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Community Structure, Regeneration Status and Tree Biomass of *Shorea robusta* Gaertn. in Charpala Community Forest, Rupandehi District, Central Nepal

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Abstract

Sal is a multipurpose tropical tree that grows as the dominant plant species in Nepal's lowlands. A comparative study of the Sal population structure was carried out in two blocks of Charpala Community Forest, Rupandehi. A total of 161 species of vascular plants, belonging to 135 genera and 69 families, were recorded, where Fabaceae (26 species) was the dominant family. Densities of Sal trees, saplings, and seedlings per hectare were 4000, 1945, and 742 respectively. A reverse J-shaped curve in the population structure of Block 1 indicated active natural regeneration. However, in Block 2, the lower densities of seedlings and saplings, and the higher densities of intermediate diameter classes indicated insufficient spontaneous regeneration. Average tree biomass and carbon stocks were 522.49 Mg/ha^{-1} and 245.57 Mg/ha$^{-1,}$ respectively. While Block 2 outperformed Block 1 in terms of tree density, carbon stock, and biomass, Block 1 had the higher density of seedlings and saplings, which improved the regeneration status of that site. Increased demand for lumber for construction has put existing Sal strands in Nepal under pressure. Therefore, a detailed study of its population makeup and natural renewal is crucial.

Keywords: Biomass, Carbon stock, Population structure, Regeneration, Sal

Introduction

Shorea robusta Gaertn., Sal, is a gregarious, big and light-demanding species (Pearson & Brown, 1932; Troup, 1986) belonging to the family Dipterocarpaceae. It is the most important tree species in Nepal's tropical and subtropical broadleaved forests and dominates the tarai and siwalik forest types (Chaudhary, 1998; Jackson, 1994). It can be found up to 1500 meters above sea level but is uncommon above 1,000 meters (Jackson, 1994). It thrives in both hilly and flat locations, but prefers the lower slopes and valleys where the soil is deep, moist and nourishing (Troup, 1986). Stainton (1972) divided Nepal's Sal forests into two types: Tarai and Hill sal forests. Sal can reach a height of up to 50 meters on fertile soil but it is more often seen around 20 to 25 meters in poorer soils (Fern, 2014).

It is a versatile timber tree with good socioeconomic value, used mostly for lumber, medicine, fodder, fuel wood, dry leaf for cooking and heating, fresh leaves for producing plates, edible seeds and religious uses, although it is classified as a Least Concern species on the IUCN red list (Kumar & Saikia, 2020). Because Sal is such an important aspect of forest ecosystems, it is important to understand how it regenerates naturally. Despite this, studies on Sal Forest management in Nepal are still relatively new, and the growth and yield of this species are still understudied (Paudyal, 2013).

Sal is currently endangered by sal borer assault, sal mortality, low capacity for regeneration, edapho-climatic shifts, and a number of biotic interferences (Chaubey & Sharma, 2013; Oli & Subedi 2015; Raj, 2018). In Sal, hollowness is a frequent issue that causes a sizable amount of timber to be lost each year (Tripathi & Adhikari, 2021). Wind, heat, lightening, rain, bacterial and fungal infestation and occasionally self-pruning (dropping of lower branches) all stress plants physiologically, exposing and excavating the heartwood, causing hollowness in trees (Goldingay, 2009).

Natural regeneration is an important part of tropical forest dynamics that helps to sustain and maintain biodiversity (Getachew et al., 2010; Rahman et al., 2011), as evidenced by population structure (Tiwari et al., 2018). The natural regeneration process in forests is governed by various factors including seed yield, dormancy, viability and distribution of seeds, seedling recruitment, and intra- and inter-specific competition among seedlings (Basyal et al., 2011; Napit, 2015). The degree to which a forest is regenerating reveals its vitality and health and a healthy forest guarantees successful regrowth in the future. Existence of various age groups of seedling, sapling and tree species determines the forest's capacity for regeneration and productivity (Chauhan et al., 2008). In addition, Sal regeneration is a difficult issue that has no clear solution (Bisht, 1989).

The present populations of Sal are facing major risks as a result of rising demand for and exploitation of its timber. Hence, it is essential to comprehend Sal's population structure and dynamics in their native environments. Therefore, this study was carried out to document the natural regeneration of Sal in Charpala Community Forest, Rupandehi district, as well as its biomass, carbon stock, community makeup and population structure.

Materials and Methods

Study area

The current research was conducted at Charpala Community Forest (CF), Butwal-12, Tamnagar, Rupandehi district, Nepal. The CF is located between 83° 22' 58" and 83° 27' 02" N latitude and 27° 41' 7" and 27° 44' 45" E longitude (Figure 1). The forest covers a total area of 2010.4 ha., with a total of 13,960 households using it. It is the country's largest community forest in terms of both area and number of user households. For effective management, sustainable utilization of forest and forest resources, control and prevention of forest fires, plant regeneration, and biodiversity protection, the forest is divided into five blocks. Blocks 1, 2, and 3 are located in the lowland tarai, whereas Blocks 4 and 5 are located in the Churia hills. Block 1 (Birghat Khanda) and Block 2 (Charpala Khanda) both dominated by Sal (*Shorea robusta*) were sampled for vegetation study.

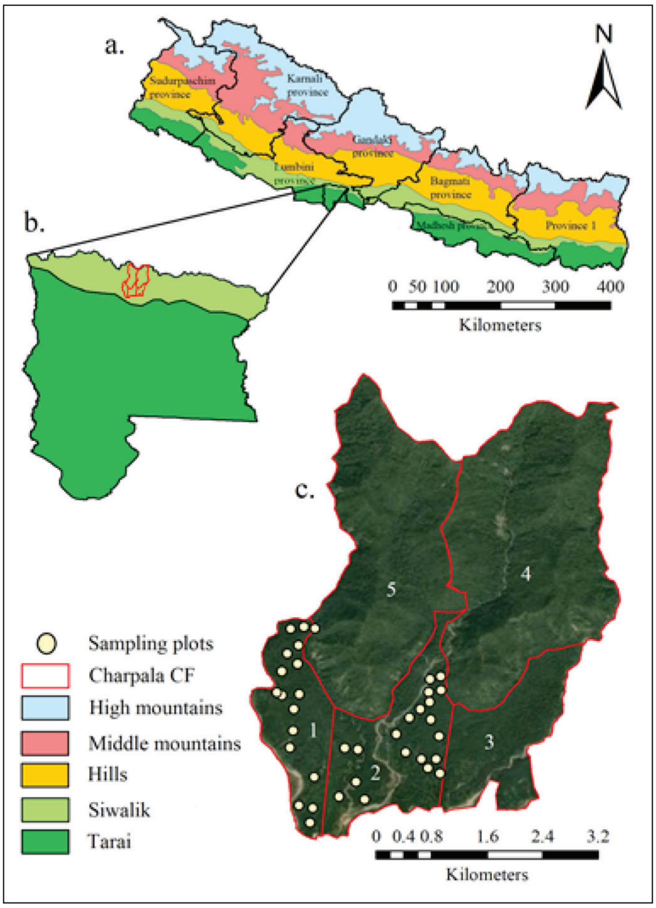

Figure 1: Map of study area showing, **a.** Rupandehi district in Lumbini province of Nepal, **b.** Charpala CF in Rupandehi district, **c.** five blocks of Charpala CF

Block 1 (Birghat khanda) comprises of Sal (*Shorea robusta*), Asna (*Terminalia elliptica* Willd.), Bhalayo (*Semecarpus anacardium* L. fil.), Barr (*Ficus benghalensis* L.), Banjhi (*Terminalia anogeissiana* Gere & Boatwr.), Kusum (*Schleichera oleosa* (Lour.) Oken). Similarly, Block 2 (Charpala khanda) is dominated by Sal Mixed Forest. The dominant plant species comprise Sal (*Shorea robusta*), Banjhi (*T. anogeissiana*), Asna (*T. elliptica*), Sisau (*Dalbergia sissoo* Roxb. ex DC.), Simal (*Bombax ceiba* L.), Jhingad (*Lannea coromandelica* (Houtt.) Merr.), Kusum (*Schleichera oleosa*), Kadam (*Neolamarckia cadamba* (Roxb.) Bosser), Kyamuna (*Syzygium nervosum* DC.).

Sampling

Quadrats in each block were randomly selected and explored at intervals of 50 m. The tree density of *Shorea robusta* was studied using 10 m × 10 m quadrats. All the plants found in 10 m × 10 m quadrats were recorded as well. Each quadrat was divided into four quarters of 5 m × 5 m each, two of which were chosen diagonally for sapling and seedling sampling.

A total of 40 plots for trees and 80 plots for saplings and seedlings were studied. In each plot, number and size of individuals of *S. robusta* were recorded. Circumference at breast height (CBH) of each tree of *S. robusta* was measured at 1.37 m above the ground level using measuring tape which was later on converted into diameter at breast height (DBH). The height of trees was measured using Apresys Rangefinder. Individuals were grouped into different life stages: tree ($DBH > 10$ cm), sapling ($DBH < 10$ cm, height > 30 cm) and seedling (height < 30 cm) (Sundriyal & Sharma, 1996). The density diameter curve was determined by dividing trees into different size classes based on DBH of 5 cm intervals (Zobel et al., 1987).

Estimation of biomass and carbon stock

The allometric equation developed by Chave et al. (2005) for the tropical forest was used to estimate the aboveground biomass of the trees. According to this model, the above-ground biomass (AGB) of a tree (kg) = $0.0509 \times \rho D^2 H$, where ρ = wood density ($g.cm^{-3}$), D = diameter at breast height (cm), and H = tree height (m). The global database was used for the dry wood density (Zanne et al., 2009). Destructive sampling is the most accurate way to estimate biomass, but it is rarely employed since it is expensive, labor intensive and time consuming. As a result, below-ground biomass (BGB) estimates are frequently provided as a percentage of the AGB (Mokany et al., 2006). The BGB was estimated by assuming that it constitutes 26% of the AGB (Eggleston et al., 2006). The total biomass (only living) is the sum of the AGB and BGB of the trees. The living C-stock was calculated by multiplying the sum of the dry living biomass by 0.47 (Eggleston et al., 2006).

Plant identification and data analysis

The plant specimens were identified with the help of standard taxonomic literatures (Fraser-Jenkins et al., 2015; Grierson & Long, 1983-2001; Press et al., 2000; Siwakoti & Varma, 1999; Zheng-Yi & Raven, 1996-2003; Plants of the World Online:https://powo.science.kew.org/) and by tallying with the specimens housed at National Herbarium and Plant Laboratories (KATH). Nomenclature follows the Catalogue of Life (Bánki et. al., 2022).

Descriptive statistics were applied to generate means for the comparison study. Data were tested for normality (Shapiro–Wilk test, $p > 0.05$). The mean values were compared between two sites (Blocks 1 and 2) using ANOVA for normal data. Non-normal data were compared by Mann-Whitney U test. All the analyses were done using Microsoft Excel 2007 and IBM SPSS (Version 25).

Results and Discussion

Community structure

A total of 161 species of vascular plants belonging to 135 genera of 69 families were recorded (Appendix). The dominant families were Fabaceae (26 spp.), followed by Asteraceae (11 spp.), Lamiaceae and Poaceae (10 spp. each) (Figure 2). Block 1 comprised of 106 species of vascular plants, belonging to 86 genera and 43 families, while Block 2 comprised 129 species belonging to 104 genera and 45 families. The higher species richness in Block 2 than in Block 1 might be due to mild disturbance like grazing, which help in seed dispersal (Bhatta & Devkota, 2020).

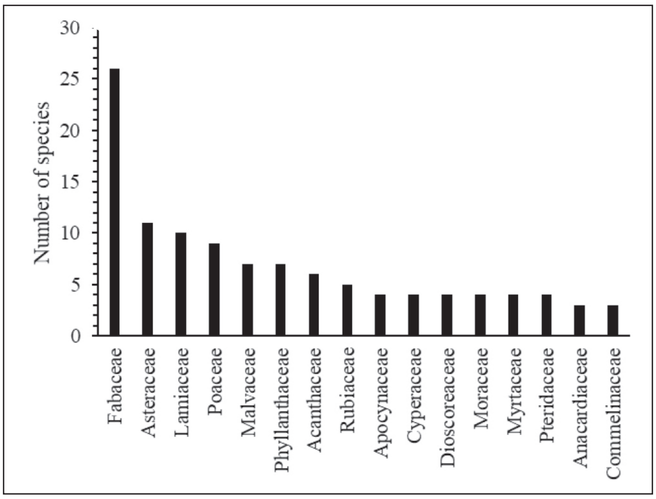

Figure 2: Number of species among the families

Population structure and regeneration

The regeneration potential of a forest species is characterized by a sufficient number of seedlings and saplings (Pallardy, 2010). Study area showed good regeneration, as the density of seedlings and saplings was higher compared to trees (Figure 3). The density of seedlings, saplings and trees of *S. robusta* in the study area were 4000, 1945 and 742 individuals ha^{-1} respectively. The density of seedlings and saplings was higher in Block 1 than in Block 2. Similarly, tree density was found higher in Block 2 compared to that in Block 1 (Table 1).

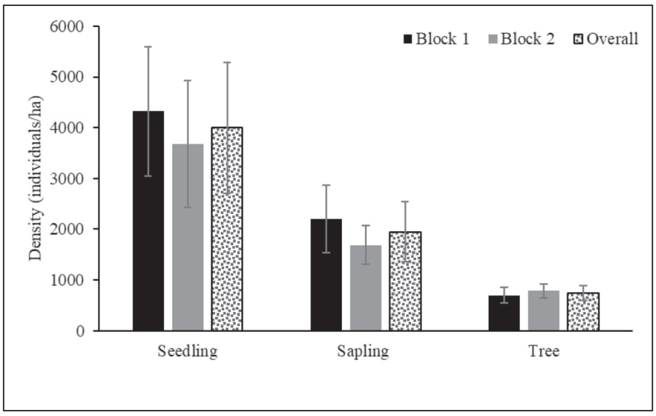

Figure 3: Density of seedlings, saplings and trees of Sal in Blocks 1 and 2 of Charpala CF

The higher density of seedlings and saplings in Block 1 might be due to the open canopy compared to Block 2, as the development of seedling and sapling are favored by open space rather than under shade (Troup, 1986). Canopy coverage is one of the best criteria for judging the status of forest regeneration, as it determines the amount of light reaching forest floor. Solar radiation plays a vital role in the germination and establishment of seedlings (Champion & Seth, 1968). It has also been reported that mild disturbance seems to favor seedling survival (Sapkota et al., 2009). Although the forest had high regeneration potential, all established seedlings did not get the chance to develop into the sapling stage which may be due to human interference like grazing, trampling, forest fire, lopping and unsustainable harvesting of forest resources. Similar findings have been made by Napit (2015).

Table 1: Mean values of the density, diameter at breast height (DBH), height and carbon stock in Block 1 and Block 2 of Charpala CF

	Block 1	Block 2	F	p-value
Seedling density	4320.00	3680.00	2.571	0.117
Sapling density	2200.00	1690.00	8.858	0.005
Tree density	700.00	785.00	3.495	0.069
DBH (cm)	21.43	25.68	9.740	0.003
Height of trees (m)	12.86	16.51	27.282	<0.0001
Biomass (Mg ha^{-1})	481.19	564.88	-	0.221
Carbon stock (Mg ha^{-1})	226.16	265.49	-	0.221

The diameter distribution of the *S. robusta* trees showed a reverse J-shaped curve in Block 1, which indicates the immature condition and hence, a sustainable and good regeneration state of the forest (Awasthi et al., 2015; Basyal et al., 2011; Chauhan et al., 2008) (Figure 4). A similar reverse J-shaped curve was also obtained in many previous studies (Acharya & Shrestha, 2011; Oli & Subedi, 2015). However, in Block 2, higher tree densities in intermediate diameter classes were seen which cannot be considered as a sustainable and viable type of forest. It may be due to human disturbances like selective felling of lower girth class individuals for regular thinning. A similar result was obtained in various other studies (Das et al., 2017; Sharma et al., 2020).

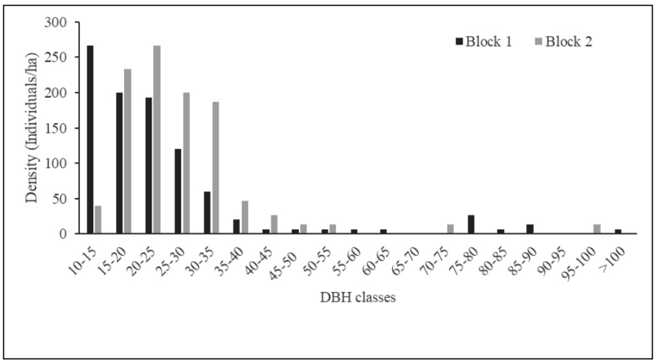

Figure 4: Density of sal in different size classes in Block 1 and Block 2 of Charpala CF

Biomass and carbon stock

The mean tree biomass and carbon stock of *Shorea robusta* in the study area were 522.49 Mg ha^{-1} and 245.57 Mg ha^{-1} respectively. The estimated biomass and carbon stock for *S. robusta* in the present study were found lower compared to that reported by Joshi et al. (2021) in the subtropical forest of India, whereas it is higher than the carbon stock estimated in various other studies such as Chand et al. (2018), Shahid & Joshi (2018), Joshi et al. (2021). According to Johnson and Coburn (2010), forest trees usually sequestrate maximum carbon between the ages of 10 to 30 years. For instance, at the age of 30 years, forests sequestrate about 200-520 tons of carbon dioxide (CO_2) per hectare.

Biomass and carbon stock were higher in Block 2 (564.88 Mg ha^{-1} and 265.49 Mg ha^{-1}) compared to that of Block 1 (481.19 Mg ha^{-1} and 226.16 Mg ha^{-1}) (Figure 5, Table 1). This might be due to higher tree density in Block 2 compared to Block 1. Further, heights of trees as well as DBH were also higher in Block 2 which also resulted in higher biomass values. These findings are concurrent with those of Joshi et al. (2020).

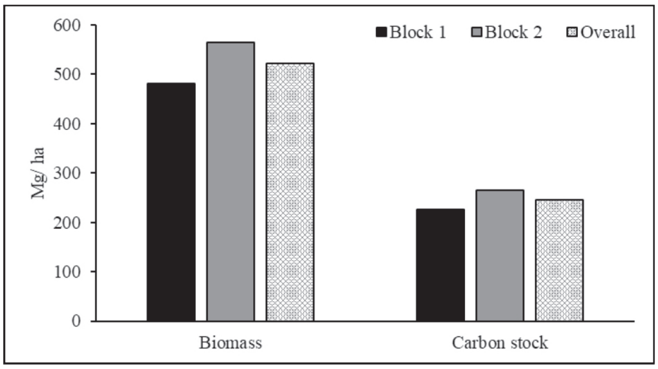

Figure 5: Total biomass and carbon stock of sal trees in Block 1 and Block 2 of Charpala CF

Conclusion

Sal was the dominant vegetation type with a good density of seedlings, saplings and trees in the study area. The higher density of seedlings and saplings in Block 1 with a reverse J-shaped curve denotes good regeneration. However, the higher density of intermediate diameter classes and the lower density of seedlings and saplings in Block 2 indicates comparatively poor natural regeneration in that block. Since both tree density and trees with larger diameter class were higher in Block 2, mean tree biomass and carbon stocks were higher in Block 2 compared to Block 1. This study can provide basic understanding of the status of Sal Forest in the lowlands of Nepal.

Author Contributions

Both the authors have contributed equally to bring the manuscript in this form.

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References

Acharya, R., & Shrestha, B. B. (2011). Vegetation structure, natural regeneration, and management of Parroha community forest in Rupandehi district. *Nepal. Scientific World*, 9, 70-81.

Awasthi, A., Bhandari, S. K., & Khanal, Y. (2015). Does scientific forest management promote plant species diversity and regeneration in sal (*Shorea robusta*) forest? A case study from Lumbini collaborative forest, Rupandehi, Nepal. *Banko Janakari*, *25*, 20-29.

Bánki, O., Roskov, Y., Döring, M., Ower, G., Vandepitte, L., Hobern, D., Remsen, D., Schalk, P., DeWalt, R. E., Keping, M., Miller, J., Orrell, T., Aalbu, R., Adlard, R., Adriaenssens, E., Aedo, C., Aescht, E., Akkari, N., Alonso-Zarazaga, M. A., et al. (2022). Catalogue of Life Checklist (Version 2022-01-14). Catalogue of Life. https://doi.org/10.48580/d4tp.

Basyal, S., Lekhak, H. D., & Devkota, A. (2011). Regeneration of *Shorea robusta* Gaertn. in tropical forest of Palpa district, Central Nepal. *Scientific World*, *9*, 53-56.

Bhatta, S. P., & Devkota A. (2020). Community structure and regeneration status of Sal (*Shorea robusta* Gaertn.) forests of Dadeldhura district, Western Nepal. *Community Ecology*, *21*, 191-201.

Bisht, A. P. S. (1989). *Microsite mosaic and under canopy vegetation dynamics of Sal communities* *in East and West Dehradun Forest Division*. (Unpublished Doctoral dissertation), Garhwal University, India.

Champion, H. G., & Seth, S. K. (1968). *A revised survey of forests types of India*. Government of India.

Chand, H. B., Singh, H., & Chhetri, R. (2018). Carbon sequestration potential in Sahid Smriti community forest: A case study of Terai region of Nepal. In S. K. Acharya, D. Basu, & M. M. Adhikary (Eds.), *International Conference on Agriculture and Allied Sciences: The Productivity, Food Security and Ecology* (pp. 108-113). Krishi Sanskriti.

Chaubey, O. P., & Sharma, A. (2013). Population structure and regeneration potential of Sal (*Shorea robusta* Gaertn. f.) and its associates in Sal bearing forests of Satpura Tiger Reserve. *International Journal of Bio-Science and Bio-Technology*, *5*(6), 63-70.

Chaudhary, R.P. (1998). *Biodiversity in Nepal: Status and conservation*. Craftsman Press.

Chauhan, P. S., Negi, J. D. S., Singh, L., & Manhas, R. K. (2008). Regeneration status of Sal forests of Doon Valley. *Annals of Forestry*, *16*(2), 178-182.

Chave, J., Andalo, C., Brown, S., Cairns, M. A., Chambers, J. Q., Eamus, D., Fölster, H., Fromard, F., Higuchi, N., Kira, T., Lescure, J. P., Nelson, B. W., Ogawa, H., Puig, H., Rie´ra, B., & Yamakura, T. (2005). Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia*, *145*(1), 87-99.

Das, S. C., Alam, M. S., & Hossain, M. A. (2017). Diversity and structural composition of species in dipterocarp forests. A study from Fasiakhali Wildlife Sanctuary, Bangladesh. *Journal for Forestry Research*, *29*(5), 1241-1245. https://doi.org/10.1007/s11676-017-0548-7.

Eggleston, H. S., Buendia, L., Miwa, K., Ngara, T., & Tanabe, K. (2006). *Guidelines for National Greenhouse Gas Inventories*. IPCC National Greenhouse Gas Inventories Programme.

Fern, K. (2014). *Shorea robusta*. Useful Tropical Plants. https://tropical.theferns.info/viewtropical.php?id=Shorea+robusta.

Fraser-Jenkins, C. R., Kandel, D. R., & Pariyar, S. (2015). *Ferns and Fern-allies of Nepal* (Vol. 1). Department of Plant Resources.

Getachew, T., Demel, T., Masresha, F., & Erwin, B. (2010). Regeneration of seven indigenous tree species in a dry Afromontane Forest, Southern Ethiopia. *Flora*, *205*, 135-143.

Goldingey, R. L. (2009). Characteristics of tree hollows used by Australian birds and bats. *Wildlife Research*, *36*, 394.

Grierson, A. J. C., & Long, D. G. (1983-2001). *Flora of Bhutan* (Vols. 1-2). Royal Botanic Garden Edinburgh; Royal Government of Bhutan.

Jackson, J. K., (1994). *Manual of afforestation in Nepal* (2nd ed.). Forest Research and Survey Center.

Johnson, I., & Coburn, R. (2010). *Trees for carbon sequestration. Prime Facts 981.* NSW Government.

Joshi, R., Pangeni, M., Neupane, S. S., & Yadav, N. P. (2021). Regeneration status and carbon accumulation potential in community managed Sal (*Shorea robusta*) forests of far-western Tarai Region, Nepal. *European Journal of Ecology*, *7.1*, 26-39.

Joshi, R., Singh, H., Chhetri, R., & Yadav, R. (2020) Assessment of carbon sequestration potential in degraded and non-degraded community forests in Tarai region of Nepal. *Journal of Forest and Environmental Science*, *36*(2), 113-121.

Joshi, V. C., Negi, V. S., Bisht, D., Sundriyal, R. C., & Arya, D. (2021). Tree biomass and carbon stock assessment of subtropical and temperate forests in the Central Himalaya, India. *Trees, Forests and Peopl*e, *6*. https://doi.org/10.1016/j.tfp.2021.100147.

Kumar R., & Saikia, P. (2020). Forest Resources of Jharkhand, Eastern India: Socio-economic and Bio-ecological Perspectives. In N. Roy, S. Roychoudhury, S. Nautiyal, S. Agarwal, & S. Baksi (Eds), *Socio-economic and eco-biological dimensions in resource use and conservation* (pp. 51-102). Springer. https://doi.org/10.1007/978-3-030-32463-6_4.

Mokany, K., Raison, J. R., & Prokushkin, A. (2006). Critical analysis of root: shoot ratios in terrestrial biomes. *Glob. Change Biol.*, *12*, 84-96.

Napit, R. (2015). Species diversity, forest community structure and regeneration in Banke National Park. *Nepal Journal of Science and Technology*, *16*(1), 17-30.

Oli, B. N., & Subedi, M. R. (2015). Effects of management activities on vegetation diversity, dispersion pattern and stand structure of community-managed forest (*Shorea robusta*) in Nepal. *International Journal of Biodiversity Science, Ecosystem Services and Management*, *11*, 96-105.

Pallardy, S. G. (2010). *Physiology of woody plants*. Academic Press.

Paudyal, B. K. (2013). Regeneration, growth of hill sal and plant diversity in community forest: A case study from Pragatisil community forest in Kaski district, Western Nepal. *Banko Janakari, 23*(2), 37-43.

Pearson, R. S., & Brown, H. P. (1932). *Commercial timbers of India: their distribution, supplies, anatomical structure, physical and mechanical properties and uses* (Vol. 1). Central Publication Branch, Government of India.

Press, J. R., Shrestha, K. K., & Sutton, D. A. (2000). *Annotated checklist of the flowering plants of Nepal*. The Natural History Museum.

Rahman, M. D., Khan, M. A. S. A., Roy, B., & Fardusi, J. (2011). Assessment of natural regeneration status and diversity of tree species in the biodiversity conservation areas of Northeastern Bangladesh. *Journal of Forestry Research*, *22*, 551-559.

Raj, A. (2018). Population structure and regeneration potential of Sal dominated tropical dry deciduous forest in Chhattisgarh, India. *Tropical Plant Research*, *5*(3), 267-274.

Sapkota, I. P., Tigabu, M., & Odén, P. C. (2009). Spatial distribution, advanced regeneration and stand structure of Nepalese Sal (*Shorea robusta*) forests subject to disturbances of different intensities. *Forest Ecology and Management*. *257*, 1966-1975.

Shahid, M., & Joshi, S. P. (2018). Carbon stock variation in different forest types of Western Himalaya, Uttarakhand. *Journal of Forest and Environmental Science*, *34*(2), 145-152.

Sharma, K. P., Bhatta, S. P., & Lamsal, S. K. (2020). Species diversity and regeneration status of community-managed hill sal (*Shorea robusta*) forest in Central Nepal. *Current Science*, *119*(1), 83-92.

Siwakoti, M., & Varma, S. K. (1999). *Plant diversity of Eastern Nepal: Flora of plains of Eastern Nepal*. Bishen Singh Mahendra Pal Singh.

Stainton, J. D. A. (1972). *Forests of Nepal*. John Murray.

Sundriyal, R. C., & Sharma, E. (1996). Anthropogenic pressure on tree structure and biomass in the temperate forest of Mamlay watershed in Sikkim. *Forest Ecology and Management*, *81*, 113-134.

Tiwari, O. P., Rana, Y. S., Krishan, R., Sharma, C. M., & Bhandari, B. S. (2018). Regeneration dynamics, population structure, and forest composition in some ridge forests of the Western Himalaya, India. *Forest Science and Technology*, *14*(2), 66-75. https://doi.org/10.1080/21580103.2018.1447517.

Tripathi, S., & Adhikari, Y. (2021). Wood loss assessment in forest of Sal (*Shorea robusta*) by heart rot of central Tarai of Nepal. *International Journal of Forestry Research*, *2021*, Article 6673832. https://doi.org/10.1155/2021/6673832.

Troup, R. S. (1986). *The silviculture of Indian trees*. International Book Distributors.

Zanne, A. E., Lopez-Gonzalez, G., Coomes, D. A., Ilic, J., Jansen, S., Lewis, S. L., Miller, R. B., Swenson, N. G., Wiemann, M. C., & Chave, J. (2009). Data from: Towards a worldwide wood economics spectrum. Dryad Digital Repository. https://doi.org/10.5061/dryad.234.

Zheng-Yi, W., & Raven, P. H. (1996-2003). *Flora of China* (Vols. 1-25). Science Press; Missouri Botanical Garden Press.

Zobel, D. B., Jha, P. K., Behan, M. J., & Yadav, U. K. R. (1987). *A practical manual for ecology*. Ratna Book Distributors.

Appendix : List of plant species in the study plots

Scientific Name	Family
Achyranthes aspera L.	Amaranthaceae
Acmella paniculata (Wall. ex DC.) R.K.Jansen	Asteraceae
Adenostemma lavenia (L.) Kuntze	Asteraceae
Adiantum sp.	Pteridaceae
Adina cordifolia (Roxb.) Brandis	Rubiaceae
Aegle marmelos (L.) Corrêa	Rutaceae
Ageratina adenophora (Spreng.) R.M.King & H.Rob.	Asteraceae
Ageratum conyzoides L.	Asteraceae
Ageratum houstonianum Mill.	Asteraceae
Albizia julibrissin Durazz.	Fabaceae
Alternanthera philoxeroides (Mart.) Griseb.	Amaranthaceae
Anisomeles indica (L.) Kuntze	Lamiaceae
Asparagus racemosus Willd.	Asparagaceae
Azanza lampas (Cav.) Alef.	Malvaceae
Barleria cristata L.	Acanthaceae
Biancaea decapetala (Roth) O.Deg.	Fabaceae
Bombax ceiba L.	Malvaceae
Bonnaya ciliata (Colsm.) Spreng.	Linderniaceae
Bridelia retusa (L.) A.Juss.	Phyllanthaceae
Buchanania cochinchinensis (Lour.) Almeid	Anacardiaceae
Caesulia axillaris Roxb.	Asteraceae
Callicarpa vestita Wall. ex C.B.Clarke	Lamiaceae
Canscora alata (Roth) Wall.	Gentianaceae
Canscora sp.	Gentianaceae
Carex cruciata Wahlenb.	Cyperaceae
Carex sp.	Cyperaceae
Casearia graveolens Dalzell	Salicaceae
Cassia fistula L.	Fabaceae
Catunaregam spinosa (Thunb.) Tirveng.	Rubiaceae
Chlorophytum arundinaceum Baker	Asparagaceae
Chromolaena odorata (L.) R.M.King & H.Rob.	Asteraceae
Chrysopogon aciculatus (Retz.) Trin.	Poaceae
Chrysopogon zizanioides (L.) Roberty	Poaceae
Cissampelos pareira L.	Menispermaceae
Cissus discolor Blume	Vitaceae
Clematis acuminata DC.	Ranunculaceae
Clerodendrum indicum (L.) Kuntze	Lamiaceae
Clerodendrum infortunatum L.	Lamiaceae
Colebrookea oppositifolia Sm.	Lamiaceae
Commelina benghalensis L.	Commelinaceae
Coniogramme affinis Hieron.	Pteridaceae
Crotalaria alata Buch.-Ham. ex D.Don	Fabaceae
Crotalaria albida B.Heyne ex Roth	Fabaceae
Crotalaria sessiliflora L.	Fabaceae
Curculigo orchioides Gaertn.	Hypoxidaceae
Curcuma aromatica Salisb.	Zingiberaceae
Cyanotis cristata (L.) D.Don	Commelinaceae
Cyanthillium cinereum (L.) H.Rob.	Asteraceae
Cymbopogon citratus (DC.) Stapf	Poaceae
Cynodon dactylon (L.) Pers.	Poaceae
Cyperus brevifolius (Rottb.) Hassk.	Cyperaceae
Cyperus sp.	Cyperaceae
Dalbergia latifolia Roxb.	Fabaceae
Dalbergia pinnata (Lour.) Prain	Fabaceae
Dalbergia sissoo Roxb. ex DC.	Fabaceae

Scientific Name	Family
Dillenia indica L.	Dilleniaceae
Dioscorea alata L.	Dioscoreaceae
Dioscorea belophylla (Prain) Voigt ex Haines	Dioscoreaceae
Dioscorea bulbifera L.	Dioscoreaceae
Dioscorea prazeri Prain & Burkill	Dioscoreaceae
Diospyros sp.	Ebenaceae
Eclipta prostrata (L.) L.	Asteraceae
Elephantopus scaber L.	Asteraceae
Eranthemum purpurascens Wight ex Nees	Acanthaceae
Eriocaulon nepalense var. *luzulifolium* (Mart.) Praj. & J.Parn.	Eriocaulaceae
Eriocaulon nepalense var. *nepalense*	Eriocaulaceae
Evolvulus nummularius (L.) L.	Convolvulaceae
Ficus auriculata Lour.	Moraceae
Ficus elmeri Merr.	Moraceae
Ficus hispida L.f	Moraceae
Ficus racemosa L.	Moraceae
Flemingia chappar Buch.-Ham. ex Benth.	Fabaceae
Flemingia macrophylla (Willd.) Kuntze ex Merr.	Fabaceae
Flemingia strobilifera (L.) W.T.Aiton	Fabaceae
Garuga pinnata Roxb.	Burseraceae
Grewia optiva J.R.Drumm. ex Burret	Malvaceae
Grona heterocarpos (L.) H.Ohashi & K.Ohashi	Fabaceae
Grona triflora (L.) H.Ohashi & K.Ohashi	Fabaceae
Hellenia speciosa (J.Koenig) S.R.Dutta	Costaceae
Hemionitis sp.	Pteridaceae
Ichnocarpus frutescens (L.) W.T.Aiton	Apocynaceae
Imperata cylindrica (L.) P.Beauv.	Poaceae
Indigofera heterantha Wall. ex Brandis	Fabaceae
Indigofera trifoliata L.	Fabaceae
Ipomoea purpurea (L.) Roth	Convolvulaceae
Justicia simplex D.Don	Acanthaceae
Lagerstroemia parviflora Roxb.	Lythraceae
Lannea coromandelica (Houtt.) Merr.	Anacardiaceae
Leea asiatica (L.) Ridsdale	Vitaceae
Litsea monopetala (Roxb.) Pers.	Lauraceae
Ludwigia hyssopifolia (G.Don) Exell	Onagraceae
Lygodium flexuosum (L.) Sw.	Schizaeaceae
Lygodium japonicum (Thunb.) Sw.	Schizaeaceae
Mallotus philippensis (Lam.) Mull. Arg.	Euphorbiaceae
Mesosphaerum suaveolens (L.) Kuntze	Lamiaceae
Millettia extensa (Benth.) Benth. ex Baker	Fabaceae
Mitragyna parvifolia (Roxb.) Korth	Rubiaceae
Murdannia nudiflora (L.) Brenan	Commelinaceae
Murraya koenigii (L.) Spreng.	Rutaceae
Murraya paniculata (L.) Jack	Rutaceae
Oplismenus burmanni (Retz.) P.Beauv.	Poaceae
Ougeinia oojeinensis (Roxb.) Hochr.	Fabaceae
Parthenocissus semicordata (Wall.) Planch.	Vitaceae
Phanera vahlii (Wight & Arn.) Benth.	Fabaceae
Phoenix sylvestris (L.) Roxb.	Arecaceae
Phyllanthus clarkei Hook.f.	Phyllanthaceae
Phyllanthus emblica L.	Phyllanthaceae
Phyllanthus glaucus Wall. ex Müll.Arg.	Phyllanthaceae
Phyllanthus niruri L.	Phyllanthaceae
Phyllanthus urinaria L	Phyllanthaceae
Phyllanthus virgatus G.Forst.	Phyllanthaceae

Scientific Name	**Family**
Phyllodium pulchellum (L.) Desv.	Fabaceae
Piper longum L.	Piperaceae
Platostoma coloratum (D.Don) A.J.Paton	Lamiaceae
Pogonatherum crinitum (Thunb.) Kunth	Poaceae
Pogostemon benghalensis (Burm.f.) Kuntze	Lamiaceae
Premna barbata Wall. ex Schauer	Lamiaceae
Psidium guajava L.	Myrtaceae
Pteris L.	Pteridaceae
Rauvolfia serpentina (L.) Benth. ex Kurz	Apocynaceae
Rauvolfia tetraphylla L.	Apocynaceae
Rostellularia procumbens (L.) Nees	Acanthaceae
Rostellularia quinqueangularis (J.Koenig ex Roxb.) Nees	Acanthaceae
Rungia pectinata (L.) Nees	Acanthaceae
Saccharum spontaneum L.	Poaceae
Schleichera oleosa (Lour.) Oken	Sapindaceae
Selaginella kraussiana (Kunze) A.Braun	Selaginellaceae
Selaginella sp.	Selaginellaceae
Semecarpus anacardium L.f.	Anacardiaceae
Senegalia catechu (L.f.) P.J.H.Hurter & Mabb.	Fabaceae
Senna corymbosa (Lam.) H.S.Irwin & Barneby	Fabaceae
Senna tora (L.) Roxb.	Fabaceae
Setaria pumila (Poir.) Roem. & Schult.	Poaceae
Shorea robusta Gaertn.	Dipterocarpaceae
Sida acuta Burm.f.	Malvaceae
Sida rhombifolia L.	Malvaceae
Smilax aspera L.	Smilacaceae
Smilax ovalifolia Roxb. ex D.Don	Smilacaceae
Sohmaea laxiflora (DC.) H.Ohashi & K.Ohashi	Fabaceae
Spatholobus parviflorus (Roxb. ex G.Don) Kuntze	Fabaceae
Spermacoce pusilla Wall.	Rubiaceae
Spermadictyon suaveolens Roxb.	Rubiaceae
Sunhangia elegans (DC.) H.Ohashi & K.Ohashi	Fabaceae
Syzygium cumini (L.) Skeels	Myrtaceae
Syzygium jambos (L.) Alston	Myrtaceae
Syzygium nervosum A.Cunn. ex DC.	Myrtaceae
Tectaria sp.	Polypodiaceae
Tectona grandis L.f.	Lamiaceae
Terminalia alata Heyne ex Roth	Combretaceae
Terminalia anogeissiana Gere & Boatwr.	Combretaceae
Thelypteris sp.	Aspleniaceae
Themeda caudata (Nees ex Hook. & Arn.) A.Camus	Poaceae
Toona hexandra (Wall.) M.Roem.	Meliaceae
Trachelospermum lucidum (D.Don) K.Schum.	Apocynaceae
Tridax procumbens L.	Asteraceae
Triumfetta rhomboidea Jacq.	Malvaceae
Urena lobata L.	Malvaceae
Wendlandia appendiculata Wall. ex Hook.f.	Rubiaceae
Woodfordia fruticosa (L.) Kurz	Lythraceae
Ziziphus jujuba Mill.	Rhamnaceae
Ziziphus mauritiana Lam.	Rhamnaceae