of forests and enhanced forest productivity.

**Keywords:** Allometric equation, carbon sequestration, population curve, regeneration structure

## INTRODUCTION

Forest ecosystems play a vital role in the overall carbon cycle and climate change and trap and store a considerable quantity of carbon over time (Magar and Shrestha, 2015; Nugroho et al., 2022). Forests comprise around 31% of the world's terrestrial surface and are projected to store 289 Gt of carbon biomass (FAO 2010), greater than the quantity of carbon in the atmosphere. However, between 2005 and 2010, the tropical forest experienced a worldwide reduction in its area, with an annualized rate of 0.5 Gt of carbon reserves in forest biomass (FAO 2010). Furthermore, in the 1990s, deforestation, recognized as a key source of biological diversity loss, contributed around 5.8 GtCO2/year to world greenhouse gas emissions (Karousakis 2007). Thus, today's forest ecosystem has the challenge of devising effective strategies and techniques for enhancing forest regeneration conditions and restoring abandoned areas (Chand et al., 2018). Deforestation prevention is, therefore, a generally acknowledged acceptable mitigation strategy for mitigating climate change in the short term (Karki et al. 2017), and it is gaining traction across scientific communities and carbon negotiation mechanisms like REDD+ (reduced emissions from deforestation and forest degradation).

Regeneration is an essential component for the existence and survival of species in a community. Research has shown the impact of the devolved management of forests in Nepal as a representative picture of forest regeneration and conservation (Sharma et al., 2020; Joshi, 2021). The existence of distinct age groups of seedlings, saplings, and trees characterizes a forest's regeneration and production capacity (Karki et al., 2017), which subsequently aids in understanding the state of tree communities, regeneration, and variety for conservation purposes (Chazdon et al. 2020). Environmental variables, soil quality, human pressures, and management techniques influence species regeneration. They may also be used to see if forest management results in increased productivity and the preservation of forest biodiversity (Joshi et al., 2019). The severity of management interventions differs in forest regeneration complexities and species composition, highlighting the importance of continuous inspection and assessment of silvicultural initiatives to facilitate optimal forest management on regeneration structure and composition, along with species diversity (Pathak et al. 2017).

Nepal is considered the pioneer country in designing and promoting Community Forest (CF) management strategy (Pandey et al. 2012), in which land is handed to Community Forest Users Groups (CFUGs). The decentralization of ownership of forest resources from the state to communities is portrayed in this management system, which symbolizes a paradigm change in Nepal's forestry industry (Karky and Skutsch 2010). Community forests have been reported to operate as a carbon sink, accumulating around 20% of Nepal's total carbon stored. Forest carbon storage and dynamics are particularly crucial, especially in developing countries such as Nepal. Nepal's forest contributes around 176.95 t/ha of carbon stock, with tree constituent accounting for 61.53%, forest soil accounting for 37.80%, and litter and detritus accounting for 0.67%. Carbon stock did not distinguish substantially based on species richness or litter cover, but it does tend to influence over management duration time (Joshi 2021). Beginning with establishing the REDD mechanism, the carbon sequestration capability of forests has been actively investigated and debated worldwide. Because community forestry is seen as a viable forest management initiative in Nepal, the governments and forestry-related non-governmental agencies want to include it in the REDD program (Chakma and Gautam 2019). That necessitates the assessment of the forest carbon stored in community forests. Quantifying carbon stock generates CF's carbon credit potential and assists CFUGs in understanding the role of CF in the earth's climate regulation, eventually motivating users to enhance forest management and conservation (Aryal et al., 2013). Therefore, we analyzed the regeneration condition of Nepalese community forests and their carbon-accumulation capacity, allowing us to understand better the impacts of forest management and silvicultural activities on the fundamental health and prosperity of the forests. Thus, this work uses a comparative study focused on two community-managed forests (CFs) in the Mid-Western Hilly area to address the mechanisms responsible for regeneration and carbon build-up, which is under-represented in the previous literature.

## MATERIALS AND METHODS

### Study area

The study area was Bayaldhungaa Pahapu (Ward no.9) and Bayaldhungaa (Ward no. 6) community forests (CF) of Aathbis municipality of Dailekh District, Nepal. Dailekh District is located in the Karnali Province of the hilly part of Nepal (28°50'15"N; 81°42'28"E) (Figure 1). The district's elevation is steep, ranging from upper tropical (544 m asl) to subalpine (up to 4168 m asl). The average annual rainfall is 185.07 mm, and the temperature ranges from 20 to 35ºC.

Bayaldhungaa Pahapu CF covers an area of 229.42 ha at 1600-2700 m asl, whereas Bayaldhungaa CF covers an area of 489.62 ha at 1600-2800 m asl. Therefore, according to the geographical condition and species composition, community forest user groups (CF manuals) partitioned the entire forest area into separate blocks. That way, Bayaldhungaa Pahapu CF was divided into three blocks and Bayaldhungaa CF into four blocks.

The study area has a natural forest where we can find broadleaved tree species. Both CF consists of a dominant natural species, Sal (*Shorea robusta* Gaertn.), and other associate species, such as Kafal (*Myrica esculenta* Buch.-Ham. ex D.Don) and Lali gurans (*Rhododendron arboreum* Sm.).

The field study was carried out during the dormant stage of the plant, i.e., the winter season (January-February 2021).

### Forest sampling design and measurement

The community forests were mapped by using GPS and Arc Map 10.8 software. A sum of 76 rectangular sample plots (25 in Bayaldhunga Pahapu and 51 in Bayaldhunga CF), each of 500 m$^2$, were established using systematic sampling of the intensity of 0.5% in both community forests.

In every sample plot, four rectangular plots with measurements of 5m*2m, 5m*5m, 10m*10m, and 50m*10m were used for sampling seedlings (Height<1m), saplings (Height≥1m, DBH <10cm), poles (10cm≤DBH <30cm), and trees (DBH≥30cm), respectively. In addition, regenerations (seedlings and saplings) were recorded in the field (MoFSC 2010) to calculate density. For example, in a 12.62 m$^2$ plot, the height of every tree was recorded with a Silva clinometer, and the diameter at breast height (DBH) of every tree inside the sample plot was recorded with a diameter tape.

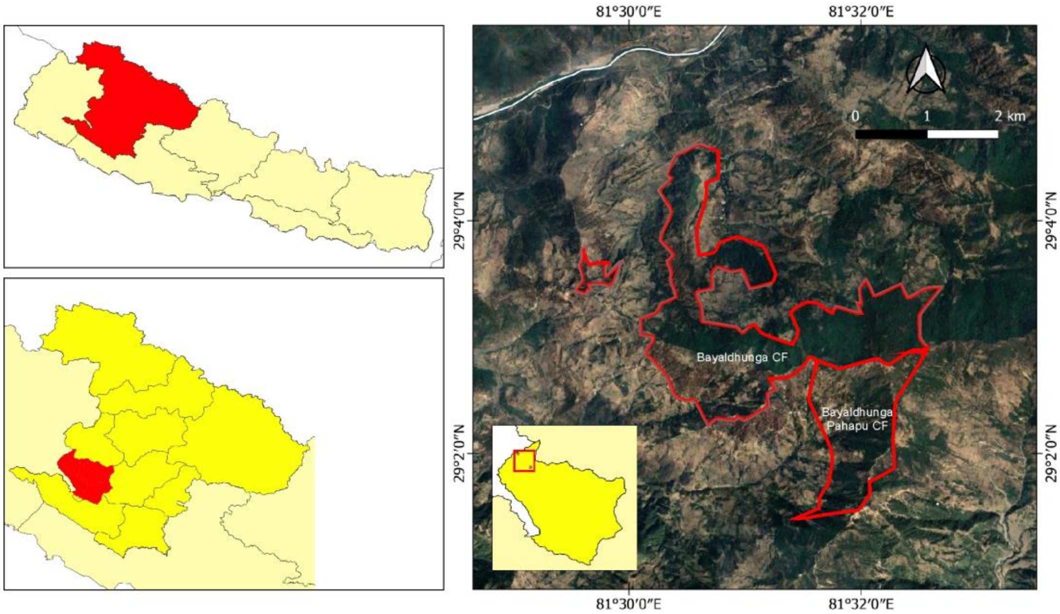


**Figure 1.** Map of the study area in the Dailekh District, Nepal

## Quantitative analysis

*Regeneration density*

The number of total saplings and trees was calculated using the number of individuals gathered during the carbon stock inventory, with saplings described as those with a DBH of lesser than 10 cm and trees described as those with a DBH of greater than 10 cm (Måren et al. 2015; Chand et al. 2018). Individuals with DBH 1 cm (height within 15 cm and 137 cm) were called seedlings (Måren et al. 2015) and were assessed in 76 sample plots employing 2m*5m measurements. Finally, each sample plot's seedlings, saplings, poles, and trees were counted, and the final numbers were added, averaged, and noted for density calculations. The following equation was used to compute density:

$$Density\left(\frac{no}{ha}\right) = \frac{Total\ number\ of\ individuals\ in\ each\ life\ form}{Total\ no.of\ sample\ plots\ studied * area\ of\ each\ plot(m^2)} * 10000$$

Similarly, the density of particular species was calculated by the given below equation:

$$Density\left(\frac{no}{ha}\right) = \frac{Total\ number\ of\ individuals\ of\ each\ species\ in\ each\ life\ form}{Total\ no.of\ plots\ studied * area\ of\ each\ plot(m^2)} * 10000$$

*Community attributes (Importance Value Index)*

The density, frequency, and basal area of species of trees were estimated for quantitative analysis (Zobel et al. 1987). The Importance Value Index (IVI) notion was devised to convey any species' dominance and ecological accomplishment with a particular single value. It was computed to estimate the significance of every species in the plant communities by introducing additional relative values of the three variables: density, frequency, and basal area (Curtice 1959).

$$I.V.I = RD + RF + RBA$$

Where, I.V.I. = Importance Value Index, RD = Relative Density, RF = Relative Frequency, and RBA = Relative Basal Area.

*Aboveground tree biomass and carbon estimation*

A non-destructive approach was applied in this study to estimate biomass. The following allometric equation was used to compute the aboveground tree biomass (AGTB) (Chave et al. 2005).

$$AGTB = 0.0509 * D^2 * WD * H$$

Where, D = Tree diameter at breast height (cm), WD = Wood specific density ($kgm^{-3}$), H = Tree height (m) for trees (DBH ≥ 10 cm) (Chave et al. 2005).

*Carbon stock of species*

Individual tree species' summed carbon stocks in community forests were estimated by summing the overall density values of the entire forest for that particular species. Then, the proportionate amount of carbon stock for each ha of all species available in the forest was divided by the aggregate of carbon stock of a particular species in the same forest to calculate the percent proportion of carbon stock of particular tree species in a forest (Joshi and Singh 2020). The given equation calculated it:

$$Carbon\ stock\ of\ tree\ species\ \% = \frac{Sum\ of\ carbon\ stock\ of\ a\ particular\ tree\ species(ha)}{Sum\ of\ carbon\ stochk\ of\ all\ tree\ species(ha)} * 100$$

## Statistical analysis

To determine the significance of the differences among CFs, species, and related interactions, a two-way analysis of variance (ANOVA) test was used. The CF scale was used to quantify carbon stocks. In contrast, three analytical replications of each CF were used to quantify the species-wise net carbon stock among the similar variety in community forests. Replications were allocated randomly to generate an equal number of replications of both CFs, to solve a challenge with the uneven number of plots for species and CFs. SPSS software and Microsoft Excel (2010) were used for statistical analysis. The standard error (± SE) followed all the mean values.

# RESULTS AND DISCUSSION

## Quantitative analysis

*Regeneration status of species in CF*

Compared to Bayaldhunga CF, the regeneration condition of the Bayaldhunga Pahapu CF was significant. Bayaldhunga Pahapu CF had seedlings of 11 species from the 25 sample plots investigated, whereas Bayaldhunga CF had seedlings of 14 species from the 51 sample plots. In Bayaldhunga Pahapu CF, the maximum number of seedlings was *S. robusta*, followed by *Alnus nepalensis* D.Don, and *Pyrus pashia* Buch.-Ham. ex D.Don, and *Persea duthiei* (King ex Hook.fil.) Kosterm. Similarly, in Bayaldhunga CF, the maximum number of seedlings was *S. robusta*, followed by *P. duthiei*, *A. nepalensis*, and *Quercus semecarpifolia* Sm. In comparing both CFs, *S. robusta* was the most prominent in both the seedling and sapling stages. The total seedlings in Bayaldhunga Pahapu and Bayaldhunga CF were calculated to be 5,840 and 4,903 $ind.ha^{-1}$, respectively (Table 1). Similarly, the total sapling number was higher in Bayaldhunga Pahapu CF than in Bayaldhunga CF, calculating 1,712 and 1,412 $ha^{-1}$, respectively.

Therefore, Bayaldhunga Pahapu CF had a better regeneration condition than Bayaldhunga CF (Table 1). Similarly, Sal (*S. robusta*) seedlings and saplings were more consistent and abundant in the Bayaldhunga Pahapu community forest, which had a greater density and periodicity than the Bayaldhunga community forest. Therefore, it suggests that the dispersion of Sal (*S. robusta*) seedlings and saplings is consistent and that the forest composition and structure are unlikely to alter in the coming years.

*DBH distributions*

When comparing the two community forests, it was reported that Bayaldhunga CF contributed most of the trees' overall diameter categories (from DBH>10cm). In Bayaldhunga Pahapu and Bayaldhunga CFs, there were 47 and 88 individuals in the diameter class (10-20) cm, accordingly. On the other hand, trees with a diameter of more than 50 cm were the lowest represented in both CFs (Figure 2).

*Forest structure*

Seedlings had a higher density in saplings and trees across both CFs. The presence of large numbers of seedlings on the community understory indicates that the forest site has significant regeneration potential (Figure 3).

*Community attributes (Importance Value Index)*

From the entire sample plots of both community forests, 18 tree species were identified and documented. However, in Bayaldhunga Pahapu CF, 12 species with a total of 144 trees were identified and analyzed. Similarly, in Bayaldhunga CF, 16 tree species were identified and measured, totaling 278 trees. Hence, Bayaldhunga Pahapu CF had a greater tree density (355 ind.ha$^{-1}$) than Bayaldhunga CF (325 ind.ha$^{-1}$) (Table 2). The *S. robusta* was the most prominent tree species in the Bayaldhunga Pahapu and Bayaldhunga community forests, with IVI values of 101.30 and 90.35, respectively. *Aesculus indica* (Colebr. ex Cambess.) On the other hand, hook. (1.85) and *Quercus leucotrichophora* A.Camus (1.52) had the lowest IVI in Bayaldhunga Pahapu and Bayaldhunga community forests, respectively (Joshi et al. 2019).

## Biomass and carbon estimation

*Aboveground tree biomass (AGTB) and carbon stock*

Mean AGTB and carbon stock in Bayaldhunga Pahapu CF were 126.69 t.ha$^{-1}$ and 59.54611098 t.ha$^{-1}$, respectively. Similarly, the AGTB and carbon stock in Bayaldhunga CF were 110.3504368 ± 43.05 t.ha$^{-1}$ and 51.8647053 t.ha$^{-1}$, respectively. Hence, net AGTB and carbon stock in Bayaldhunga Pahapu CF were higher than in Bayaldhunga CF (Figure 4). This result might be attributed due to the presence of large-sized trees, which have larger biomass content (Joshi and Singh 2020).

## Contribution of tree species in carbon stock

In the case of the layer of the tree, *S. robusta* had the maximum carbon stock contribution to both community forests contributing 29.94301 t.ha$^{-1}$ (50.28542%) in Bayaldhunga Pahapu CF and 38.95303 t.ha$^{-1}$ (75.10508%) in Bayaldhunga CF. The *S. robusta* was followed by *Michelia champaca* L. (11.48415 t.ha$^{-1}$) and *A. nepalensis* (5.421748 t.ha$^{-1}$) in Bayaldhunga Pahapu and Bayaldhunga community forests (Table 3). The least carbon stock was calculated in *Juglans regia* L. (0.3631702784 t.ha$^{-1}$) and *Quercus lanata* Sm. (0.65669209152 t.ha$^{-1}$) of Bayaldhunga Pahapu and Bayaldhunga community forests. Some other tree species likewise represented a significantly larger percentage of carbon stock in both community forests (Table 3).

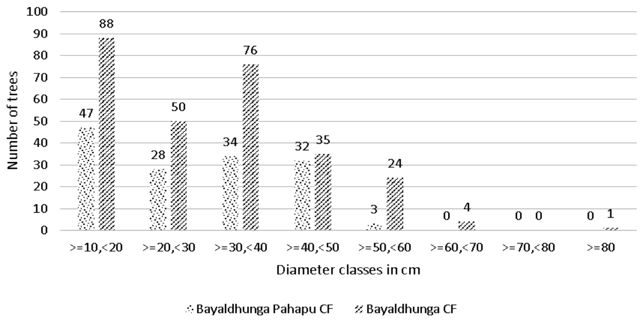


**Figure 2.** Distribution of DBH in Bayaldhunga Pahapu and Bayaldhunga CFs, Dailekh District, Nepal

**Table 1.** Overview of particular species seedlings and saplings regeneration status in Bayaldhunga Pahapu and Bayaldhunga CFs, Dailekh District, Nepal

| Species | Bayaldhunga Pahapu CF | | | | Bayaldhunga CF | | | |
|---|---|---|---|---|---|---|---|---|
| | Individuals ha^(-1) | | Proportion (%) | | Individuals ha^(-1) | | Proportion (%) | |
| | Seedlings | Saplings | Seedlings | Saplings | Seedlings | Saplings | Seedlings | Saplings |
| *Shorea robusta* | 1360 | 384 | 23.3677 | 22.42991 | 902 | 243 | 18.3969 | 17.20963 |
| *Alnus nepalensis* | 880 | 256 | 15.12027 | 14.95327 | 667 | 173 | 13.60392 | 12.25212 |
| *Persea duthiei* | 600 | 208 | 10.30928 | 12.14953 | 824 | 235 | 16.80604 | 16.64306 |
| *Michelia champaca* | 480 | 208 | 8.247423 | 12.14953 | 0 | 0 | 0 | 0 |
| *Pyrus pashia* | 640 | 144 | 10.99656 | 8.411215 | 196 | 47 | 3.997553 | 3.328612 |
| *Quercus semecarpifolia* | 520 | 160 | 8.934708 | 9.345794 | 510 | 133 | 10.40179 | 9.419263 |
| *Lyonia ovalifolia* | 520 | 160 | 8.934708 | 9.345794 | 216 | 47 | 4.405466 | 3.328612 |
| *Juglans regia* | 160 | 48 | 2.749141 | 2.803738 | 0 | 0 | 0 | 0 |
| *Daphniphyllum himalense* | 360 | 96 | 6.185567 | 5.607477 | 0 | 0 | 0 | 0 |
| *Aesculus indica* | 120 | 16 | 2.061856 | 0.934579 | 78 | 24 | 1.590863 | 1.699717 |
| *Quercus floribunda* | 200 | 32 | 3.436426 | 1.869159 | 176 | 71 | 3.589639 | 5.028329 |
| *Rhododendron arboreum* | 0 | 0 | 0 | 0 | 510 | 165 | 10.40179 | 11.68555 |
| *Brassaiopsis glomerulata* | 0 | 0 | 0 | 0 | 137 | 71 | 2.794208 | 5.028329 |
| *Persea odoratissima* | 0 | 0 | 0 | 0 | 157 | 39 | 3.202121 | 2.76204 |
| *Quercus lamellosa* | 0 | 0 | 0 | 0 | 137 | 31 | 2.794208 | 2.195467 |
| *Myrica esculenta* | 0 | 0 | 0 | 0 | 275 | 94 | 5.608811 | 6.657224 |
| *Ficus religiosa* | 0 | 0 | 0 | 0 | 118 | 39 | 2.40669 | 2.76204 |
| *Quercus lanata* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 5840 | 1712 | 100.3436 | 100 | 4903 | 1412 | 100 | 100 |

The mean carbon stock of common species in both CFs ranged from 1.38 to 34.44 $t.ha^{-1}$ (Table 4). The highest mean value was recorded in *S. robusta* (34.44 $t.ha^{-1}$), followed by *A. nepalensis* (6 $t.ha^{-1}$), *Q. semecarpifolia* (3.36 $t.ha^{-1}$), *M. esculenta* (2.915178 $t.ha^{-1}$), *Daphniphyllum himalense* (Benth.) Müll.Arg. (2.400733 $t.ha^{-1}$ ), and minimum in *Quercus floribunda* Lindl. ex A.Camus (1.38 $t.ha^{-1}$ ).

**Table 2.** Importance Value Index (IVI) of tree species

| Species name | Bayaldhunga Pahapu CF | Bayaldhunga CF |
|---|---|---|
| *Shorea robusta* | 101.05 | 94.3 |
| *Alnus nepalensis* | 62.09 | 46.91 |
| *Persea duthiei* | 18.05 | 37.35 |
| *Michelia champaca* | 21.31 | 0 |
| *Pyrus pashia* | 13.91 | 5.90 |
| *Quercus semecarpifolia* | 32.06 | 18.31 |
| *Lyonia ovalifolia* | 14.90 | 6.34 |
| *Juglans regia* | 5.59 | 0 |
| *Daphniphyllum himalense* | 11.22 | 5.08 |
| *Aesculus indica* | 1.85 | 5.38 |
| *Quercus floribunda* | 7.16 | 8.63 |
| *Rhododendron arboreum* | 0 | 23.46 |
| *Brassaiopsis glomerulata* | 0 | 6.40 |
| *Persea odoratissima* | 0 | 12.49 |
| *Quercus lamellosa* | 0 | 6.06 |
| *Myrica esculenta* | 10.74 | 15.72 |
| *Ficus religiosa* | 0 | 6.20 |
| *Quercus lanata* | 0 | 1.38 |

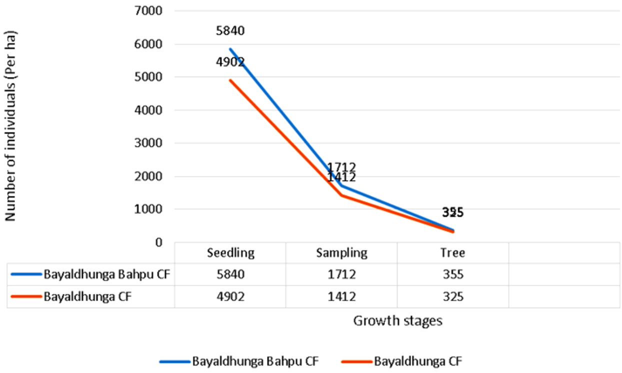


**Figure 3.** Inverse J-shaped curve indicating the immature condition of community forests

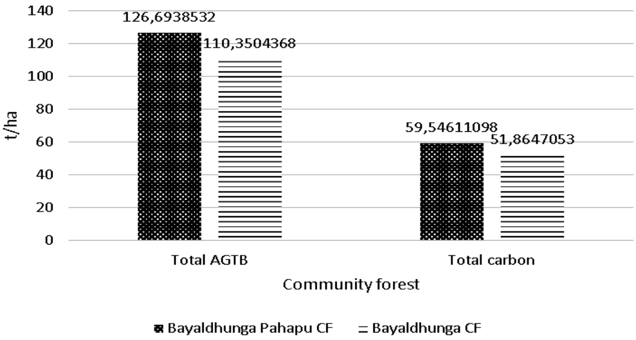


**Figure 4.** Total AGTB accumulation and carbon stock in Bayaldhunga Pahapu and Bayaldhunga CFs, Dailekh District, Nepal

**Table 3.** The percentage share of species contribution on carbon stock of Bayaldhunga Pahapu and Bayaldhunga CFs, Dailekh District, Nepal

| Bayaldhunga Pahapu CF | | | Bayaldhunga CF | | |
|---|---|---|---|---|---|
| **Species name** | **Carbon stock ta/ha** | **C (%)** | **Species name** | **Carbon stock ta/ha** | **C (%)** |
| *Shorea robusta* | 29.94301 | 49.39274 | *Shorea robusta* | 38.95303 | 65.81616 |
| *Michelia champaca* | 11.48415 | 18.94376 | *Alnus nepalensis* | 5.421748 | 9.160741 |
| *Alnus nepalensis* | 6.584624 | 10.86172 | *Persea duthiei* | 2.329855 | 3.936589 |
| *Quercus semecarpifolia* | 5.821574 | 9.603024 | *Myrica esculenta* | 2.118139 | 3.578869 |
| *Myrica esculenta* | 3.712218 | 6.123519 | *Rhododendron arboreum* | 1.968236 | 3.325588 |
| *Quercus floribunda* | 1.637367 | 2.700931 | *Persea odoratissima* | 1.882466 | 3.180669 |
| *Daphniphyllum himalense* | 0.793708 | 1.309267 | *Daphniphyllum himalense* | 1.462981 | 2.471895 |
| *Juglans regia* | 0.36317 | 0.59907 | *Quercus floribunda* | 1.131694 | 1.912143 |
| *Lyonia ovalifolia* | 0.282483 | 0.465972 | *Quercus semecarpifolia* | 0.906719 | 1.532018 |
| | | | *Aesculus indica* | 0.708447 | 1.197012 |
| | | | *Quercus lamellosa* | 0.6694 | 1.131038 |
| | | | *Quercus lanata* | 0.656692 | 1.109566 |
| | | | *Ficus religiosa* | 0.552334 | 0.93324 |
| | | | *Brassaiopsis glomerulata* | 0.422855 | 0.714468 |
| Total | 60.6223 | 100 | Total | 59.1846 | 99.99999 |

**Table 4.** Mean carbon stock by common species in Bayaldhunga Pahapu and Bayaldhunga CFs, Dailekh District, Nepal

| Common species | Bayaldhunga Pahapu CF | Bayaldhunga CF | Mean |
|---|---|---|---|
| *Shorea robusta* | 29.94301257 | 38.95303 | 34.44802 |
| *Alnus nepalensis* | 6.584623888 | 5.421748 | 6.003186 |
| *Quercus semecarpifolia* | 5.821574226 | 0.906719 | 3.364146 |
| *Myrica esculenta* | 3.71221787 | 2.118139 | 2.915178 |
| *Quercus floribunda* | 1.637366674 | 1.131694 | 1.38453 |
| *Daphniphyllum himalense* | 1.68873984 | 3.112726 | 2.400733 |
| Mean | 8.231255844 | 8.607343 | |

**Table 5.** Two-way ANOVA test between the common tree species of Bayaldhunga Pahapu and Bayaldhunga CFs, Dailekh District, Nepal

| Source of variation | SS | Df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Species | 1683.11597 | 5 | 336.62319 | 30.725751 | 0.00092607 | 5.05032906 |
| CF | 0.18795277 | 1 | 0.1879528 | 0.0171557 | 0.90089835 | 6.60789097 |
| Error | 54.7786773 | 5 | 10.955735 | | | |
| Total | 1738.0826 | 11 | | | | |

Note: Where,* $p< 0.05$ is considered statistically significant. Total species-wise carbon stock in both Bayaldhunga Pahapu CF and Bayaldhunga CF statistically showed a significant difference in the total quantity of carbon storage in both community forests (p 0.05)

## Discussion

*Regeneration and other attributes*

Compared to Bayaldhunga CF, the number of total seedlings, saplings, and tree density was greater in Bayaldhunga Pahapu CF. That is because the canopy cover and ground vegetation cover of Bayaldhunga Pahapu CF were greater than Bayaldhunga CF. Sal (*S. robusta*) has dominated both community forests' seedling and sapling layers. The higher density of Sal species (seedlings and saplings) may be attributed to the impact of low canopy cover in community forests, which enabled ample sunlight to reach the understory and generated an environment suitable for the plentiful establishment of Sal species seedlings and saplings (Joshi and Singh 2020). The regeneration capacity of light-demanding species like Sal is assisted by a large canopy gap proportion (low canopy cover) (Sapkota et al. 2009). Therefore, the number and density of seedlings and saplings reflect a CF's regenerating ability (Pallardy 2010). In both community forests, the total number of individuals declined from the early regeneration period to the later development phases.

The current study on forest regeneration conditions indicates a trend comparable to that of Kandel (2007). The entire chart was inverse J-shaped, indicating the community forests' juvenile condition (Chauhan et al. 2008) and also indicative of sustainable regeneration (Acharya et al. 2015) (See Figure 3).

*Community attributes*

The *S. robusta* has the highest Importance Value Index (IVI) in both Bayeldhunga Pahapu and Bayeldhunga CFs, with values of 101.30, and 90.34, respectively. A species' high IVI value indicated dominance, ecological success, good regeneration power, and higher ecological intensity (Shameem and Kangroo 2011), implying that S. robusta was the most significant and dominating tree species across both communities' forests. As a result of significant forest deterioration or disturbance activities, historically dominating species like *S. robusta* with the other companion species as a dominant characters during their recruitment stage have vanished (Onaindia et al. 2004).

*Sal forest and carbon stock*

The carbon sequestration of trees fluctuates with the forest's successional stage, and its capacity is determined by the forest type, age, tree size, density, and stand quality (Joshi and Singh 2020). The carbon absorbed by plants is deposited as biomass as the age of the forest increases.

Many trees surveyed in community forests had a DBH of less than 20 cm. Thus, if forests are well-stocked, trees store carbon at a significant rate between of ages of 10, 20, and 30, according to Johnson and Coburn (2010). For example, at the age of 30 years, forests with productivity ranging from extremely low to high typically store 200-520 tons of carbon dioxide ($CO_2$). So, the community forests analyzed may have the ability to sequester more carbon. Carbon sequestration is influenced by the yearly growth rate of forests, which is positively related to age. Because mature trees grow slower than new trees, aged forests with more than mature stands have a large carbon store but a poor carbon sequestration rate. Among the community forests investigated, Bayaldhunga Pahapu CF had a greater tree biomass stock than Bayaldhunga CF. The aboveground tree biomass and carbon stock in Bayaldhunga Pahapu CF were 126.69 $t.ha^{-1}$ and 59.546 $t.ha^{-1}$, respectively, which was higher than in Bayaldhunga CF (biomass 119.34 $t.ha^{-1}$, and carbon 51.86 $t.ha^{-1}$, respectively). The FRA report 2014 indicates that the sum of carbon stock from the forest of the Terai region is 89.18 $t.ha^{-1}$; Sal was the biggest provider of carbon stock in the tree layer with 49.392% (29.943 $t.ha^{-1}$), and 65.816% (38.953 $t.ha^{-1}$) in both Bayaldhunga Pahapu and Bayaldhunga CFs, respectively, according to our study. Sal species contributed 95% and 86% of carbon stock in both study areas, respectively, following the trends seen in Gorkha's Sal-dominated two CFs, where Sal contributed 95% and 86% of C-stock (Neupane and Sharma 2014).

In conclusion, the carbon storage of forests increased as the tenure of sustainable forest management increased. In contrast, the density of seedlings, saplings, as well as trees in the analyzed CFs was in the sequence seedlings > saplings > trees. As a result, the concept that community-managed forest biomass C-stock grows with management tenure and community-managed forests exhibit strong regeneration status has been accepted. Bayaldhunga Pahapu CF had more seedlings, saplings, and trees than Bayaldhunga community forests. Sal seedlings and saplings had a higher total number (density) than other related species in both Community Forests. The *S. robusta* was the most common species, contributing significantly to both community forests' carbon stocks (49.392% in Bayaldhunga Pahapu CF and 65.816% in Bayaldhunga CF). Other species, such as *M. champaca, A. nepalensis, Q. semecarpifolia*, and *M. esculenta*, made substantial contributions. Community forest management had a beneficial impact on forest regeneration and carbon stock, indicating that carbon capture and storage have a favorable effect on biodiversity, which leads to increased forest productivity. Both community forests, however, require extra steps to increase tree richness. Thus, this study strongly promotes implementing sustainable management approaches, such as those employed in management and conservation. These community-managed forests should also be evaluated for participation in the REDD+ system to benefit from carbon credits, which will help to improve forest conditions and local livelihoods.

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