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Assessing Forest Structure and Biodiversity in Community Forests and the Spatial Distribution of Local Disturbances

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Abstract

Understanding forest structure, biodiversity, and local disturbance patterns is critical for effective community forest management, yet such integrated assessments remain limited. This study evaluates forest structure, plant biodiversity, and the spatial distribution of local disturbances in three community forests (Banelpokhari, Okhardhara, and Suntalidada) located in Godawari Municipality, Nepal. Using a systematic random sampling design, 90 circular plots were established to measure trees (500 m^2), poles (100 m^2), saplings (25 m^2), and seedlings (10 m^2). Biodiversity indices (Shannon–Wiener, evenness, richness, Importance Value Index) were computed, and Sentinel-2A imagery (2017 and 2022) was analyzed using NDVI to assess land cover changes. Results show that *Pinus roxburghii* was the dominant species across all forests, with the highest IVI (281.25) in Okhardhara CF. Suntalidada CF exhibited the greatest Shannon–Wiener diversity ($H' = 3.52$), evenness (0.96), and species richness (25). Forest structure revealed the highest stem density in the 0–10 cm diameter and 0–5 m height classes, and the lowest in >40 cm and >20.1 m classes. Key disturbances included road development, encroachment, soil erosion, and illegal logging. From 2017 to 2022, dense forest cover decreased by 9% (Banelpokhari), 19% (Okhardhara), and 11% (Suntalidada), with concurrent increases in sparse vegetation and infrastructure. These findings underscore the need for targeted conservation interventions, adaptive management, and collaborative approaches to mitigate anthropogenic pressures and sustain biodiversity in community-managed forests.

Keywords: Community Forests, Disturbance, Diversity Index, Forest structure, Sentinel-2A.

1. Introduction

Forests, covering approximately 30% of the Earth's land area, are indispensable components of global ecosystems, providing essential services and housing significant biodiversity (Ritzer, 2012; Fichtner & Härdtle, 2021). However, forests worldwide face complex challenges such as deforestation, habitat fragmentation, and biodiversity loss, which jeopardize their ecological integrity and the multitude of benefits they offer to humanity (Kumar et al., 2022; Bhattacharya, 2025). In Asia, a region celebrated for its rich biodiversity, effective conservation strategies are essential to counter these threats and safeguard forest ecosystems for future generations (Xu et al., 2019). Nepal nestled within the Himalayas, exemplifies the intricate interplay between conservation imperatives and developmental pressures. With over 37% of its land area covered by forests, Nepal is a biodiversity hotspot, boasting diverse ecosystems and unique flora and fauna (Paudel et al., 2022; Bhandari, 2025). Nevertheless, rapid urbanization, unsustainable land use practices, and climate change impacts pose formidable challenges to the country's forest ecosystems (Mir et al., 2015). Forest structure

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refers to the spatial distribution (horizontal and vertical) of vegetation layers, including trees, shrubs, and ground cover (Hui et al., 2019). Forests are three-dimensional systems where biophysical structure plays a major role in ecosystem function and diversity (Mitchell et al., 2023). Forest structure is both a product of forest dynamics and biophysical processes, as well as a template for biodiversity and ecosystem function (Hansen et al., 2019). Consequently, understanding forest structure is vital to unlocking the history, function, and future of a forest ecosystem (Feng et al., 2025).

Plant diversity plays a significant role in community stability, ecosystem productivity, and ecological services, all of which are highly beneficial to humanity and economic development (Ruiz-Benito et al., 2014). It is well-known that the development of human societies including anthropogenic activities, affects Earth's systems and can threaten their resilience (Quijas et al., 2010). The twin burdens of deforestation and forest degradation continues to pose significant challenges to all living species due to the rising production of greenhouse gases (GHGs), especially CO_2.Consequently, carbon emissions are increasing steadily due to massive deforestation (Mandal et al., 2016). Comparative assessments of disturbed and non-disturbed forest ecosystems have demonstrated that human interventions significantly influence carbon sequestration potential, highlighting the importance of sustainable forest management for climate change mitigation (Joshi & Singh, 2020). Empirical evidence from Nepal's Terai region shows that non-degraded community forests store nearly twice as much carbon as degraded ones, highlighting the climate mitigation value of maintaining forest condition (Joshi et al., 2020a). Complementing these field-based assessments, Singh et al. (2023) employed machine learning algorithms with Sentinel-2A data to model above-ground tree biomass in similar Terai landscapes, demonstrating the potential of remote sensing for carbon monitoring. Forests are a crucial renewable resource that provides services and commodities to both people and the environment, addressing fundamental human needs while serving as a significant wellspring of livelihood and monetary gain worldwide (Singh et al., 2022). Despite this significance, substantial forest areas in Nepal remain uncharted by scientific exploration, and the country lacks a comprehensive database of its flora. Pine-dominated forests (*Pinus roxburghii*) are widespread across Nepal's mid-hills and have been the subject of recent structural and carbon-related studies (Ayer et al., 2024; Acharya et al., 2025). Similar vegetation analyses in other Nepalese community forests, such as those in the Terai region, have demonstrated the utility of diversity indices and the Importance Value Index (IVI) for informing sustainable management (Joshi et al., 2019). Consequently, this research utilized on-site sampling to unveil the current diversity and condition of flora, categorized by growth stages, within Godawari Municipality, Lalitpur. In this context, the study contributes to the Nagoya Protocol of the Convention on Biological Diversity, regarding biodiversity preservation and future management initiatives. Remote sensing, particularly Airborne Laser Scanning (ALS), plays a pivotal role in elucidating forest biodiversity, encompassing aspects such as animal ecology and tree species diversity. Integrating ALS data with other remote sensing datasets can enhance the precision and comprehensiveness of biodiversity assessments (Toivonen et al., 2023). However, it is important to note that Normalized Difference Vegetation Index (NDVI) mapping solely provides specific insights into vegetation cover, excluding the multifaceted aspects inherent in agricultural land-use systems which result from elements such as geomorphology, soil composition, water availability, and climate. Furthermore, NDVI fails to incorporate details concerning hierarchical patterns and ecological processes, which are vital for comprehending the ecologically pertinent facets of land-use systems (Myers, 1997; Huang et al., 2025). Despite these limitations, NDVI combined with ground-based forest inventory has proven valuable for assessing biodiversity and carbon stocks in Nepalese community forests. For instance, Thakur et al. (2024) demonstrated a positive linear relationship between NDVI and aboveground carbon stocks across three community forests in Mahottari district, validating the utility of Sentinel-2A imagery for forest monitoring in Nepal. The study aims to develop a holistic understanding of the ecology within community forests. This encompasses evaluating forest structure, biodiversity, and the spatial distribution of local disturbances. By addressing these knowledge gaps and fostering interdisciplinary collaboration, this research contributes to the preservation of forest ecosystems and the promotion of sustainable development in Godawari Municipality and similar regions worldwide.

2. Materials and Methods

2.1. Study Area

The research was conducted in Lalitpur District, located between 85°17′00″ E and 85°17′06″ E longitude and 27°32′25″ N and 27°34′14″ N latitude (Figure 1). The district lies in the hilly terrain of Bagmati Province in central Nepal. The specific study site is Godawari Municipality, which comprises 14 wards, covers an area of 96.11 km², and has a population of 78,301. Elevation variations within Godawari create distinct climatic conditions: a subtropical climate between 1,000 and 2,000 m, and a temperate climate above 2,000 m. Three community forests (CFs), Banelpokhari, Okhardhara, and Suntalidada located on Godavari Hill were selected for the study. This area is part of the sub-Himalayan Mahabharat Range, with an altitudinal range of 1,400 m to 2,100 m above sea level, and features diverse broadleaved evergreen forests. The vegetation comprises three distinct evergreen broadleaved forest types: mixed *Pinus* forest, *Schima–Castanopsis* forest, oak-laurel forest, and evergreen oak forest (Baniya et al., 2020). The total areas of Banelpokhari, Okhardhara, and Suntalidada CFs are 72.44 ha, 77.91 ha, and 112.01 ha, respectively.

Owing to climatic variations, vegetation ranges from subtropical to temperate zones. Dominant tree species include *Pinus roxburghii*, *Rhododendron arboreum*, *Quercus semecarpifolia*, and *Juglans regia*. The study area comprises heterogeneous ethnic communities, predominantly Brahmin, Chhetri, Janajati, and Dalit. Most residents are Hindu or Buddhist. The three CFs have 55, 158, and 46 households, with populations of 305, 988, and 230, respectively. Agriculture is the primary occupation, supplemented by government jobs, foreign employment, and military service. Livestock rearing is an integral part of agricultural practices.

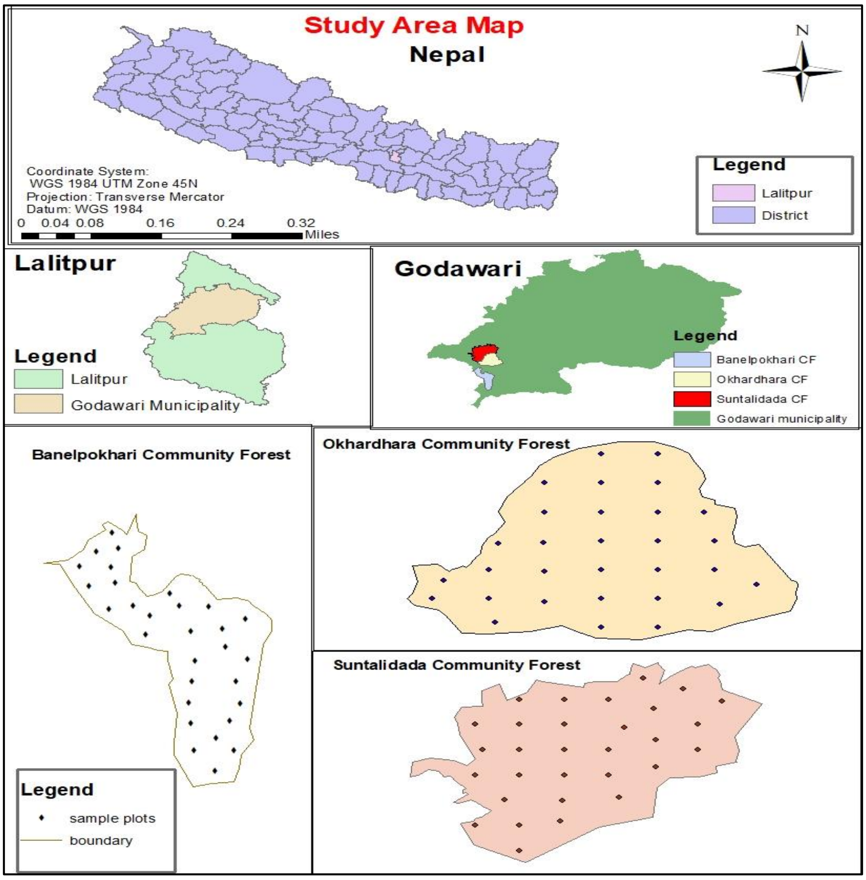

Figure 1. Map of the study area

2.2. Data Collection

The research utilized both descriptive and exploratory research designs to collect and analyze primary and secondary data. A preliminary field survey was carried out to identify the study sites and assess the general distribution patterns of vegetation communities and landscape features. Local residents, community forest executive members, and forest officers were consulted to gather information regarding forest types, landscape characteristics, and site history. Study sites were selected across an elevational gradient starting from 1,000 m. A systematic random sampling method was employed within the elevational range of 1,000 m to 2,000 m. Forest surveys were conducted along existing foot trails. A total of 90 circular sample plots were established. In each plot, diameter at breast height (DBH), total height, and crown diameter were measured for trees, poles, and saplings. For seedlings, height and collar diameter (at 15 cm above ground) were recorded.

Prior to field sampling, area delineation and a species checklist were prepared to record presence/absence of taxa. Field visits employed standard forest inventory techniques. Plots were demarcated using iron pegs and measuring tapes. Following Nepal's Forest Inventory Guideline 2071, circular plot radii were: 12.6 m for trees (500 m²), 5.64 m for poles (100 m²), 2.8 m for saplings (25 m²), and 1.78 m for seedlings (10 m²). At each plot center, coordinates were recorded using a Global Positioning System (GPS, Garmin eTrex), along with aspect and dominant vegetation types. Collected plant species were identified in the field with the help of *Flowers of the Himalaya* and its supplement (Stainton, 1988) and *The Orchids of Nepal* (Raskoti, 2009). Species that could not be identified in the field were collected, tagged, dried, and brought to the Central Department of Botany for further identification. Secondary data were collected from research articles, reports, forest working plans, and university libraries. Disturbed areas within community forests were identified through key informant interviews (KII) and focus group discussions (FGD) combined with field observations.

2.3. Data Analysis

The research employed both quantitative and statistical analyses across different phases of the study.

2.3.1. Analysis of Forest Structure

Forest structure was characterized by analyzing:

a) **Diameter class distribution** (stems per hectare) across five classes: <10 cm, 10.1–20 cm, 20.1–30 cm, 30.1–40 cm, and >40.1 cm.

b) **Height class distribution** (stems per hectare) across five classes: 0–5 m, 5.1–10 m, 10.1–15 m, 15.1–20 m, and >20.1 m.

2.3.2. Forest Biodiversity Indicators

Community quantitative parameters such as density, frequency, abundance, and basal area were calculated following Cottam and Curtis (1956).

a) Density, frequency, and abundance:

$$Density = \frac{\text{Total number of individuals of the species}}{\text{Total number of quardats studied}} \tag{1}$$

$$\text{Frequency}(\%) + = \frac{\text{Total number of quardants in which the species occurred}}{\text{Total number of quardats studied}} \times 100 \tag{2}$$

$$\text{Abundance} = \frac{\text{Total number of individuals of the species}}{\text{Total number of quardats in which the species occured}} \tag{3}$$

b) Basal area: For each tree, basal area (BA) was calculated from diameter at breast height (d in meters):

$$BA\left(m^2\right) = \pi \times \frac{\mathrm{d}^2}{4} \tag{4}$$

$$Basal\ Area\ per\ hac = \frac{\text{Total Basal Area of a species}}{\text{Total number of Quadrates} \times \text{Area of Quadrate}} \times 10000 \tag{5}$$

c) Relative measures and Importance Value Index (IVI):

$$Relative\ Frequency(\%) = \frac{\text{Frequency of individual species}}{\text{Sum of the frequencies for all species}} \times 100 \tag{6}$$

$$Relative\,Density(\%) = \frac{\text{Density of individual species}}{\text{Total density of all species}} \times 100 \tag{7}$$

$$Relative\,Basal\,Area(\%) = \frac{\text{Basal area of individuals species}}{\text{Total Basal Area of the species}} \times 100 \tag{8}$$

$$Importance\ Value\ Index\ (IVI) = Relative\,frequency + Relative\ density + Relative\ basal\ area \tag{9}$$

2.3.2.1. Diversity indices

a) Shannon–Wiener index (H′) (Ma and Liu, 1994):

$$H' = -\sum_{i=1}^{s} (pi \cdot lnpi) \tag{10}$$

where pipi = proportion of individuals of species ii (ni/Nni/N), SS = number of species.

b) Pielou's evenness index (e) (Strong, 2016):

$$e = \frac{H'}{\ln S} \tag{11}$$

c) Species richness (Margalef's index):

$$Species\,richness = \frac{\mathrm{S}}{\sqrt{\mathrm{N}}} \tag{12}$$

where N= total number of individuals across all species.

d) Similarity index: Community similarity between forests was assessed using the Czekanowski coefficient (Sørensen, 1948):

$$S_c = \frac{2\sum_{i=1}^{m} \min(X_{i,}\ _{Y_i})}{\sum_{i=1}^{m} X_i + \sum_{i=1}^{m} Y_i} \tag{13}$$

where, X_i and Y_i = abundance of species I in two sites, $\sum_{i=1}^{m} \min(X_{i,}\ _{Y_i})$ = the lesser abundance where the species occurs in both sites, m = total number of species.

2.4. Analysis of local disturbance

To assess spatial distribution of local disturbances within the three CFs, we used Sentinel-2A imagery. These satellite images underwent processing in QGIS to classify land cover and calculate forest extent. The spatial distribution analysis encompassed identifying disturbed areas and evaluating local distance factors within the study area. Additionally, field-based ground-truthing was conducted to verify the classification results.

2.5. Satellite image interpretation

Sentinel-2A imagery was used to assess changes in forest cover. Two time-series satellite images were downloaded from European Space Agency (https://scihub.copernicus.eu/dhus/#/home). The first image was acquired on May 3, 2017 and second on May 1, 2022. The spatial resolution of the spectral bands used (B4 and B8) is 10 m. The imagery was atmospherically corrected using the Sen2Cor plug-in in the SNAP (Sentinel Application Platform) software (Version 4.0.0). The pre-processing also included spatial resampling of all bands to a common resolution of 10 meters. These images were then used to calculate the NDVI. The NDVI assisted in the analysis of forest health and land cover. It is a dimensionless index that describes the difference between visible and near-infrared reflectance of vegetation cover and is used to estimate the density of greenery within an area (Ashbindu, 1989).

NDVI = (NIR-Red) / (NIR+Red),

where NIR is near-infrared light and Red is visible red light.

Two different Sentinel-2 images (2017 and 2022) were analyzed for each CF. During this procedure two object levels were created. The classification based on the range of NDVI values was accomplished using calculations derived from field data, and elevation maps with different biodiversity categories were created. For this segmentation, spectral bands 4 and 8 (spatial resolution 10 m) were taken into account, with equal weights. The processing was done in Quantum Geographic Information System (QGIS) for segmentation at this level, ensuring independence from spectral features and forest composition. Various parameters were used to obtain effective forest patches (map units) for estimating biodiversity.

2.6. Statistical analysis

Forest stand characteristics, specifically the diameter and height of trees, were analyzed. Descriptive statistics were performed to determine the mean, standard error, standard deviation, maximum and minimum of these characteristics. Graphical presentations were created using Microsoft Excel 2016 and QGIS.

3. Results

3.1. Forest Structure in community forest

3.1.1. Diameter distribution in community forests

The diameter distribution across all CFs showed the highest number of trees per hectare within the < 10 cm class while those with 40.1 cm and above was the lowest. Among the three forests, tree density was highest in Suntalidada CF lowest in Banelpokhari CF. Compared to the trees in the < 10 cm class, the number of trees per hectare in the 10.1 - 20 cm class was lower. This was followed by that the 20.1 – 30 cm class, which exhibited even lower density across all CFs. However, in each of the three CFs, the density of trees with diameter between 30.1 cm to 40 cm was found to be higher than those with diameter above 40.1 cm.

In the CFs, the highest density per hectare in terms of diameter distribution was observed within the category of trees with diameters < 10 cm across all three forests. Conversely, the trees with diameters of 40.1 cm and above exhibited the lowest density. Among the three forests, Suntalidada CF boasted the highest tree density, while the lowest was recorded in Banelpokhari CF. In contrast to trees with diameters less than 10 cm, the stem count per hectare in the range of 10.1 cm to 20 cm diameter demonstrated a lower figure. Subsequently, within the diameter range of 20.1 cm to 30 cm, there was a further reduction in tree density observed across all CFs. Notably, within each of the three CFs, trees with diameters spanning 30.1 cm to 40 cm exhibited a greater density than those with diameters surpassing 40.1 cm (Figure 2).

3.2. Descriptive statistics of diameter distribution in community forests

The greatest density was documented within the 0 – 10 cm diameter range in Banelpokhari CF, Okhardhara CF, and Suntalidada CF, registering figures of 283±46.8 N ha^{-1}, 342.5±43.81 N ha^{-1}, and 371.5±43.81 N ha^{-1}, respectively. On the other hand, the diameter range of 20.1-30 cm in Suntalidada CF exhibited the highest density at 249±28.53 N ha^{-1}. In a corresponding manner, the lowest density figures were recorded within the above 40 cm diameter class, with 7.15±4.62 N ha^{-1} in Banelpokhari CF, 5.8±2.9 N ha^{-1}in Okhardhara CF, and 5.11±2.86 N ha^{-1} in Suntalidada CF (Table 1).

3.3. Height distribution in community forests

In accordance with the distribution of tree heights, the density of trees was most prominent within the Suntalidada CF, followed by the Okhardhara CF and subsequently the Banelpokhari CF. The stem count per hectare peaked within the height range of 0 to 5 m across all three forests. Subsequently, the category of trees ranging from 5.1 to 10 m in height emerged as the second-highest in terms of tree count per hectare within all three forests. Conversely, the distribution of trees exceeding 20.1 m in height exhibited the lowest count per hectare across the entire study area (Figure 3).

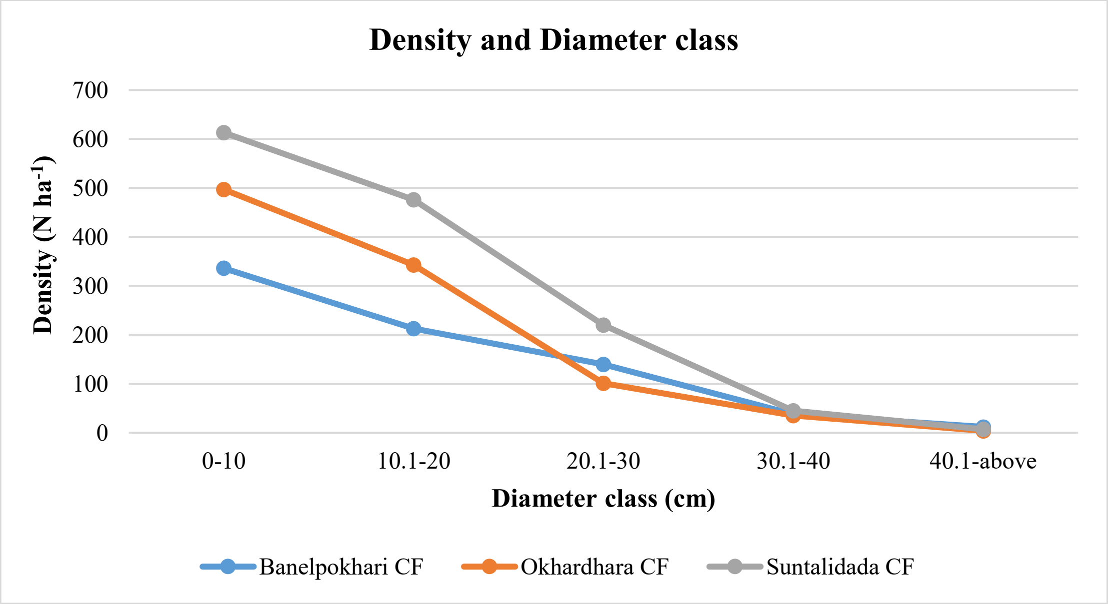

Figure 2. Density of tree according to diameter class in different CFs

Table 1. Descriptive statistics of diameter distribution in community forests

Diameter(cm)	Mean±SE	SD	MAX	MIN
Banelpokhari CF				
0-10	283.16±46.8	147.46	495	67
10.1-20	214±34.43	102.04	318	14
20.1-30	107.20±28.83	70.29	236	16
30.1-40	29.03±2.86	17.98	84	13
40.1-above	7.15±4.62	2.32	14	1
Okhardhara CF				
Diameter(cm)	**Mean±SE**	**SD**	**MAX**	**MIN**
0-10	342.01±26.36	221.67	613	65
10.1-20	255.29±36.08	187.39	448	14
20.1-30	85.02±6.41	56.33	220	14
30.1-40	23.60±3.6	16.75	80	10
40.1-above	5.8±2.9	1.21	8	1
Suntalidada CF				
Diameter(cm)	**Mean±SE**	**SD**	**MAX**	**MIN**
0-10	371.5±43.81	258.11	877	65
10.1-20	310.3±35.26	192.36	515	14
20.1-30	249.13±28.53	78.52	310	15
30.1-40	26.77±13.09	17.45	85	10
40.1-above	5.11±2.86	2.69	12	1

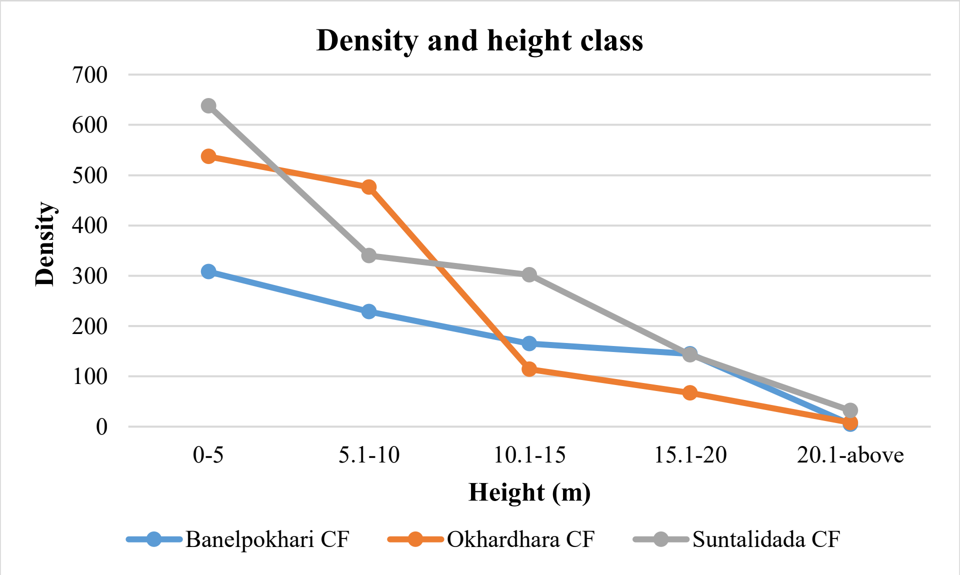

Figure 3. Density according to tree height in different CFs

3.4. Descriptive statistics of height distribution in community forests

Upon conducting descriptive analysis of tree density, it was determined that the highest stem count was observed within the height range of 0 to 5 m in all three forests, while the lowest stem count was found in the category exceeding 20.1 m. In the subgroup encompassing heights below 5 m, the standard deviation values were 139.14 for Banelpokhari CF, 211.54 for Okhardhara CF, and 256.42 for Suntalidada CF. In the height class of 20.1 m and above, the corresponding standard deviation values were 1.61 for Banelpokhari CF, 2.01 for Okhardhara CF, and 5.12 for Suntalidada CF. Within this latter category, the maximum counts were recorded as 32, 14, and 38 for Banelpokhari CF, Okhardhara CF, and Suntalidada CF, respectively (Table 2).

3.5. Stock (volume) distribution in community forests

The stock volume distribution of the three studied community forests is delineated (Table 3). As shown in the table, the value of volume per pole was found to be 89.99 m^3/ha in Banelpokhari CF followed by Suntalidada CF with 63.16 m^3/ha and Okhardhara CF with 53.24 m^3/ha comprising 70.51%, 73.03% and 65.02% of the total volume, respectively. In case of trees, the volume was found to be 37.63 m^3/ha in Banelpokhari CF which comprised 29.49%, 28.65 m^3/ha in Okhardhara CF comprising 34.98% and 23.32 m^3/ha in Suntalidada CF comprising 26.97% (Table 3).

3.6. Forest biodiversity indicators in community forests

The analysis of plant species biodiversity indicated that the Shannon-Wiener index values for trees, poles, saplings, and seedlings were most significant in the Suntalidada CF, registering at 3.52. Conversely, the lowest Shannon-Wiener index value (1.95) was observed in the Banelpokhari CF. The evenness index for tree species exhibited a higher value in both the Okhardhara and Suntalidada CFs, both reaching 0.96. In contrast, the evenness index for the Banelpokhari CF was 0.81. The richness value was most substantial in the Suntalidada CF, recording a value of 25, followed by the Banelpokhari CF with a value of 19. On the other hand, the Okhardhara CF displayed the lowest richness value of 16 (Table 4).

Table 2. Descriptive analysis of density on the basis of height of three CFs

Height (m)	Mean±SE	SD	MAX	MIN
Banelpokhari CF				
0-5	257.32±38.7	139.14	475	67
5.1-10	246.43±33.26	95.52	305	18
10.1-15	119.15±23.53	73.26	245	15
15.1-20	105.81±29.97	70.38	230	15
20.1-above	4.92±1.13	1.61	12	1
Okhardhara CF				
Height (m)	**Mean±SE**	**SD**	**MAX**	**MIN**
0-5	413.11±33.2	221.54	665	65
5.1-10	398.35±47.39	192.65	540	20
10.1-15	97.42±28.67	40.27	243	15
15.1-20	54.06±9.37	24.89	105	10
20.1-above	6.11±2.03	2.01	14	1
Suntalidada CF				
Height (m)	**Mean±SE**	**SD**	**MAX**	**MIN**
0-5	448.69±44.53	256.42	900	65
5.1-10	269.17±40.8	101.35	490	24
10.1-15	253.29±39.83	98.82	485	18
15.1-20	103.76±33.62	54.9	238	15
20.1-above	12.37±6.25	5.12	38	4

Table 3. Tree stock (volume) of the community forests (CFs)

Stock	Banelpokhari CF		Okhardhara CF		Suntalidada CF	
	Volume (m^3 ha)	Percentage	Volume (m^3/ha)	Percentage	Volume (m^3/ha)	Percentage
Pole	89.99	70.51	53.24	65.02	63.16	73.03
Tree	37.63	29.49	28.65	34.98	23.32	26.97
Total	127.62	100	81.88	100	86.48	100

Table 4. Biodiversity indices of plant species in community forests (CFs)

Biodiversity Index	Banelpokhari CF	Okhardhara CF	Suntalidada CF
Shannon- Wiener index (H')	1.95	3.22	3.52
Evenness	0.81	0.96	0.96
Richness	19	16	25

Since these three CFs lie at the same elevation, they share similar locality factors. Here, comparing these CFs to know about the difference in forest structure and biodiversity, despite they have a similar management framework. The biodiversity indices across all CFs, encompassing trees, poles, saplings, and seedlings, unveiled distinct patterns. The varying values of the Shannon-Wiener index, evenness, and richness across different developmental stages of the forests indicate distinct patterns of anthropogenic interference and associated challenges within each CF. In the case of mature trees, Suntalidada CF stands out with the highest diversity and richness. This suggests that social factors such as effective community management, traditional knowledge, or perhaps limited external interference allowing for the preservation of a diverse tree population. Conversely, Okhardhara CF, with the lowest diversity and richness, might face issues such as unsustainable logging practices or encroachment, possibly driven by economic pressures or insufficient community engagement in forest management.

The pattern shifts regarding poles, where Okhardhara CF exhibits the highest diversity and richness. This could imply successful reforestation efforts or robust natural regeneration, potentially supported by community initiatives or external interventions. Conversely, the lower diversity in Banelpokhari CF could be indicative of challenges such as resource exploitation or inadequate conservation measures, possibly stemming from conflicts over resource use or lack of community cohesion. Moving to saplings and seedlings, Okhardhara CF consistently shows higher diversity and richness across both stages, suggesting sustained conservation efforts or successful regeneration programs. Suntalidada CF, while still exhibiting relatively high diversity, might face issues such as invasive species or habitat degradation due to human activities, possibly linked to population pressure or inadequate enforcement of conservation policies. Banelpokhari CF, with the lowest diversity and richness, may suffer from complex social issues such as land disputes, poverty-driven illegal activities, or insufficient community participation in reforestation efforts. Overall, these findings highlight the intricate relationship between social dynamics and forest health, emphasizing the importance of community involvement, effective governance, and targeted interventions to address various challenges and ensure the long-term sustainability of CFs.

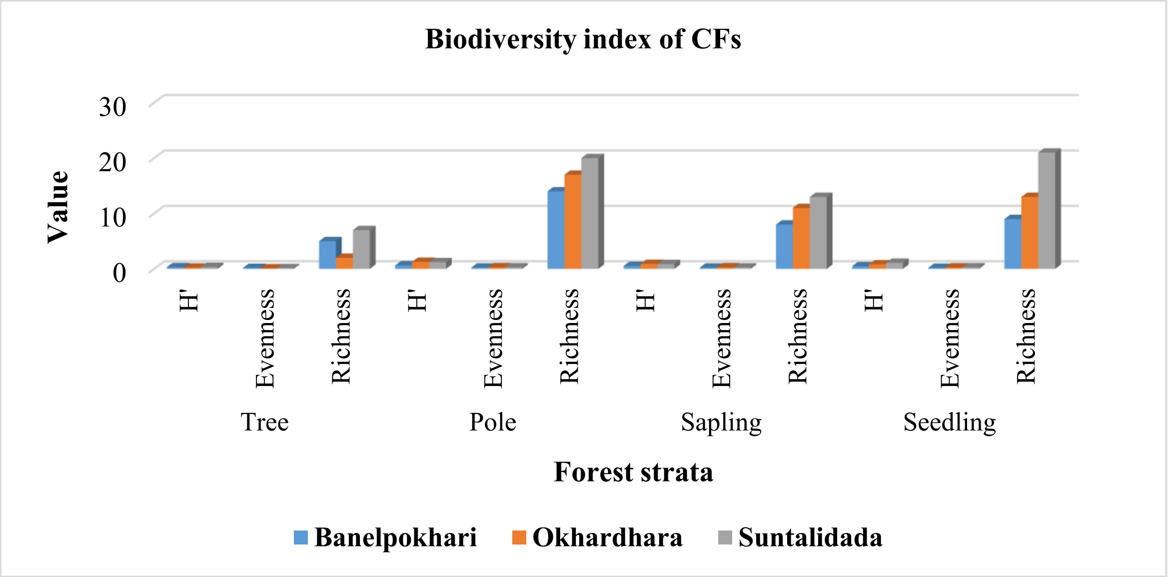

Figure 4. Biodiversity index of CF for tree, pole, sapling and seedling

3.7. Importance value index of tree species in community forests

An examination of the Importance Value Index (IVI) of tree species indicated that *Pinus roxburghii* held the highest relative frequency (90%) within Okhardhara CF. This was followed by Banelpokhari CF, where it had a relative frequency of 74.07%, while Suntalidada CF showed the lowest value at 39.39%. Notably, in terms of relative density, relative dominance, and overall IVI, *P. roxburghii* dominated across all three forests, with its prominence being most notable in Okhardhara CF, followed by Banelpokhari CF and Suntalidada CF. Furthermore, specific tree species such as *Rhododendron arboreum*, *Quercus semecarpifolia*, and *Juglans regia* were exclusively found within Banelpokhari CF. In contrast, *Quercus glauca* was observed solely in Okhardhara CF.

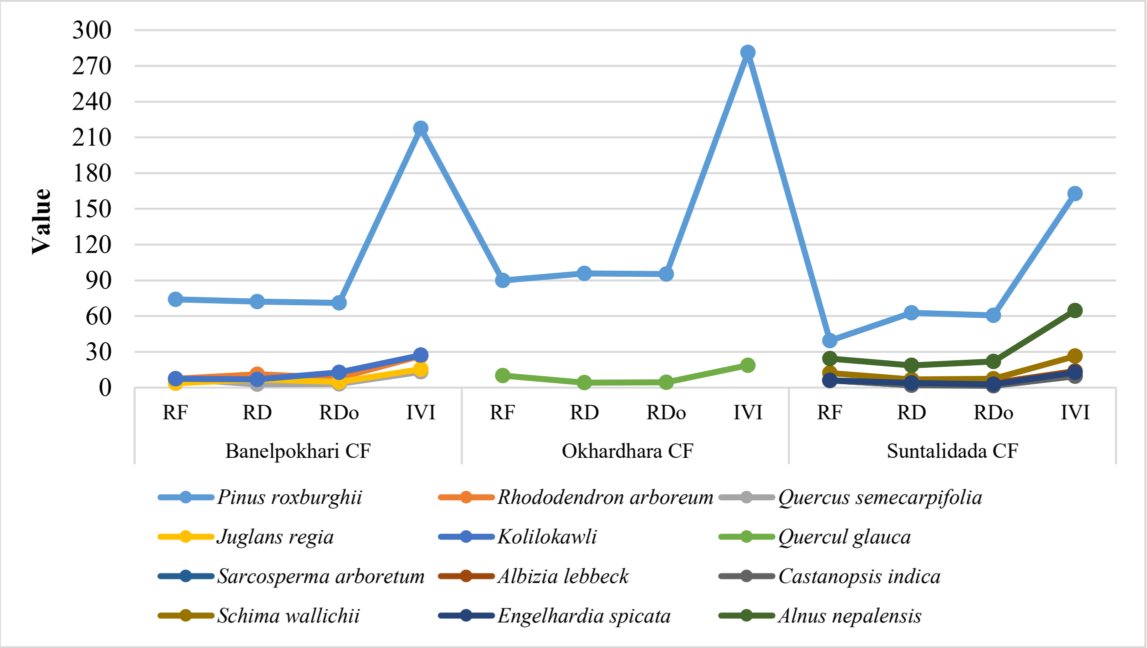

Figure 5. Importance Value Index (IVI) of tree stage plant species in community forests

Note: RF stands for Relative Frequency, RD for Relative Density, RDo for Relative Dominance and IVI for Importance Value Index.

3.8. The importance value index of pole species in community forest

The Importance Value Index (IVI) reveals distinct patterns in the relative frequencies of pole species across the three community forests, reflecting underlying socioeconomic dynamics and environmental factors. *Lyonia ovalifolia* demonstrates significant prominence in Banelpokhari CF, indicating potential ecological conditions favoring its growth. This could be attributed to specific habitat preferences or historical land use practices within the community forest. Conversely, its lower presence in Okhardhara CF and minimal occurrence in Suntalidada CF may suggest variations in soil composition, microclimatic conditions, or anthropogenic disturbances affecting its distribution. *Lithocarpus* spp., on the other hand, exhibits a contrasting pattern, with a higher presence in Suntalidada CF. This could indicate more favorable habitat conditions or conservation efforts specific to this species within the community forest. The absence of *Lithocarpus* spp. in Banelpokhari CF might be linked to ecological disturbances or selective logging practices impacting its population.

The distribution of *Quercus lanata* reflects a nuanced interplay between ecological factors and socioeconomic dynamics. Its higher relative frequency in Banelpokhari CF could be influenced by historical land-use patterns or traditional forest management practices favoring this species. Conversely, its lower presence in Okhardhara CF might be attributed to land-use changes, habitat degradation, or socio-economic pressures leading to the decline of this species in the area. *Quercus glauca*'s prevalence in Okhardhara CF suggests potential ecological suitability or management efforts supporting its growth. The species' lower occurrence in Suntalidada CF and Banelpokhari CF could be linked to habitat fragmentation, competition from other species, or limited conservation measures targeting this species. The exclusive presence of *Diphylleia grayi* in Suntalidada CF could signify unique ecological niches or conservation initiatives specific to this community forest. This might be linked to community-led conservation efforts or ecological restoration programs focused on preserving indigenous species within the forest. Overall, the distribution patterns of pole species in the community forests reflect a complex interplay of ecological factors, historical land use practices, and socioeconomic dynamics, highlighting the importance of integrated approaches to forest management and conservation.

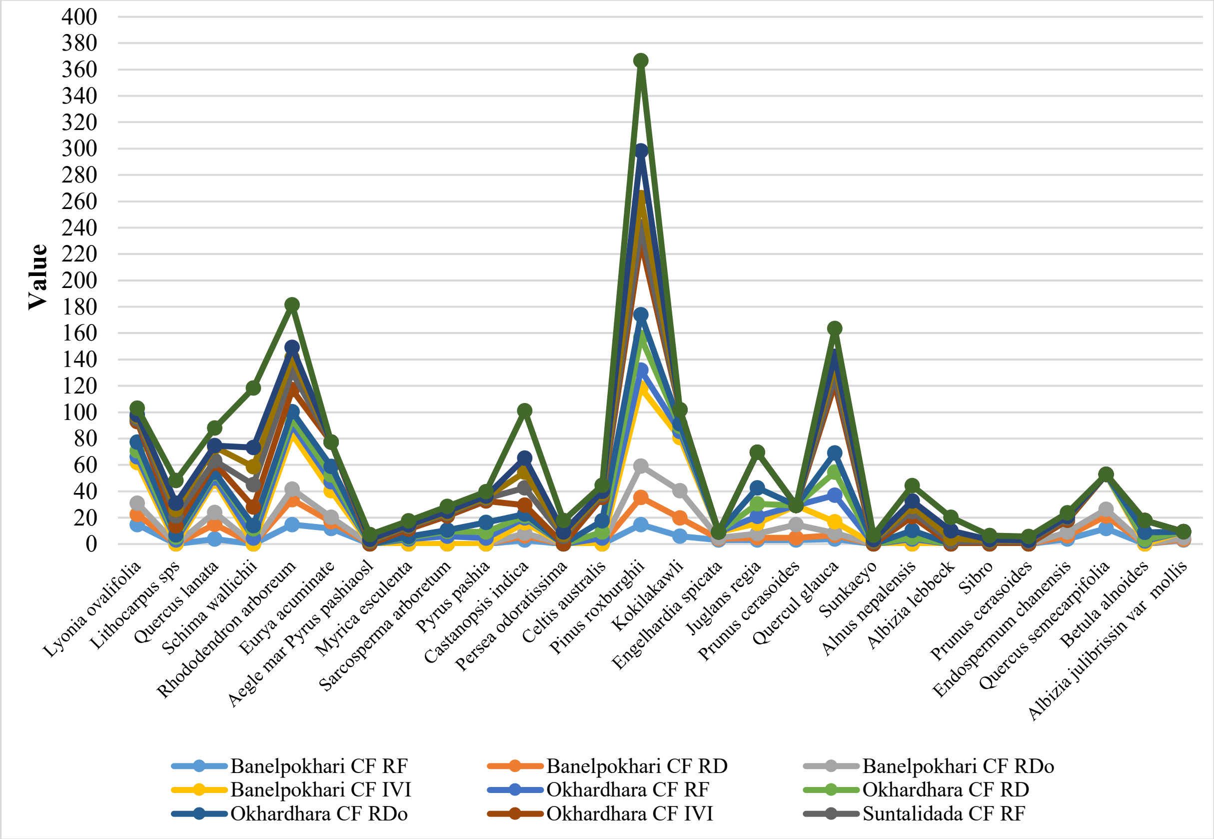

Figure 6. Importance Value Index (IVI) of pole stage plant species in community forests

3.9. The importance value index of Sapling species in community forest

Analyzing the IVI of saplings, it was found that the IVI, relative dominance, relative density,relative frequency values of *Lyonia ovalifolia* were 76.9, 25.03, 34.09 and 17.83, respectively in Banelpokhari CF which were the highest values among all three CFs. The relative frequency of Arkhaulo *Lithocarpus* spp. was higher in Suntalidada than Banelpokhari whereas rest of the three values were higher in Banelpokhari CF. Meanwhile, *Lithocarpus* spp. was absent in Okhardhara CF and *Quercus lanata* were absent in both Okhardhara and Suntalidada CFs. *Rhododendron arboretum* has highest IVI value of 49.65 in Banelpokhari CF whereas lowest 15.95 in Suntalidada CF. All four parameters were highest for *Pinus roxburghii* in Okhardhara CF (Figure 7).

3.9.1. The importance value index of seedling species in community forest

When examining the IVI of seedlings, it became evident that the relative frequency of *Lyonia ovalifolia* exhibited its highest value within Suntalidada CF, reaching 11.43%. Conversely, the lowest relative frequency, amounting to 6.32%, was observed in Okhardhara CF. Notably, the IVI value for *Lyonia ovalifolia* was most prominent in Okhardhara CF, registering 38.66, followed closely by Banelpokhari CF with a value of 35.09. In the case of *Schima wallichii*, the relative frequency reached its pinnacle in Okhardhara CF, recording a value of 3.16%, which was the highest among all three CFs. For *Myrica esculenta*, all four parameters were maximized within Banelpokhari CF. The respective values for relative frequency, relative density, relative dominance, and IVI were 28.13, 55.12, 28.08, and 111.33 for *Pinus roxburghii* within Banelpokhari CF, marking the highest figures among all three. Lastly, the relative frequency of *Juglans regia* achieved its highest value in Okhardhara CF (6.32%), while the remaining three values were notably higher in Suntalidada CF (Figure 8).

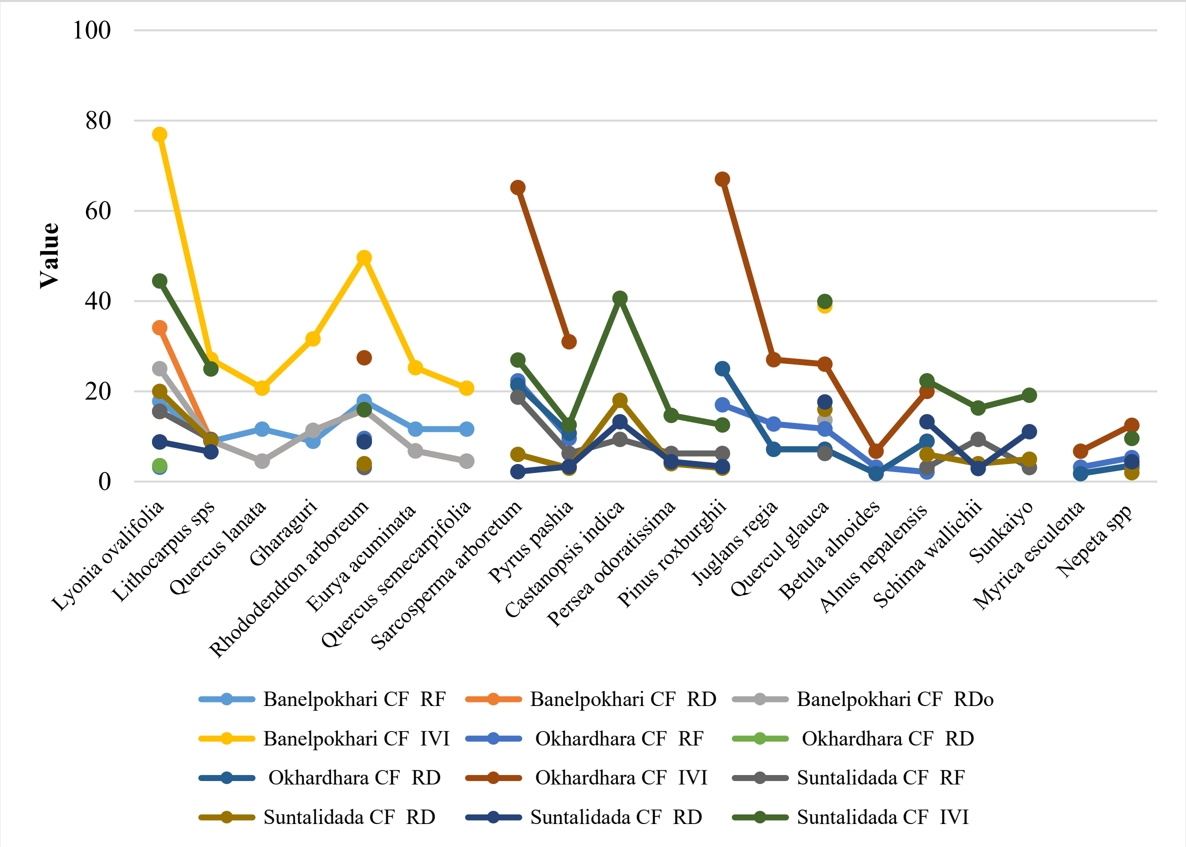

Figure 7. Importance Value Index (IVI) of sapling stage plant species in community forests

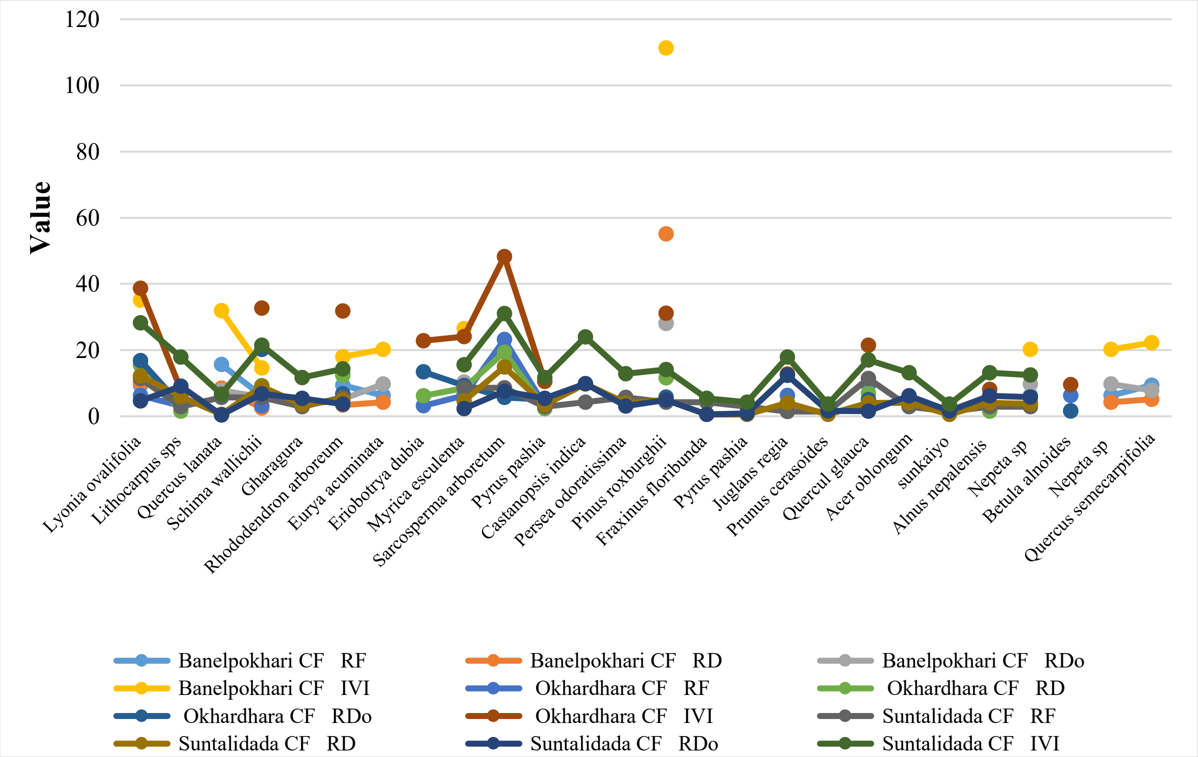

Figure 8. Importance Value Index (IVI) of seedling stage plant species in community forests

3.10. Czekanowski (Percentage similarity) index among community forests

The Czekanowski index applied to the three community forests revealed a certain degree of similarity among them. Specifically, when assessing the tree composition between Suntalidada CF and Okhardhara CF, there was a notable resemblance of species, reaching 58%. This was in comparison to the similarity between Suntalidada CF and Suntalidada CF itself. In contrast, the similarity between Okhardhara CF and Banelpokhari CF was lower, with these forests sharing only 35% of their species. Overall, the highest similarity was observed within the tree stratum, while the sapling stage exhibited the lowest degree of similarity among the studied community forests (Table 5).

3.11. Spatial distribution of local distancing factors

3.11.1. Disturbance area

To examine the extent of disturbance within the area, research was undertaken within the three CFs to investigate impacted areas. The findings revealed that among the studied CFs, Okhardhara CF exhibited the highest degree of disturbance, primarily attributed to infrastructure development such as road construction. Suntalidada CF was the second most disturbed (Table 6).

3.12. Spatial distribution of local distancing factors

By evaluating the spatial arrangement of local disruptive factors through the utilization of NDVI and validated data, the analysis depicted a notable trend. Among the three forests under study, Okhardhara CF exhibited the most substantial alterations within the five-year timeframe from 2017 to 2022. Specifically, the extent of dense forest area in Okhardhara CF diminished from 72.2 hectares (constituting 92.62%) to 56.83 hectares (equivalent to 72.91%). A similar pattern was observed in the other two CFs, where the area of dense forests also decreased over time. Conversely, contrasting trends emerged in relation to other land types, including grassland, sparse vegetation, and infrastructure, all of which experienced an increase in coverage within the span of these five years (Table 7 and Figure 9).

Table 5. Czekanowski (Percentage similarity) index of three community forests

Sites abundance	**Tree**			**Pole**			**Sapling**			**Seedling**		
	(B CF)	**(S CF)**	**(O CF)**	**(B CF)**	**(S CF)**	**(O CF)**	**(B CF)**	**(S CF)**	**(O CF)**	**(B CF)**	**(S CF)**	**(O CF)**
Banelpokhari (B CF)	1			1			1			1		
Suntalidada (S CF)	0.6	1		0.44	1		0.4	1		0.14	1	
Okhardhara (O CF)	0.75	0.75	1	0.43	0.59	1	0.18	0.32	1	0.23	0.64	1

Table 6. Total area of disturbance in three community forests

Disturbance	**Banelpokhari CF**	**Okhardhara CF**	**Suntalidada CF**
Landslide (ha)	0.08		
Encroachment (ha)	1.28	2.85	
Road (km)		1.54	1.48
Bareland (ha)		0.84	0.54

Table 7. Spatial distribution of local distancing factors

Details	**Banelpokhari CF**		**Okhardhara CF**		**Suntalidada CF**	
	2017 Area (ha)	**2022 Area (ha)**	**2017 Area (ha)**	**2022 Area (ha)**	**2017 Area (ha)**	**2022 Area (ha)**
Shrub and grassland	0.06	0.82	1.75	6.23	1.01	4.27
Sparse vegetation	0.53	5.94	3.99	13.25	6.8	14.58
Dense vegetation	71.92	65.63	72.2	56.83	104.69	92.34
Other (water, infrastructure, barren)	0.02	0.14	0.01	1.64	0.02	1.33
Total	72.53	72.53	77.95	77.95	112.52	112.52

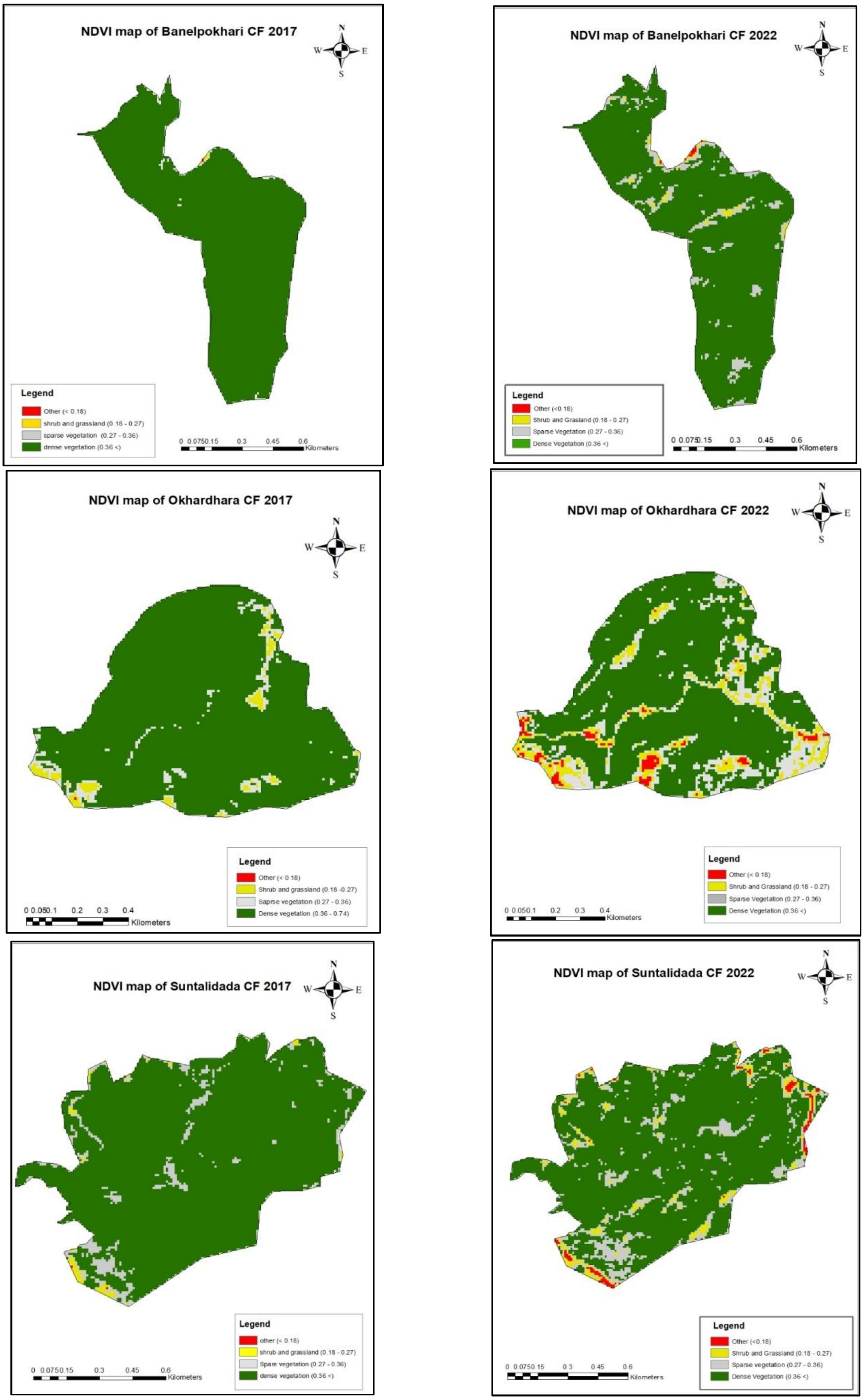

Figure 9. NDVI-based land cover classification of Banelpokhari, Okhardhara, and Suntalidada CFs in 2017 (left) and 2022 (right).

4. Discussion

The research presents significant insights into the dynamics of CFs, with a particular focus on the relationship between stem density per hectare and tree diameter, as supported by Khadka et al. (2019). Notably, it highlights the varying stem density across different diameter classes, with Suntalidada CF exhibiting a density of 613 stems per hectare within the 0-10 cm diameter class, while Banelpokhari CF records the lowest density at 336 stems per hectare. Conversely, Okhardhara CF, containing trees exceeding 40 cm in diameter, shows a considerably lower stem density of only 7 per hectare, aligning with Ahmad et al. (2014). These findings shed crucial light on the intricate relationship between stem density and tree diameter, offering valuable insights into forest structure and function. Moreover, the study delves into the dynamics of tree density across height class, revealing a notable decline as height increases. It illustrates the transition from young forest stands with higher stem density and lower height to intermediate and advanced stands with lower stem density but higher canopy coverage, indicating the complex interplay between forest age, structure, and density. Similar reverse J-shaped population curves, reflecting healthy regeneration and sustainable management, have been documented in community-managed *Shorea robusta* forests of Nepal (Joshi et al., 2021). These insights provide essential guidance for forest management practices aimed at promoting biodiversity conservation and ecosystem resilience, aligning closely with existing literature (Khadka et al., 2019). Our observed tree density range (283–371 stems ha^{-1} in the 0–10 cm diameter class) falls within the 250–800 stems ha^{-1} reported for mid-hill forests of Western Nepal (Acharya et al., 2025), confirming consistency across Nepal's mid-hill region. In contrast, Joshi et al. (2023) reported lower diversity (Shannon index 2.2) and richness (2.35) in a Mid-hills community forest of Jajarkot, highlighting how local management and disturbance regimes shape biodiversity outcomes even within similar regions.

Additionally, the research uncovers a significant positive correlation between the Shannon-Wiener index, stem density, and species richness, consistent with findings by Silva et al. (2018), which highlight the indispensable link between species richness and diversity (Ahmad et al., 2014). However, it also identifies a decline in tree species richness and diversity with increasing girth (diameter) classes, highlighting the multifaceted factors influencing forest biodiversity (Feroz et al., 2015). Through the identification of dominant species using the IVI, pivotal species such as *Pinus roxburghii* emerge, providing valuable insights into forest composition and structure (Maidu et al., 2016). The study utilizes Sentinel-2 imagery to analyze forest conditions between 2017 and 2022, attributing the decrease in dense forest area primarily to anthropogenic activities such as infrastructure development. Furthermore, the research explores the profound impact of anthropogenic activities on forest depletion, identifying forest fires, encroachment for agriculture, grazing, fodder collection, and the establishment of public parks as significant contributing factors alongside infrastructure development (Little, at al., 2018). Additionally, it considers natural hazards such as landslides as further exacerbating factors. Understanding the intricate interplay between natural and anthropogenic factors is essential for developing holistic conservation strategies that address the root causes of forest depletion while promoting sustainable forest management practices.

The assessment of disturbance within the three CFs reveals a concerning trend of degradation and habitat loss over the five-year period from 2017 to 2022. Okhardhara CF emerged as the most severely impacted, with infrastructure development, such as road construction, identified as a primary driver of disturbance. Similarly, Suntalidada CF exhibits considerable disturbance, indicating the pervasive nature of human-induced pressures on forest landscapes. The spatial distribution analysis of local disturbance factors provides valuable insights into the changing land cover dynamics within the study area. The observed decrease in dense forest area across all CFs, accompanied by an increase in cover types such as grassland, sparse vegetation, and infrastructure, underscores the escalating threats facing forest ecosystems. These alterations not only diminish biodiversity and habitat quality but also compromise ecosystem services vital for local communities, such as water regulation, carbon sequestration, and soil stability. The findings from Nepal's Terai region show that degraded community forests store approximately 50% less carbon than non-degraded ones, underscoring the climate mitigation value of maintaining forest condition (Joshi et al., 2020b). Understanding the extent and drivers of disturbances is essential for implementing effective management strategies aimed at mitigating further degradation and promoting ecosystem resilience. Finally, the study emphasizes the imperative for proactive conservation efforts to preserve the ecological integrity of forest ecosystems. By elucidating the complex relationships between forest structure, biodiversity, and environmental factors, the research offers valuable insights for evidence-based decision-making in sustainable forest management. It underscores the pivotal role of community involvement and stakeholder engagement in conservation initiatives, highlighting the indispensable contribution of local communities in safeguarding forest resources and promoting biodiversity conservation. These insights underscore the interdisciplinary nature of forest conservation and emphasize the importance of collaborative efforts among policymakers, researchers, and local communities to address the multifaceted challenges facing forest ecosystems in the Anthropocene.

5. Conclusion

Drawing upon the findings of this study, it is evident that stem density declines with increasing diameter classes, a phenomenon influenced by variations in diameter at breast height (DBH) and tree height across different sites. Notably, *Pinus roxburghii* emerged as the most prominent species, underscoring the necessity for targeted conservation efforts. The study highlights peak diversity indices during the pole stage, emphasizing the importance of adaptive management strategies to maintain habitat complexity and support diverse ecosystems. Despite variations in species distribution, there is a significant resemblance among the studied CFs, indicating the potential for collaborative management approaches. However, the analysis of Sentinel-2 images reveals a concerning trend of forest degradation, attributed to anthropogenic factors such as landslides, soil erosion, encroachment, and infrastructure development.

In response to these findings, several managerial implications become apparent. Firstly, targeted interventions such as prescribed logging, habitat restoration, and the promotion of natural regeneration are imperative to counteract forest degradation. Conservation efforts should prioritize not only the dominant species such as *Pinus roxburghii* but also aim to enhance overall biodiversity through targeted habitat management. Moreover, adaptive management approaches are essential to navigate the dynamic nature of forest ecosystems and maintain their resilience. Collaborative management efforts among neighboring forest communities can leverage shared resources and expertise to enhance conservation outcomes. Mitigating anthropogenic threats requires proactive measures including sustainable land-use planning, the enforcement of regulations, and community-based conservation initiatives. By prioritizing holistic management strategies that integrate ecological, social, and economic considerations, forest managers can ensure the long-term sustainability and vitality of community forests for future generations.

References

Acharya, S., Joshi, R., Maraseni, T.N., & Bhattarai, P. (2025). "Unraveling Elevation-Driven Variations in Forest Structure and Composition in Western Nepal". *Diversity*, *17*(8), 588. DOI: https://doi.org/10.3390/d17080588

Ahmad, A., Mirza, S.N., & Nizami, S.M. (2014). Assessment of biomass and carbon stocks in coniferous forest of Dir Kohistan, KPK. *Pakistan Journal of Agricultural Sciences*, *51*(2).

Ahmad, A., Mirza, S.N., & Nizami, S.M. (2014). Assessment of biomass and carbon stocks in coniferous forest of Dir Kohistan, KPK. *Pakistan Journal of Agricultural Sciences*, *51*(2), 345-350

Ashbindu, S. (1989). Digital change detection techniques using remotely sensed data. *International Journal of Remote Sensing, 10*(6), 989-1003.

Ayer, S., Joshi, R., Poudel, A., Prabhakar, A., Joshi, D.P., Poudel, S., Gautam, J., & Bhatta, K.P. (2024). "Quantifying Carbon Stock Variability and Aspect-Slope Impact in Sal and Pine-Dominated

Forests of Nepal". In *Forests and Climate Change: Biological Perspectives on Impact, Adaptation, and Mitigation Strategies* (pp. 709-730). Singapore: Springer Nature Singapore. DOI: https://doi.org/10.1007/978-981-97-3905-9_34

Baniya, B., Tang, Q., Koirala, M., Rijal, K., & Kattel, G. (2020). Growing Season Vegetation Dynamics Based on NDVI and the Driving Forces in Nepal during 1982- 2015. Forestry. *Journal of Institute of Forestry, Nepal, 17*, 1-22. DOI: https://doi.org/10.3126/forestry.v17i0.33619.

Bhandari, M. (2012). International Centre for Integrated Mountain Development. *The Wiley-Blackwell Encyclopedia of Globalization*. DOI: https://doi.org/10.1002/9780470670590.wbeog308.

Bhandari, M.P. (2025). *Environmental Transformation and Its Acceleration in Nepal from Known History to the Contemporary Situation*. CRC Press.

Bhattacharya, P. (2025). Forest biodiversity conservation. In *Textbook of Forest Science* (pp. 123-142). Singapore: Springer Nature Singapore. DOI: https://doi.org/10.1007/978-981-97-8289-5_7

Cottam, G., & Curtis, J.T. (1956). The use of distance measures in phytosociological sampling. *Ecology*, *37*(3), 451-460. DOI: https://doi.org/10.2307/1930167.

Feng, Q., Yang, H., Liu, Y., Liu, Z., Xia, S., Wu, Z., & Zhang, Y. (2025). Interdisciplinary perspectives on forest ecosystems and climate interplay: a review. *Environmental Reviews*, *33*, 1-21. DOI: https://doi.org/10.1139/er-2024-0010

Feroz, S.M., Kabir, M.E., & Hagihara, A. (2015). Species composition, diversity and stratification in subtropical evergreen broadleaf forests along a latitudinal thermal gradient in the Ryukyu Archipelago, Japan. *Global Ecology and Conservation*, *4*, 63-72. DOI: https://doi.org/10.1016/j.gecco.2015.05.002.

Fichtner, A., & Härdtle, W. (2021). Forest ecosystems: A functional and biodiversity perspective. In *Perspectives for Biodiversity and Ecosystems* (pp. 383-405). Cham: Springer International Publishing. DOI: https://doi.org/10.1007/978-3-030-57710-0_16

Hansen, A., Barnett, K., Jantz, P., Phillips, L., Goetz, S.J., Hansen, M., ... & De Camargo, R. (2019). Global humid tropics forest structural condition and forest structural integrity maps. *Scientific Data*, *6*(1), 232. DOI: https://doi.org/10.1038/s41597-019-0214-3

Huang, D., Zhou, Z., Zhang, Z., Dai, Q., Lu, H., Li, Y., & Huang, Y. (2025). Land Use/Land Cover Remote Sensing Classification in Complex Subtropical Karst Environments: Challenges, Methodological Review, and Research Frontiers. *Applied Sciences*, *15*(17), 9641. DOI: https://doi.org/10.3390/app15179641

Hui, G., Zhang, G., Zhao, Z., & Yang, A. (2019). Methods of forest structure research: A review. *Current Forestry Reports*, *5*(3), 142-154. DOI: https://doi.org/10.1007/s40725-019-00090-7

Jensen, J.R. (1983). Urban/suburban land use analysis. *Manual of Remote Sensing, second edition*, 1571-1666.

Joshi, P., Joshi, R., Maharjan, A., Panta, M., & Chand, P. (2023). Vegetation diversity, structure, composition and carbon stock of community managed forests of Mid-hills, Nepal. *Asian Journal of Forestry*, *7*(1), 29-36. DOI: https:// doi.org/10.13057/asianjfor/r070104

Joshi, R., Chhetri, R., & Yadav, K. (2019). "Vegetation Analysis in Community Forests of Terai Region, Nepal". *International Journal of Environment, 8*(3), 68-82. DOI: https://doi.org/10.3126/ije.v8i3.26667

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 Terai Region, Nepal. *European Journal of Ecology*, *7*(1), 26-39. DOI: https://doi.org/10.17161/eurojecol.v7i1.15005

Joshi, R., Singh, H., Chettri, R., Poudel, S., & Rijal, S. (2020b). Carbon Sequestration Potential of Community Forests: A Comparative Analysis of Soil Organic Carbon Stock in Community Managed Forests of Far-Western Nepal. *Eurasian Journal of Soil Science*, *10*(2), 96-104. DOI: https://doi.org/10.18393/ejss.825066

Joshi, R., Singh, H., Chhetri, R., & Yadav, R. (2020a). Assessment of Carbon Sequestration Potential in Degraded and Non-Degraded Community Forests in Terai Region of Nepal. *Journal of Forest and Environmental Science, 36* (2), 113-121. DOI: https://doi.org/10.7747/JFES.2020.36.2.113

Khadka, G.B., Mandal, R.A., & Mathema, A.B. (2019). Comparison Growing Stock, Carbon Stock and Biodiversity in and Around Banke National Park, Nepal. *International Journal of Botany*, *5*(3), 21-26. DOI: https://doi.org/10.20431/2455-4316.0504001.

Kumar, R., Kumar, A., & Saikia, P. (2022). Deforestation and forests degradation impacts on the environment. In *Environmental degradation: Challenges and strategies for mitigation* (pp. 19-46). Cham: Springer International Publishing. DOI: https://doi.org/10.1007/978-3-030-95542-7_2

Little, C.J., & Altermatt, F. (2018). Do priority effects outweigh environmental filtering in a guild of dominant freshwater macro-invertebrates?. *Proceedings of the Royal Society B: Biological Sciences*, *285*(1876), 20180205. DOI: https://doi.org/10.1098/rspb.2018.0205.

Mandal, R.A., Jha, P.K., Dutta, I.C., Thapa, U., & Karmacharya, S.B. (2016). Carbon sequestration in tropical and subtropical plant species in collaborative and community forests of Nepal. *Advances in Ecology*, *2016*(1), 1529703. DOI: https://doi.org/10.1155/2016/1529703.

Mir, Y.H., Mir, S., Ganie, M.A., Bhat, J.A., Shah, A.M., Mushtaq, M., & Irshad, I. (2025). Overview of land use and land cover change and its impacts on natural resources. In *Ecologically mediated development: Promoting biodiversity conservation and food security* (pp. 101-130). Singapore: Springer Nature Singapore. DOI: https://doi.org/10.1007/978-981-96-2413-3_5

Mitchell, J.C., Kashian, D.M., Chen, X., Cousins, S., Flaspohler, D., Gruner, D.S., ... & Buma, B. (2023). Forest ecosystem properties emerge from interactions of structure and disturbance. *Frontiers in Ecology and the Environment*, *21*(1), 14-23. DOI: https://doi.org/10.1002/fee.2589

Myers, N. (1997). The world’s forests and their ecosystem services. *Nature's Services: societal dependence on natural ecosystems*, 215-235.

Naidu, M.T., & Kumar, O.A. (2016). Tree diversity, stand structure, and community composition of tropical forests in Eastern Ghats of Andhra Pradesh, India. *Journal of Asia-Pacific Biodiversity*, *9*(3), 328-334. DOI: https://doi.org/10.1016/j.japb.2016.03.019.

Paudel, P.K., Khatiwada, A.P., & Ghimirey, Y. (2022). Lens for Biodiversity Conservation in Nepal: Status, Challenges and Way Forward. *Society for Conservation Biology Nepal, Kathmandu, Nepal*.

Quijas, S., Schmid, B., & Balvanera, P. (2010). Plant diversity enhances provision of ecosystem services: A new synthesis. *Basic and Applied Ecology*, *11*(7), 582-593. DOI: https://doi.org/10.1016/j.baae.2010.06.009.

Raskoti, B.B. (2009). The Orchids of Nepal. Quality Printers, Kathmandu, Nepal, 252.

Ruiz-Benito, P., Gómez-Aparicio, L., Paquette, A., Messier, C., Kattge, J., & Zavala, M.A. (2014). Diversity increases carbon storage and tree productivity in S panish forests. *Global Ecology and Biogeography*, *23*(3), 311-322. DOI: https://doi.org/10.1111/geb.12126.

Silva, C.A., Klauberg, C., Hudak, A.T., Vierling, L.A., Liesenberg, V., Bernett, L.G., & Schoeninger, E.R. (2018). Estimating Stand Height and Tree Density in *Pinus taeda* plantations using in-situ data, airborne LiDAR and k-Nearest Neighbor Imputation. *Anais da Academia Brasileira de Ciencias*, *90*(01), 295-309. DOI: https://doi.org/10.1590/0001-3765201820160071.

Singh, B., Verma, A.K., Tiwari, K., & Joshi, R. (2023). Above Ground Tree Biomass Modeling Using Machine Learning Algorithms in Western Terai Sal Forest of Nepal. *Heliyon, 9*(11), e21485. DOI: https://doi.org/10.1016/j.heliyon.2023.e21485

Singh, M., Shahina, N.N., Das, S., Arshad, A., Siril, S., Barman, D., ... & Chakravarty, S. (2022). Forest resources of the world: present status and future prospects. *Land Degradation Neutrality: Achieving SDG 15 by Forest Management*, 1-23. DOI: https://doi.org/10.1007/978-981-19-5478-8_1

Stainton, A. (1988). Flowers of Himalaya: A Supplement. Oxford University Press, Delhi, 86.

Strong, W.L. (2016). Biased richness and evenness relationships within Shannon–Wiener index values. *Ecological indicators*, *67*, 703-713. DOI: https://doi.org/10.1016/j.ecolind.2016.03.043.

Thakur, P., Joshi, R., Bhatta, S., Ghimire, S., & Silwal, R. (2024). Computing Above-Ground Carbon Stocks Using Ground-Based and Sentinel Imagery Approach. In *Forests and Climate Change: Biological Perspectives on Impact, Adaptation, and Mitigation Strategies* (pp. 771-787). Singapore: Springer Nature Singapore. DOI: https://doi.org/10.1007/978-981-97-3905-9_37

Toivonen, J., Kangas, A., Maltamo, M., Kukkonen, M., & Packalen, P. (2023). Assessing biodiversity using forest structure indicators based on airborne laser scanning data. *Forest Ecology and Management, 546,* 121376. DOI: https://doi.org/10.1016/j.foreco.2023.121376

Xu, J., Badola, R., Chettri, N., Chaudhary, R.P., Zomer, R., Pokhrel, B., ... & Pradhan, R. (2019). Sustaining biodiversity and ecosystem services in the Hindu Kush Himalaya. In *The Hindu Kush Himalaya assessment: Mountains, climate change, sustainability and people* (pp. 127-165). Cham: Springer International Publishing. DOI: https://doi.org/10.1007/978-3-319-92288-1_5

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ارزیابی ساختار جنگل و تنوع زیستی در جنگل‌های اجتماعی و توزیع مکانی اختلالات محلی

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چکیده

مطالعه ساختار و تنوع زیستی جنگل‌های اجتماعی، همراه با بررسی آسیب‌پذیری آن‌ها در برابر اختلالات محلی، هم در سطح محلی و هم در سطح جهانی بسیار محدود است. بنابراین، این مطالعه با هدف ارزیابی ساختار جنگل و تنوع زیستی در جنگل‌های اجتماعی و تحلیل توزیع مکانی اختلالات محلی انجام شد. برای این منظور، سه جنگل اجتماعی – بانلپوکاری، اوکارداره و سونتالیدادا – واقع در شهرداری گوداواری، نپال، به عنوان مناطق مطالعاتی انتخاب شدند. تفاوت اصلی میان این سه جنگل اجتماعی در شیوه‌های مدیریت جنگل و میزان وابستگی محلی به منابع جنگلی است. هر سه جنگل اجتماعی در ارتفاعات مشابه قرار دارند که منجر به عوامل محلی مشابه و در نهایت توزیع گونه‌ای و تنوع زیستی مشابه می‌شود. در این پژوهش از روش نمونه‌برداری تصادفی منظم استفاده شد و ۹۰ قطعه نمونه در سه جنگل اجتماعی احداث گردید. این قطعات نمونه شامل مناطق دایره‌ای با مساحت ۵۰۰ متر مربع برای درختان، ۱۰۰ متر مربع برای نهال‌های متوسط و ۲۵ متر مربع برای نهال‌های کوچک بود که قطر و ارتفاع گیاهان در مراحل مختلف رشد اندازه‌گیری شد. همچنین قطعات نمونه کوچک‌تر ۱۰ متر مربعی برای شمارش دانهال‌ها در نظر گرفته شد. اختلالات جنگلی از طریق مشاهدات مستقیم میدانی شناسایی شدند و شامل عواملی مانند توسعه جاده، خطوط انتقال، فرسایش خاک، تجاوز، بیماری، علف‌های هرز، تفریح و قطع غیرقانونی درختان بود. از تصاویر ماهواره‌ای Sentinel-۲A برای سال‌های ۲۰۱۷ و ۲۰۲۲ استفاده شد. شاخص‌های تنوع زیستی از جمله شاخص ارزش اهمیت (IVI) محاسبه شدند. مقادیر شاخص تفاوت نرمال‌شده پوشش گیاهی (NDVI) از تصاویر استخراج و متعاقباً برای نقشه‌برداری طبقه‌بندی استفاده شدند. نتایج نشان داد که Pinus roxburghii شایع‌ترین گونه در هر سه جنگل اجتماعی بود. به طور خاص، جنگل اجتماعی اوکارداره بالاترین IVI را برای P. roxburghii با مقدار ۲۸۱.۲۵ نشان داد. در مورد شاخص تنوع شانون-وینر (H')، جنگل اجتماعی سونتالیدادا بالاترین تنوع (۳.۵۲) را نشان داد که جنگل اجتماعی اوکارداره (۳.۲۲) و جنگل اجتماعی بانلپوکاری با کمترین تنوع (۱.۹۵) در رتبه‌های بعدی قرار داشتند. همچنین، جنگل اجتماعی سونتالیدادا بالاترین سطح یکنواختی (۰.۹۶) و غنای گونه‌ای (۲۵) را نشان داد. در مورد ساختار جنگل، بیشترین تراکم در کلاس قطری ۰-۱۰ سانتی‌متر و کلاس ارتفاعی ۰-۵ متر مشاهده شد. در مقابل، کمترین تراکم در کلاس قطری بیش از ۴۰ سانتی‌متر و کلاس ارتفاعی بالای ۲۰.۱ متر یافت شد. در هر سه جنگل اجتماعی، عوامل مؤثر بر ساختار جنگل و تنوع زیستی شامل توسعه جاده، خطوط انتقال، فرسایش خاک، تجاوز، بیماری، علف‌های هرز، تفریح و قطع غیرقانونی درختان بود. مساحت جنگل متراکم در جنگل‌های اجتماعی بانلپوکاری، اوکارداره و سونتالیدادا در سال ۲۰۱۷ به ترتیب ۷۱.۹۲ هکتار، ۷۲.۲۰ هکتار و ۱۰۴.۶۹ هکتار اندازه‌گیری شد. با این حال، تا سال ۲۰۲۲، این مناطق به جنگل‌های پراکنده تبدیل شده بودند که به ترتیب ۶۵.۶۳ هکتار، ۵۶.۸۳ هکتار و ۹۲.۳۴ هکتار اندازه‌گیری شدند. این نشان‌دهنده نرخ کاهش تقریبی ۹٪، ۱۹٪ و ۱۱٪ برای سه جنگل اجتماعی در طول دوره پنج‌ساله است.

واژه‌های کلیدی: جنگل‌های اجتماعی، اختلال، شاخص تنوع، ساختار جنگل، Sentinel-۲A.

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