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Elevational Zonation of Carbon Storage and Tree Diversity in Central Himalayan Community Forests for REDD+ and Biodiversity Conservation

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Abstract

Background: Climate change, driven largely by anthropogenic greenhouse gas emissions, has placed forest biomass and carbon management at the forefront of global mitigation strategies. In Nepal, there are a total of 23,026 community forestry user groups (CFUGs) covering 20% of the forested area and are critical to rural livelihoods, understanding the interplay between carbon stocks, biodiversity, and elevation is essential for the initiatives like REDD+ carbon financing.

Methods: This study investigates aboveground the dynamics of biomass, carbon stock, and tree species diversity along an elevational gradient in Nepal. Data from permanent sample plots in community forests were used and analyzed using R software.

Results Results reveal significant altitudinal variation as the biomass stocks were highest at lower elevations (500-1000 masl), peaking at 344.97 t ha^{-1}, while tree density peaked at 1600 ind ha^{-1} in the 2000-3000 m.a.s.l range. Species dominance shifted from *Shorea robusta* in lowlands to mixed *Quercus* and *Rhododendron* assemblages at mid-elevations, and to conifers species above 2000 m.a.sl. Species dominance shifted from *Shorea robusta* at low elevations to mixed *Quercus-Rhododendron* and then conifers at higher elevations.

Conclusion: These findings highlight that carbon-biodiversity relationships are not uniform but are mediated by elevation-specific ecological filters.

Novelty: This study provides an evidence for designing REDD+ interventions, emphasizing that effective forest carbon policy in Nepal must integrate elevation-specific conservation strategies to synergize climate mitigation with biodiversity co-benefits in the long run.

Keywords: Biomass, Carbon stock, Community forestry, Elevation, REDD+ initiatives.

Introduction

Climate change driven by anthropogenic greenhouse gas (GHG) emissions has elevated forests (and the broader AFOLU sector) to a central role in climate mitigation because they offer opportunities for both emissions reductions and enhanced removals (IPCC, 2022). Land-use change, particularly deforestation and forest degradation, has historically contributed a substantial share of global anthropogenic GHG emissions, accounting for approximately 23% during 2007–2016 and about 13% during the same period when only net land-use emissions are considered (IPCC, 2019). This underscores the relevance of forest-based mitigation and carbon finance mechanisms. In response, initiatives such as Reducing Emissions from Deforestation and Forest Degradation (REDD+) have been designed not only to reward emission reductions and carbon storage, but also to promote and support safeguards and deliver broader non-carbon co-benefits, including biodiversity conservation and livelihood support, particularly where local communities and indigenous peoples govern and manage forest resources (UNFCCC,2025).

Nepal is a forest-rich country, with forests and other wooded lands covering 44.74% of its total land area, of which 40.36% is classified as forest cover (DFRS 2015). Forest distribution varies markedly across physiographic regions: the Hill region contains the largest share of forest area, followed by the Mountain and Terai regions. Historical assessments indicate that Nepal experienced significant deforestation during the late twentieth century, particularly in the Terai and Siwaliks, driven mainly by resettlement programs, agricultural expansion, and illegal timber extraction (NFI 1999). In contrast, lower rates of deforestation in the Hills are widely attributed to the success of the community forestry (CF) programme, which has become the dominant forest management regime in the country. Although precise national estimates of CO_2 emissions from deforestation and forest degradation remain uncertain, earlier assessments suggest that the land-use sector has been a substantial source of emissions, underscoring the potential importance of forest-based mitigation initiatives such as REDD+ in Nepal.

Forests are deeply embedded in the livelihoods of Nepal's rural population, particularly in the Hill region, where community forestry provides timber, fuelwood, fodder, and other ecosystem services. Ecologically, Nepal is exceptional due to its pronounced altitudinal gradient, extending from lowland tropical forests to alpine ecosystems within a short latitudinal span.

This gradient, among the steepest in the world (Grytnes and Vetaas 2002), combined with strong east–west climatic variation, supports high biodiversity, including 118 ecosystems, 75 vegetation types, and 35 forest types (Olson and Dinerstein 1998). Such environmental heterogeneity makes Nepal an important natural laboratory for examining how forest structure, biomass, carbon stocks, and species composition vary across elevation. Climate change is expected to further alter forest ecosystems through shifts in species distributions, changes in community composition, and modified ecosystem processes, with implications for both carbon dynamics and rural livelihoods.

The Government of Nepal (GoN), through the Ministry of Forests and Environment (MoFE), has been an active participant in REDD+, including engagement through the global initiatives like the Forest Carbon Partnership Facility (FCPF) and the UN-REDD Programme. This commitment has progressed significantly with major milestones. Notably, Nepal signed an Emission Reductions Payment Agreement (ERPA) with the World Bank's Forest Carbon Partnership Facility (FCPF) Carbon Fund in February 2021, which unlocked up to US$45 million for verified emission reductions under Nepal's REDD+ Emission Reductions Program in the Terai Arc Landscape (World Bank, 2021), which enabled results-based payments for verified emission reductions under a national REDD+ framework, with benefits shared with local and community forest stakeholders through established benefit-sharing mechanisms. Nepal later received its first results-based payment of US$9.4 million for reducing approximately 1.88 million tCO_2 under this program (World Bank, 2025). In addition, Nepal submitted its national Forest Reference Level (FRL) to the UNFCCC in 2017 (UNFCCC, 2017), and its first comprehensive National REDD+ Strategy (2025–2034) was submitted to the UNFCCC in July 2025 (UNFCCC, 2025). These developments underscore the importance of robust forest monitoring and credible baseline data to quantify emission reductions and guide benefit sharing under REDD+.

To address the critical need for baseline information, the government, with support from initiatives like the Sustainable Forest Management (SFM) Project and Forestry and Climate Change (FCC) Project, has significantly enhanced its national forest monitoring system including the completion of the Second National Forest Inventory (NFI, 2015) and the ongoing Third National Forest Inventory (NFI-3), which systematically collects data on forest carbon stocks across the country(DFRS, 2015; MoFE, 2021). However, granular, local-scale baseline data on forest carbon stock and its correlation with biodiversity and other co-benefits across spatial patterns, such as altitudinal gradients, remains a gap for sub-national planning (IPBES, 2019; Körner, 2007). Research such as this study is therefore crucial, as it provides the precise, stratified local scale evidence needed to refine national benchmarks, support validation of remote-sensing-based estimates, and inform targeted, equitable, and effective REDD+ interventions that deliver both climate mitigation and biodiversity co-benefits. Local baseline information on forest carbon stocks is essential and understanding how carbon stocks co-vary with associated co-benefits such as biodiversity across key spatial gradients (e.g., altitudinal gradients) is equally important (FAO, 2013; Phelps et al., 2010). Such evidence is a critical first step for the Government of Nepal in planning and prioritizing future forest carbon interventions, including REDD+.

Research Objective

The specific objectives of this study are to:

- estimate the above and below ground biomass in different elevations of community forests of the central Himalayas and;
- develop the relationship between biomass, tree species diversity, and species composition.

Review of literature

Forest carbon dynamics along elevational gradients are a subject of global research, often revealing non-linear patterns. Studies in the Andes and the European Alps have documented mid-elevation peaks in biomass and diversity, influenced by climatic optima and historical disturbance (Moser et al., 2022; Sánchez-Cuervo et al., 2020). In the Himalayas, research has established the critical role of community forestry in enhancing forest cover and provisioning ecosystem services (Bhusal et al., 2021). Recent national-scale assessments in Nepal have improved carbon stock estimates but often lack the granularity to resolve complex elevation-specific interactions (DFRS, 2015).

Specific to carbon-biodiversity links, contemporary studies suggest context-dependent relationships. A global meta-analysis by Liang et al. (2022) found that tree diversity can positively correlate with carbon storage, particularly in heterogeneous environments, by promoting niche complementarity. In Nepal, Pandey et al. (2023) reported that community-managed forests in the mid-hills stored substantial carbon while maintaining higher species richness compared to state-managed forests. However, Ghimire et al. (2021) noted that the strength of the carbon-diversity relationship weakened at higher elevations in a protected area of eastern Nepal, likely due to environmental stress filters.

Recent literature highlights a significant gap: while the success of community forestry is acknowledged, and national carbon inventories exist, integrated analyses of how carbon and biodiversity co-vary across the full elevational spectrum within community-managed landscapes are scarce (Bhattarai et al., 2022). This study directly addresses this gap by providing an elevation-stratified analysis, offering locally relevant data crucial for validating remote sensing products and tailoring REDD+ interventions that deliver both climate and biodiversity co-benefits.

Methods

2.1 Study area

This study was carried out in the community managed forests (CFs) in Dolakha and Chitwan district namely Charnawati and Kayarkhola watersheds situated in Bagmati Province of Nepal (Figure1). Where, Kayarkhola watershed spans the Siwalik and Hill regions and Charnawati watershed extends across the Hill and Mid-mountain regions. General information on the two watersheds is provided in Figure 1.

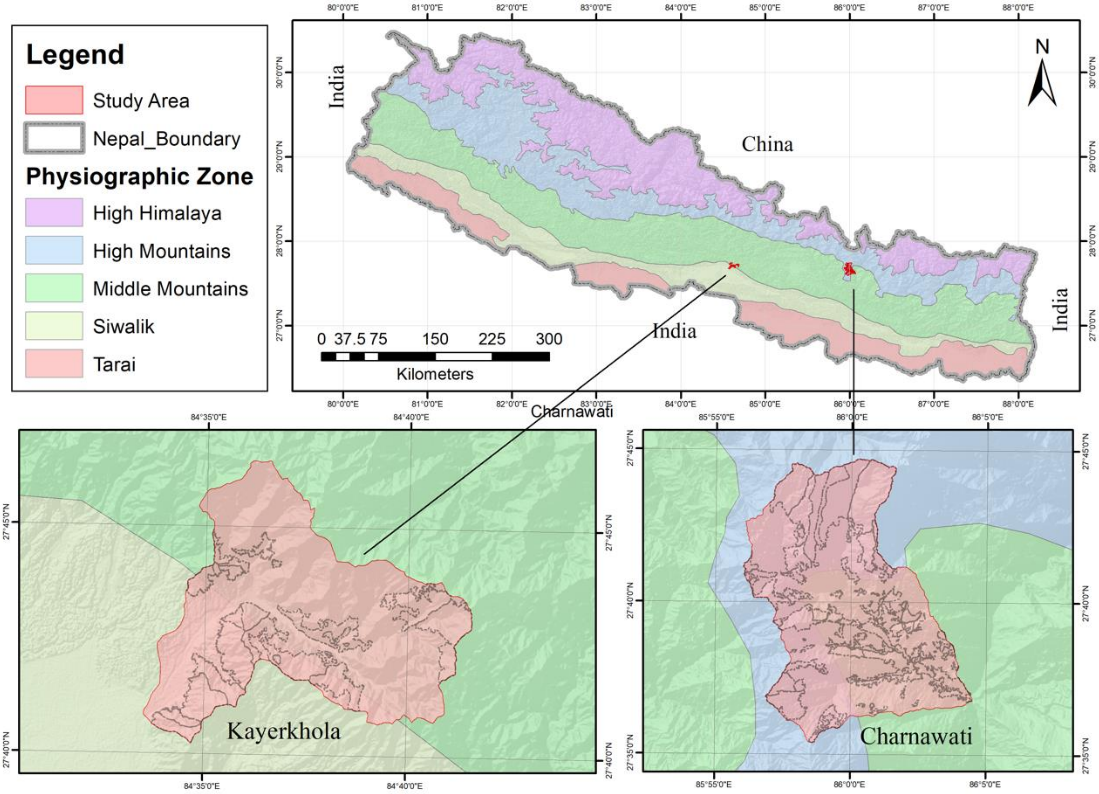

Figure 1: Location of the study sites in Nepal

Vegetation analysis

We conducted a random sampling in the permanent plots in community forests (CFs) located in two watersheds in the Central and Western Development Regions of Nepal, representing the Siwalik, Hill, and Middle Mountain physiographic zones. We capture variation in tree biomass, circular permanent sample plots (each 250 m², radius 8.92 m) were established across the study watersheds. A total of 80 plots were laid out, including 30 plots in the Charnawati watershed and 50 plots in the Kayerkhola watershed. Plot locations were randomly selected using maps and subsequently established in the field. Within each plot, tree species were identified, and diameter at breast height (dbh) and tree height were measured for all trees with dbh ≥ 5 cm.

Diameter was recorded using a diameter tape, while tree height was measured using clinometers and linear tape or a Vertex-IV hypsometer with transponder. All fieldwork were conducted between March and June 2020.

Forest tree biomass and carbon

Tree allometric equations developed by Chave et al. (2005) were applied to mean diameter at breast height (dbh), tree height, and wood-specific gravity of each species to estimate the biomass stock of individual tree components. Biomass for each sampling plot was calculated by summing the biomass (kg) of all trees within the plot and dividing by the plot area (250 m^2), yielding biomass density in kg m^{-2}. This value was subsequently converted to tonnes per hectare (t ha^{-1}) by multiplying by 10. As the study sites are located in the tropical region, tree biomass was converted to carbon stock using the default carbon fraction of 0.47, following IPCC (2006) guidelines.

Tree species diversity

The study focused the trees with ≥5 cm dbh to compare tree species diversity and tree carbon stock along the physiographic gradients. Quantified importance value indices (IVI) following (Newton, 2007). The importance value index, that combines frequency, density and dominance values, has been widely used to measure species composition (Mclaren et. al 2005). The importance value index was calculated using the following equation provided by Husch et al. (2003).

Results

Vegetation parameters

The Analysis of vegetation structure across elevational gradients revealed significant variation in both tree density and basal area. The highest tree density (4,720 individuals ha^{-1}) was recorded between 2,000–3,000 m above sea level (masl), whereas maximum basal area (121.97 m^2 ha^{-1}) occurred at 1,000-2,000 masl. In contrast, the lowest values for both parameters were observed at 500-1,000 masl, with tree density of 120 individuals ha^{-1} and basal area of 0.71 m^2 ha^{-1} (Table 1). Elevations below 500 masl exhibited a significant relationship with both tree density and basal area.

Species importance value index (IVI) showed a declining trend with increasing elevation. *Shorea robusta* (Sal) emerged as the dominant species up to 1,000 masl, contributing maximally to basal area and IVI. Above this threshold, *Rhododendron arboreum* (Guras) and *Schima wallichii* (Chilaune) dominated the forest community between 1,000 to 3,000 masl.

Table 1: Vegetation characteristics

Altitude (mt)	Tree density (No. ha^{-1})			Basal area (m^2 ha^{-1})			Biomass (t DM ha^{-1})		
	Minimum	Mean ± SE	Maximum	Minimum	Mean ± SE	Maximum	Minimum	Mean ± SE	Maximum
<500	240	1400.95 ± 92.05^{ab}	4160	2.12	28.08 ± 2.09^{a}	90.95	4.40	272.94 ± 27.42^{a}	1084.7
500-1000	120	829.40 ± 58.32^{c}	3000	0.71	31.16 ± 1.86^{ab}	79.53	1.20	344.97 ± 29.94^{a}	1056.5
1000-2000	80	1153.06 ± 87.64^{a}	4200	0.00	24.30 ± 1.81^{c}	121.97	0.00	138.54 ± 13.08^{b}	714.1
2000-3000	160	1600.40 ± 101.64^{b}	4720	3.04	36.04 ± 1.80^{b}	88.60	4.83	158.60 ± 11.66^{b}	508.3

The superscript letters in mean value indicate significant differences in parameters between the altitudinal gradient computed by Welch Two Sample t-test ($p = <0.05$).

Tree biomass and tree carbon stock

Total tree biomass varied significantly across elevational gradients, ranging from 508.39 to 1,084.71 t ha^{-1} (Table 2). Statistically significant differences in biomass were observed between elevation classes, particularly below 500 masl and 500 to 1,000 masl, as well as between 1,000 to 2,000 masl and 2,000 to 3,000 masl. Correspondingly, carbon stock followed a similar pattern, ranging from 238.94 to 509.81 t C ha^{-1} across the elevational gradient (Figure 2).

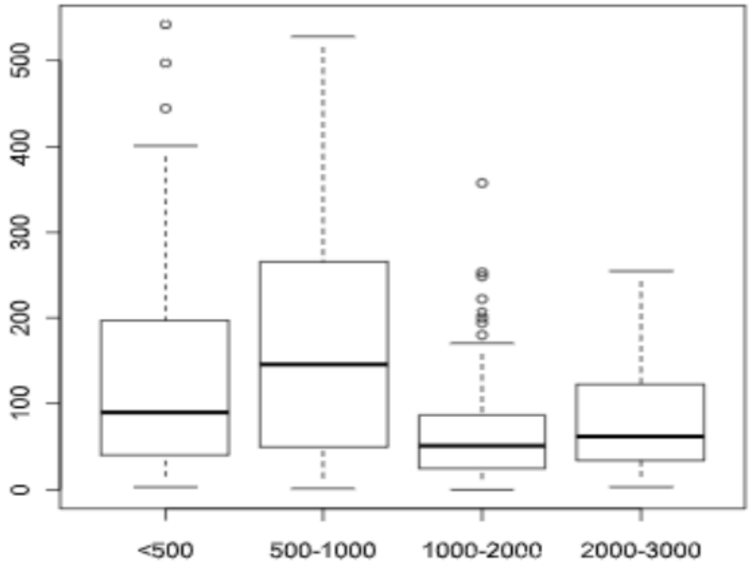

Figure 2: Box and whisker plot for above ground carbon stock

Forest tree species diversity

Elevational gradients influenced tree species diversity, though the pattern was not uniform across all elevations. Species richness decreased monotonically from 1,000 to 2,000 m to 2,000–3,000 m above sea level. However, below 500 m, a gradual increase in diversity was observed (Figure 3). Despite these trends, the relationship between elevation and species diversity was not statistically significant (P = 0.8699 for elevations <500 masl; Table 2). Overall, tree species diversity declined with increasing elevation across the study gradient.
In this study we found that the tree species diversity decreased or changed according to the elevational gradient**,** the tree species diversity decreased with increasing elevational range

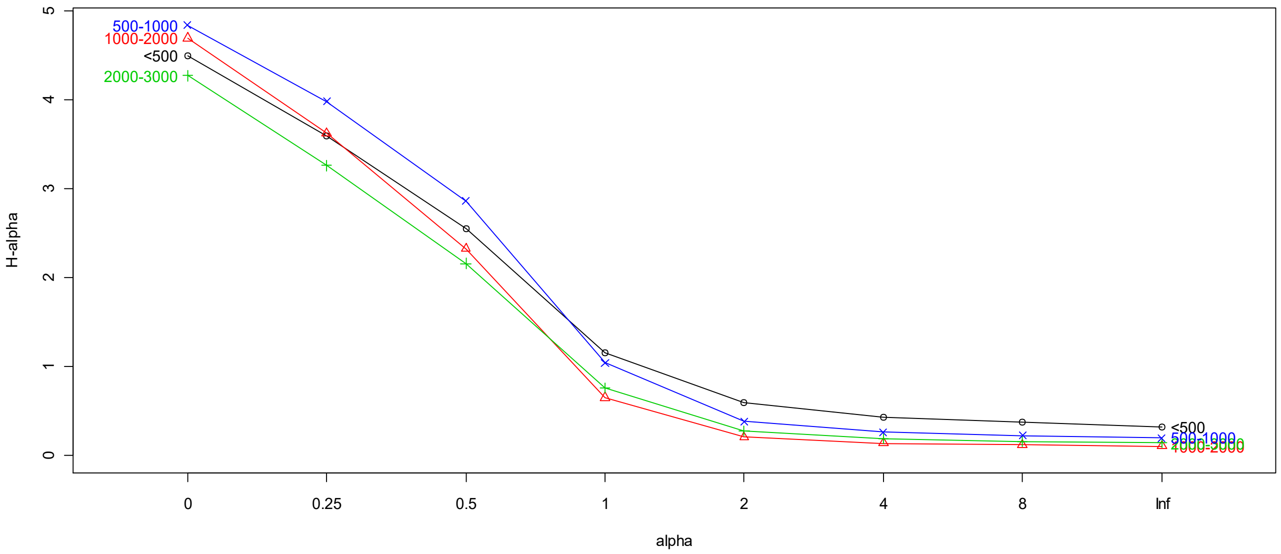

Figure 3: Comparison of diversity profiles of trees (≥5 cm dbh) in the study sites

Species area curve

The Species area curves were generated from species richness calculated across all possible quadrat combinations (Figure 4). This relationship connects biodiversity with geographical space; larger areas support more species due to both sampling effects (more samples representing larger areas) and ecological processes such as island biogeography, habitat heterogeneity, succession, species–energy dynamics, target-area effects, incidence functions, and small-island habitat characteristics, including disturbance.

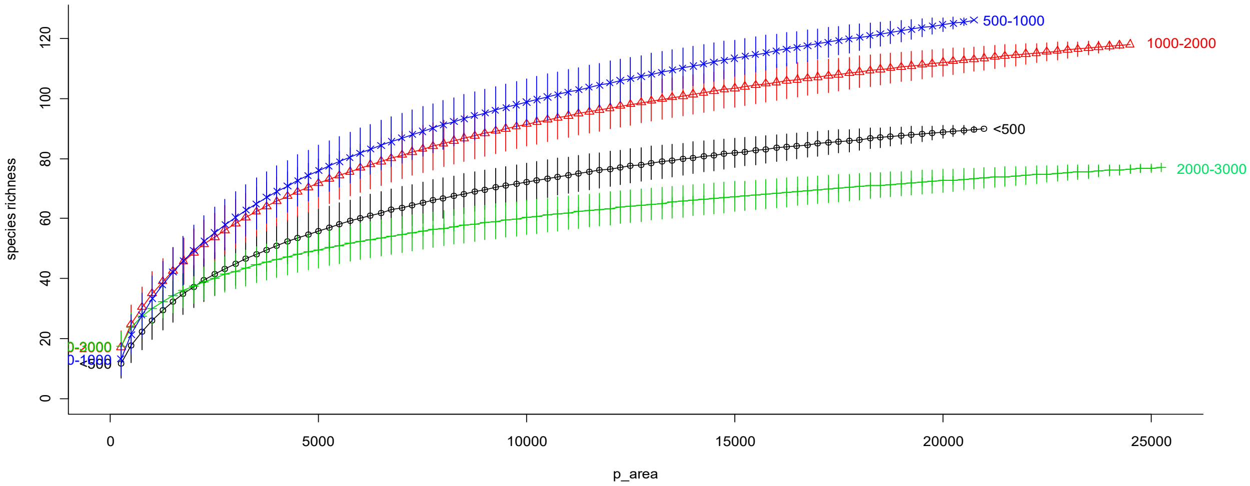

Figure 4: Species area curve in the study sites

Species importance value

Tree Importance Value Index (IVI) across elevational gradients in two central Himalayan watersheds revealed distinct ecological stratification shaped by temperature, moisture, and biotic interactions. Below 1,000 m, warm-humid conditions favoured for *Shorea robusta* with high IVI scores. At 1,000- 2,000 m, mixed forests emerged with peak IVI for oaks and pines, reflecting optimal growing conditions and niche partitioning. Above 2,000 m, conifers (*Abies, Picea*) dominated, though IVI declined due to harsher climates, while *Rhododendron* maintained ecological importance at timberline (Figure 5).

This gradient represents functional responses to environmental filters: lower elevations exhibit dominance by few robust taxa, mid-elevations show balanced species packing, and higher elevations reflect filtering of stress-tolerant species. IVI profiles identify keystone species for ecosystem stability, nutrient cycling, and habitat provision at each elevation. Under climate change, this elevational IVI distribution serves as a baseline to predict species shifts, invasions, and biome transitions, offering critical insights for conservation planning and climate-resilient forest management in the Himalayas.

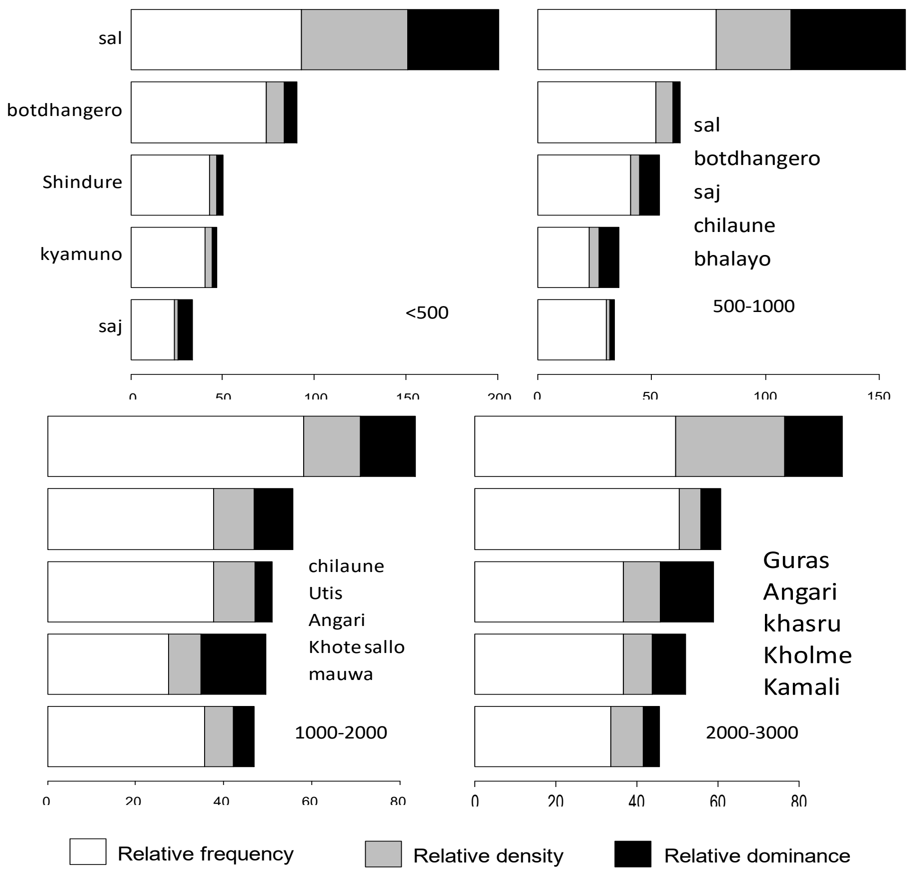

Figure 5: Species area curve

Tree species diversity, carbon stock and elevation

The relationships between species diversity, biomass, and carbon stocks varied distinctly across elevational gradients, with critical implications for carbon sink management (Table 2). At low elevations (<500 m), altitude showed a significant positive relationship with carbon stock ($p=0.002$), though with low explanatory power ($R^2=0.11$), indicating subtle carbon increases with elevation. In mid-elevations (500–1,000 m), altitude correlated negatively with forest height ($p=0.016$), suggesting structural transition, but showed no link to carbon. At 1,000–2,000 m, forest height and carbon exhibited a marginally significant positive relationship ($p=0.054$)—the strongest in the gradient—implying that height predicts carbon better in temperate forests, while altitude-carbon turned weakly negative. Above 2,000 m, a significant but weak positive altitude-carbon relationship re-emerged ($p=0.030$), reflecting alpine conifer dominance, though height-carbon turned negative, indicating structural decoupling from environmental stress.

Critically, all models exhibited very low explanatory power ($R^2 < 0.11$), underscoring that carbon stocks are governed by complex interactions of species composition, climate, and disturbance rather than single-factor linear relationships. Ecological drivers of forest carbon shift fundamentally across elevations: mid-elevations show strongest structural control, while low and high zones are more influenced by altitude-related environmental filters.

Table 2. Relationship between tree species diversity, carbon stock and elevation.

		Diversity and **CStock**		**Alti** and **CStock**		**Alti** and **Species diversity**
<500		y = 0.016x + 0.844		y = 0.017x - 3.614		y = -0.000x + 0.949
	R^2	0.017		0.109		**0.000**
	R^2Adj.	0.005		0.098		-0.012
	P	0.233		**0.002**		0.870
500-1000		y = 0.011x + 0.789		y = 0.000x + 3.899		y = -0.000x + 1.459
	R^2	0.008		0.0001		0.069
	R^2Adj.	-0.005		-0.0112		0.058
	P	0.433		0.830		**0.016**
1000-2000		y = 0.046x + 0.417		y = -0.001x + 3.382		y = -0.000x + 0.785
	R^2	0.039		0.033		0.018
	R^2Adj.	0.028		0.023		0.008
	P	0.054		0.076		0.189
2000-3000		y = -0.017x + 0.550		y = 0.001x - 0.732		y = 0.000x + 0.198
	R^2	0.011		0.040		0.020
	R^2Adj.	0.001		0.030		0.010
	P	0.288		**0.030**		0.162

Discussion

The findings of this study reveal complex and non-linear relationships among elevation, forest structure, carbon stocks, and biodiversity in Nepal's community forests, offering critical insights for forest management and climate policy. The observed peak in aboveground carbon stocks at lower elevations (<1000 masl) aligns with the high productivity of tropical and subtropical forests dominated by *Shorea robusta*, a species characterized by high wood density and large basal area, which together enhance biomass accumulation (Chave et al., 2014). This pattern is further supported by the high importance value index (IVI) of *S. robusta* in this elevation zone, underscoring its dominant contribution to stand-level carbon storage. Conversely, the highest tree density in the 2000–3000 masl range, coupled with lower biomass, indicates a stand structure characterized by smaller, stress-adapted species a typical pattern in high-elevation temperate and subalpine forests where environmental harshness limits individual tree size but not necessarily stem count (Singh et al., 1994). This analysis of community forests across Nepal's central Himalayan elevation gradient reveals a fundamental ecological trade-off shaped by climate, species traits, and management history. While tree density significantly increases with elevation peaking at 1,600 stems ha^{-1} in the 2,000–3,000 m zone due to stress-adapted, smaller trees aboveground biomass shows an inverse and dramatic decline, falling by over 50% from the productive lowlands (<1,000 m; 273–345 t ha^{-1}) to the higher zones. This trade-off reflects the combined influence of climate, species functional traits, and long-term management history in shaping forest carbon dynamics.

The observed shift in species composition along the elevational gradient from *Shorea robusta* dominance at lower elevations to mixed broadleaf–conifer stands and ultimately to Rhododendron and conifer dominance at higher elevations—mirrors well-documented biome transitions driven by declining temperature and changing moisture regimes (Grytnes & Vetaas, 2002). The IVI profiles provide a quantitative fingerprint of these transitions, demonstrating how ecological dominance shifts from a small number of highly competitive species in lowland forests to a more environmentally filtered assemblage of stress-tolerant species at higher elevations (Curtis & McIntosh, 1951; Grytnes & Vetaas, 2002). This sharp gradient underscores that carbon storage is disproportionately concentrated in lower-elevation forests, particularly those dominated by high wood-density *Shorea robusta*, consistent with the strong influence of wood density and stand structure on biomass accumulation (Chave et al., 2009; Chave et al., 2014).

A distinctive and critical finding is the significant mid-elevation (1,000–2,000 m) decline in biomass, which deviates from the unimodal elevation-biomass patterns often reported in less-disturbed mountain systems (Körner, 2007; Ensslin et al., 2015). This depression in biomass is likely linked to a legacy of higher anthropogenic pressure in these more accessible landscapes, where repeated extraction and disturbance may have maintained forests in younger or structurally simplified successional stages (Martin et al., 2015). These results confirm that drivers of forest carbon storage are neither uniform nor purely climatic, but are jointly shaped by elevation-specific ecological constraints and human influence. Consequently, effective REDD+ and forest management policies must adopt a stratified approach: prioritizing conservation of high-carbon Sal forests in the lowlands, enhancing restoration and structural complexity in the utilized mid-hills, and preserving the high-density, high-elevation forests primarily for their biodiversity, watershed regulation, and resilience functions.

Our results indicate that mid-elevation forests, while having moderate carbon stocks, host the most balanced species composition and the strongest positive relationship between forest height and aboveground carbon among elevation zones. This pattern suggests that structural complexity, rather than stem density alone, plays a key role in regulating carbon storage in these forests, consistent with ecological theory that niche complementarity in diverse stands enhances total ecosystem carbon capture (Liang et al., 2016).

The regression analysis reveals the context-dependency of carbon drivers. The significant but weak positive relationship between altitude and carbon at the highest and lowest elevations suggests that broad-scale environmental gradients (temperature, precipitation) set the potential carbon ceiling, but within-zone variation is governed by other additional biotic and management-related factors. The absence of a strong, consistent relationship between forest height (a proxy for structure) and carbon across all zones, except the mid-elevation belt, is particularly informative. This pattern implies that allometric relationships and wood density vary significantly among the functional types that dominate different elevations (e.g., light-wooded pioneers at high elevations vs. dense-wooded climax species at low elevations) (Chave et al., 2014). These results indicate that forest structure–carbon relationships are elevation specific and decoupling challenges the use of simple, universal predictive models for carbon estimation in topographically complex regions like the Himalayas (Asner et al., 2010).

The low R^2 values across all regression models are a crucial result, indicating that single-factor explanations are insufficient to explain spatial variation in forest carbon stocks. Carbon stock at any given point is likely the product of a complex interaction between historical disturbance (e.g., community forestry practices), edaphic factors, microclimate, species functional traits, and current stand age, rather than a single dominant driver (IPCC, 2019; Poorter et al., 2015). This complexity presents both a challenge and an opportunity for REDD+ implementation. It is a challenge because simplistic, plot-scale carbon assessments may fail to capture the processes that underpin long-term carbon stability. At the same time, it represents an opportunity to promote more holistic, landscape-scale REDD+ planning approaches that explicitly integrate biodiversity conservation and watershed protection, which can enhance ecosystem resilience and support sustained carbon storage over time (IPCC, 2019; FAO, 2013).

Conclusion and Recommendation

This investigation delivers an elevation-stratified assessment of aboveground carbon stocks and tree diversity in community forests across Nepal's central Himalayas, establishing foundational benchmarks for climate adaptation and forest governance. Carbon accumulation reached its zenith in low-elevation stands (<1,000 masl) where *Shorea robusta* prevails, whereas stem density attained maximum values in high-altitude zones (2,000–3,000 masl) characterized by hardy, smaller-statured species. Importance Value Index (IVI) patterns faithfully mirror the floristic succession from thermophilic broadleaf communities in the foothills through mixed temperate assemblages in intermediate zones to cold-tolerant conifers and Rhododendron at timberline.

Notably, the interrelationships among elevation, stand structure, and carbon storage are not invariant but exhibit pronounced zonation. Marginal yet statistically significant elevation-carbon correlations manifest at the gradient's lower and upper extremities, whereas a meaningful structure-carbon linkage materializes exclusively within mid-elevation temperate belts. Uniformly modest model fits ($R^2 < 0.11$) substantiate a pivotal insight: carbon dynamics within this heterogeneous montane landscape elude prediction based solely on altitudinal or structural metrics. Rather, they represent synergistic outcomes of species compositional turnover, anthropogenic legacies, topographic microclimates, and substrate variability.

These findings carry substantial weight for Nepal's REDD+ architecture and forest stewardship. Blanket policies will inevitably falter; instead, physiographically calibrated strategies are imperative. Lowlands demand safeguarding of carbon-dense Sal forests; mid-hills require fostering of structural intricacy and biocultural richness; high mountains necessitate preservation of hydrological integrity and endemic biodiversity. Such elevation-sensitive governance ensures that climate finance simultaneously bolsters carbon sequestration, ecological resilience, and community prosperity. Ultimately, this work reaffirms that safeguarding the Himalayan elevational continuum in all its complexity remains indispensable for Nepal's climate resilience and the persistence of its irreplaceable biological heritage.

Author Contribution

Nabin Raj Joshi: Conceptualization, Methodology, Investigation, Formal Analysis, Writing Original Draft, Project Administration Data Curation. **Dipendra Kshetri and Gunanand Pant:** Writing, Data analysis, Review & Editing.

Conflict of Interest: The authors declare no conflict of interest.

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