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Floristic Composition, Diversity and Carbon Stock Along Altitudinal Gradient in Hasantar Community Forest, in Nagarjun Municipality, Kathmandu District

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Abstract

This study has attempted to estimate above and below ground biomass along altitudinal gradient and examined the relation between carbon stock and diversity indices. The study area was categorized into three sections based on the elevation interval of 200m ranging from 1300m to 1900m. Vegetation sampling was performed in 33 circular plots, each of 500m^2 and was selected based on systematic random sampling. Phyto-sociological parameters and above and below ground biomass and total carbon stock were calculated for each section of the study area. Carbon stock showed negative and insignificant relation with species evenness (r=-0.24, P= 0.17) and positive but insignificant relation with species richness (r=0.17, p=0.34) and Simpson's index of dominance (r=0.18, P=0.31). However, humped shaped and statistically insignificant (P=0.93) relationship was observed between Shannon diversity index and carbon stock. This research results provide baseline information for the management of Hasantar community forest.

Keywords: *Altitudinal gradient, Carbon stock, Community Forest, Diversity indices, Phyto-sociological parameters*

Introduction

Nepalese forest is manifested by the tropical forest in terai, deciduous and coniferous forests in the subtropical and temperate region and the meadows and grasslands at high altitude. Forests in Nepal along with other wooded land comprise 6.61 million hectare of the total area of the country (DFRS, 2015). Over grazing, forest fire, landslide and bush cutting are major factors of forest disturbance. Forest destruction and degradation leads to the biodiversity loss and climate change in a long run (Gebrewahid and Meressa 2020, Talbot 2010). Forest has a significant role in carbon cycle globally as it acts as both sources and sinks of carbon (Huang et al., 2020).

Community forestry is one of the major participatory forest management practices, was initiated in 1970's with the purpose of people's participation in the protection, management and utilization of the forest resources (Acharya, 2002). By the year 2015, the total carbon stock of Nepalese forest was estimated 176.95 t/ha (DFRS, 2015). Poudel et al. (2022) has stated community forestry plays essential role in enhancing carbon sink as well as limiting deforestation and forest degradation. Study of Rana et al. (2017) has reported the success of community forest in the annual increment of the carbon stocks, although estimation of carbon stock has been studied less in community forest of Nepal (Bohara et al., 2021).

Forest carbon stocks are largely dependent on species composition and forest structure and land use system (Shrestha et al., 2013). Higher the wood plant density, higher will be the biomass carbon storage (Rahayu et al., 2005). Along with supporting ecosystem processes, function and services (Gebrewahid and Meressa, 2020), forests play an essential role in the global carbon cycle (Huang et al., 2020; Midgley et al., 2010). Understanding the relationship between carbon stock and diversity indices, improve environmental benefits of carbon storage and biodiversity conservation (Gebrewahid and Meressa, 2020).

Floristic composition, diversity measures and carbon stock of forest provides the baseline information for the formulation of community forest management and conservation strategy. Diversity indices like species evenness, Shannon-wiener and Simpson's index of dominance enhance the understanding towards the relation between carbon storage and biodiversity measures. Thus, this study has attempted to estimate above and below ground carbon stock along altitudinal gradient and understand the relation between carbon stock and diversity indices.

Materials and Methods

Study Area

The study was carried out in Hasantar Community Forest (hereafter, HCF) in Nagarjung Municipality, Kathmandu District. The study area occupies 55.4 hectare and has been surrounded by Raniban Community Forest in the south and human settlement in other aspects. Geographic location of the study area is located between latitudes of 26.22' and 30.27'N and the longitudes of 80.40' and 88.12'E and elevation ranging from 1300 to 1900 meter above mean sea level. Climate is mild, generally warm and temperate. The study area receives precipitation of about 1505 mm annually in average and an average temperature range from 18°C to 24°C. HCF is Northwest facing natural forest and is dominated by *Schima wallichii* and *Rhododendron arboretum* (Silwal 2019, Gautam, 2019).

Sampling Design: Vegetation sampling was performed based on systematic random sampling approach. In total, thirty-three circular plots of area 500m^2 were laid in three different elevations in the interval of 200m, elevation ranging from 1300m to 1900m *i.e.* Section 1 (1300-1500m), Section 2 (1500-1700m) and Section 3 (1700-1900m). Tree species with DBH greater than 10cm were only considered (Sundriyal and Sharma 1996). Tree height (h) and diameter at breast height (DBH) at 1.3m from the ground of individual tree inside the plot were measured. Fiberglass measuring tape was used to prepare sampling plots. Tree height was measured using clinometer and DBH was measured using DBH tape. Latitude, longitude and altitude of each sampling plots were recorded using Garmin GPS.

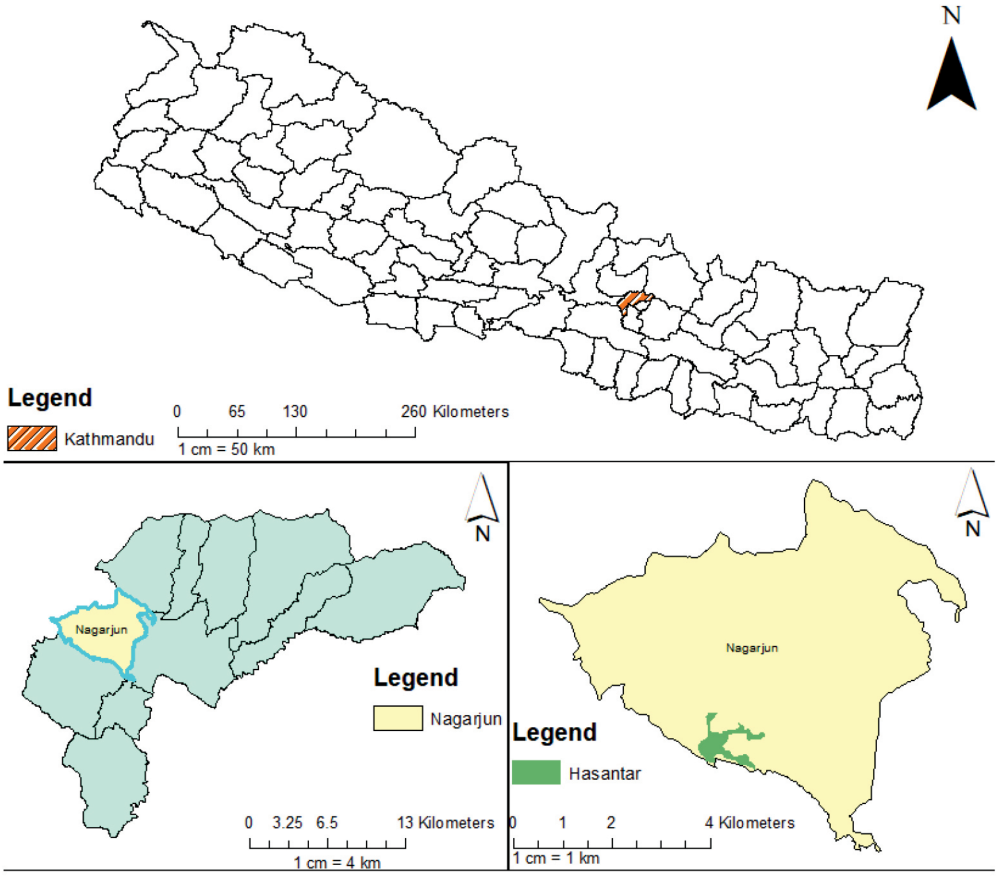

Figure 1: Map of Nepal indicating Nagarjun Municipality. Green color in the Map indicates Hasantar community forest

Data Analysis

Quantitative Vegetation analysis

Vegetation data were tabulated and ecological parameters such as density, frequency and basal area were determined quantitatively (Curtis and McIntosh 1951) in MS Excel 2016. The relative values of density, frequency and basal area summed to obtain Importance value index (IVI) of each tree species. Alpha diversity (species richness, evenness and Shannon diversity index) along altitudinal gradient were determined. Allometric equation (Chave et al. 2005) was used to estimate above ground tree biomass (AGTB).

$$\text{AGTB (t/ha)} = 0.0509 \times \varrho \times D^2 \times h$$

ϱ =wood specific gravity (g/cm^3*)*

D= diameter at breast height (cm) and

h=tree height (m)

Below ground tree biomass (BGTB) was determined based on root to shoot ratio value of 1:5 *i.e*. 20% of AGTB (MacDicken 1997). Further, Total biomass was determined by summing AGTB and BGTB. In order to estimate carbon stock, biomass stock densities was multiplied with default carbon factor *i.e.* 0.47 (Change 2006).

The relationships between carbon stock and diversity measure were examined using Pearson correlation coefficient and represented in scatter plots.

Results and Discussion

Floristic Composition and Diversity Indices

A total of 18 species belonging to 11 families were recorded in 33 sampling plots (Figure 2). Fabaceae (4 species) was dominant family followed by Ericaceae, Myricaceae, Rosaceae and Theaceae (2 species each). Seven species (*Quercus lanata*, *Lyonia ovalifolia*, *Myrsine capitellata*, *Schima wallichii*, *Eurya acuminate*, *Choerspondias axillaris*, and *Engelhardia spicata*) were common in all sites. *Bauhinia variegate*, *Castanopsis indica*, *Myri*ca *esculenta, pyrus pashia*, *Morus alba*, *Ziziphus incurve* were recorded only in section 1 and section 2. *Rhododendron arboretum* and *Alnus nepalensis* were recorded only in section 2 and section 3. *Pyrus cerasoides* and *Duabanga grandiflora* were present only in section 2 and section 3 respectively.

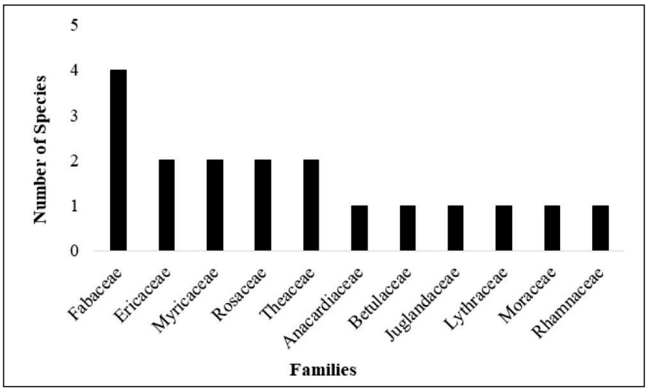

Figure 2: Number of species in different families of vegetation recorded

The study revealed decreasing total density and total basal area of tree species with increasing altitude (Table 1). It might be due to decreasing adaptability of trees at higher altitude (Ghimire et al. 2008). Total density of *Rhododendron arboretum* was found highest (131 ind/ha) followed by *Schima wallichii* (129 ind/ha). Total basal area of *Schima wallichii* was recorded highest (14.68 m^2/ha) followed by *Rhododendron arboretum* (5.16 m^2/ha). In section 3, forest was dominated by *Rhododendron arboretum* having higher density and basal area. However, in section 1, density and basal are of the *Schima wallichii* was noticed higher. Density of *Bauhinia variegate* was recorded higher in section 2 but basal area of *Schima wallichii* was measured higher.

Altitude gradients provide natural climate variations, where key environmental factors such as air temperature, humidity and associated soil properties (pH, temperature, soil depth) affect plant growth and tree distribution, that change significantly within a limited range (Gong et al. 2020, Sundqvist et al. 2013). The enough seedling composition is underpinning for the successful regeneration of natural forest (Nagel et al. 2010, Sinz et al. 2011). In addition, low moisture (Rodríguez-García et al. 2010), low temperature (Pardos et al. 2007) and drought (Padilla and Pugnaire 2007) are not much favorable for the development of seedlings.

Table 1: Phyto-sociological parameters

	Section 1	Section 2	Section 3
Species Richness	14	17	10
Species Evenness	0.73	0.86	0.74
Shannon Diversity Index	1.59	2.02	1.22
Simson's Index of Dominance	0.74	0.81	0.61
Total Density (ind/ha)	807	635	628
Total Basal area (m^2/ha)	14.41	12.05	9.35

Note: ind-individuals, ha-hectare

Species richness (17), and evenness (0.86) was found higher in section 2 and thus Shannon diversity index (2.02) was higher at section 2 (Table 1). Simpson's index of dominance was found ranging between 0.49 to 0.99. In general, tree species richness declines along with increasing elevation (Chikanbanjar et al. 2020, Fosaa 2004). In contrary, this study has represented hump shaped curve instead declining trend. It might be due to consideration of small elevation interval. Along with the altitude, aspects and microclimate influences the distribution of tree species in forest type (Ghimire et al. 2008). Assessment of Panchase protected area has reported similar tree diversity (1.12-2.15) (Chikanbanjar et al. 2020). Giri et al. (2008) has also reported Shannon diversity in the range of 0.88-2.11 of the Nainital catchment area which is alike to this study.

The IVI of the tree species was found ranging from 4.35 to 74.67. Based on IVI, *Schima wallichii* was found to be most important species (74.67) in whole forest followed by *Rhododendron arboreum* (42.72), *Castanopsis indica* (25.13) and *Bauhinia variegate* (25.11). However, *Rhododendron arboretum* was found dominated in section 3 with IVI 94.65. Section 1 and section 2 was dominated by *Schima wallichii* with IVI 67.37 and 85.93 respectively.

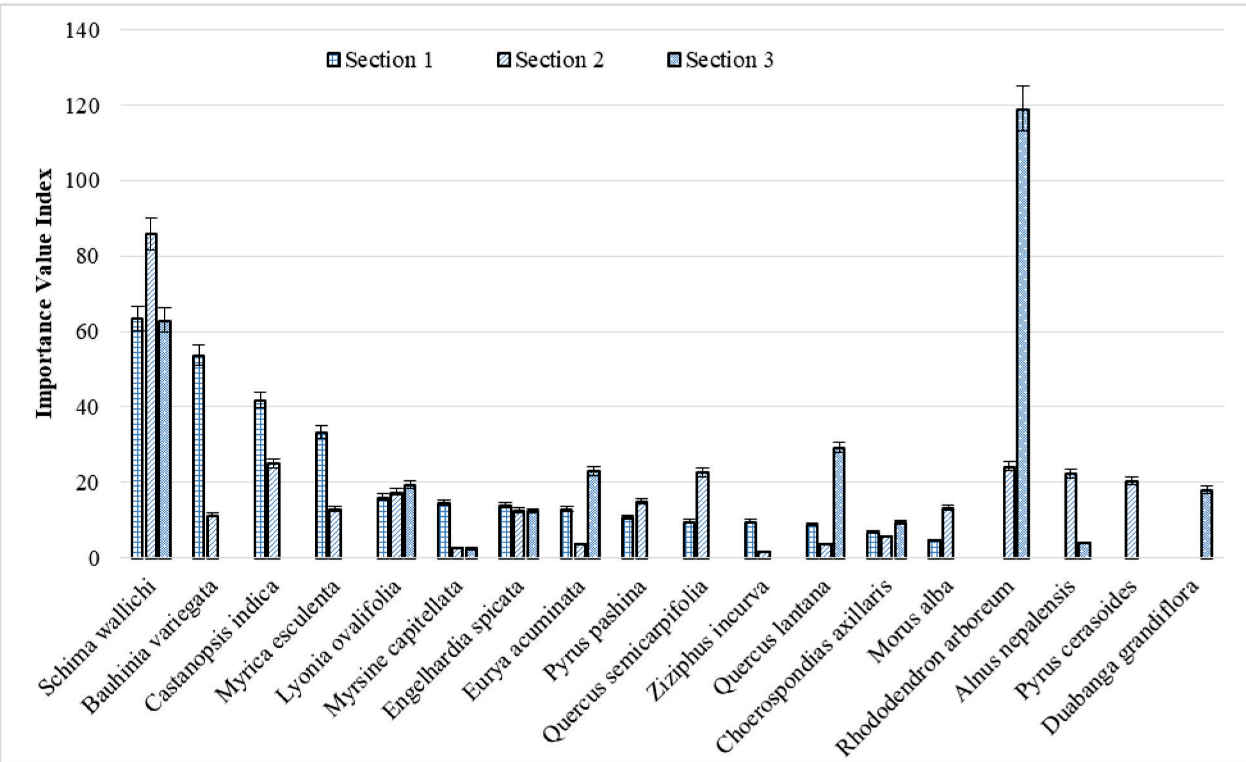

Figure 3: Composition of vegetation along altitudinal gradient. The error bars represent percent error

Carbon Stock of Forest Community

Carbon stock varied with the tree species. *Schima wallichii* comprised 45.08% of the total carbon stock of the HCF followed by *Rhododendron arboretum* (12.32%) and *Duabanga grandiflora* (0.5%) (Figure 4).

The total carbon stock was found higher in Section 1 i.e., 667.7±21.65 with total AGTB (1183±38.39) and total BGTB (236.77±7.67) (Table 2).

Species wise carbon stock found ranging from 7.82–702.29t/ha. Among the recorded species, carbon stock of *Schima wallichii* was found the highest (702.29t/ha) followed by *Rhododendron arboretum* (191.97t/ha) and *Myrica esculenta* (188.08t/ha). The higher carbon stock of *Schima wallichii* might be due to higher density and basal area.

Higher tree density and relative basal area results in higher biomass and thus carbon stock. Shrestha (2016) has also estimated vegetation type, age of the stands, surrounding environment, management activities and other human induced disturbances are key responsible for the variation in carbon stock. Wodajo et al. (2020) reported declining AGTB and BGTB along the increasing altitudinal gradient which might be due to absence of species with large DBH and basal area. Factors comprising soil, humidity, temperature and geomorphological factors determines the dominancy of small size plant in higher elevation (Gedefaw et al. 2014). In addition, higher dependency of adjacent community on the forest products for their livelihood influence carbon pool of the forest (Wodajo et al. 2020). In contrary to biomass of the forest stands decreases with the elevation (Kunwar and Chaudhary 2004), this study has estimated less biomass at Section 2. This might be due to anthropogenic disturbance. Disturbance reduces the growth and productivity of trees, either by damaging their physical structure or by limiting access to resources such as sunlight, water, and nutrients which lead to smaller and less

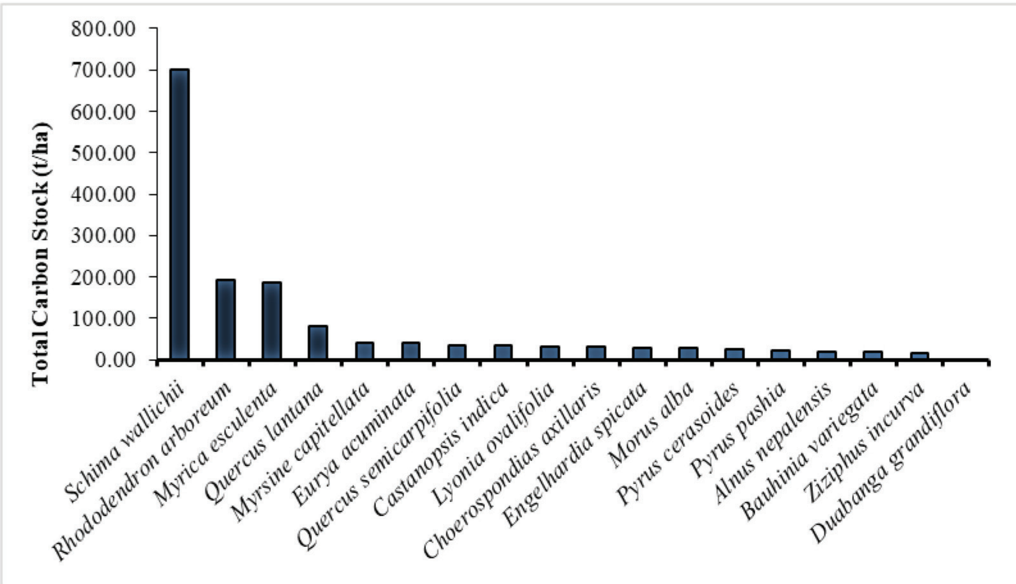

Figure 4: Species wise carbon stock in HCF

Table 2: Carbon stock along different altitudinal gradient

	AGTB±SD (t/ha)	BGTB±SD (t/ha)	TB±SD (t/ha)	Total C±SD (t/ha)
Section 1	1183±38.39	236.77±7.67	1420±46.07	667.7±21.65
Section 2	739.94±35.41	147.98±7.08	887.92±42.49	417.32±19.97
Section 3	753.12±22.12	150.62±4.43	903.75±26.6	424.76±12.51

Note: AGTB-Above ground tree biomass, BGTB- Below ground tree biomass, TB-Total Biomass, C-Carbon, SD-Standard deviation

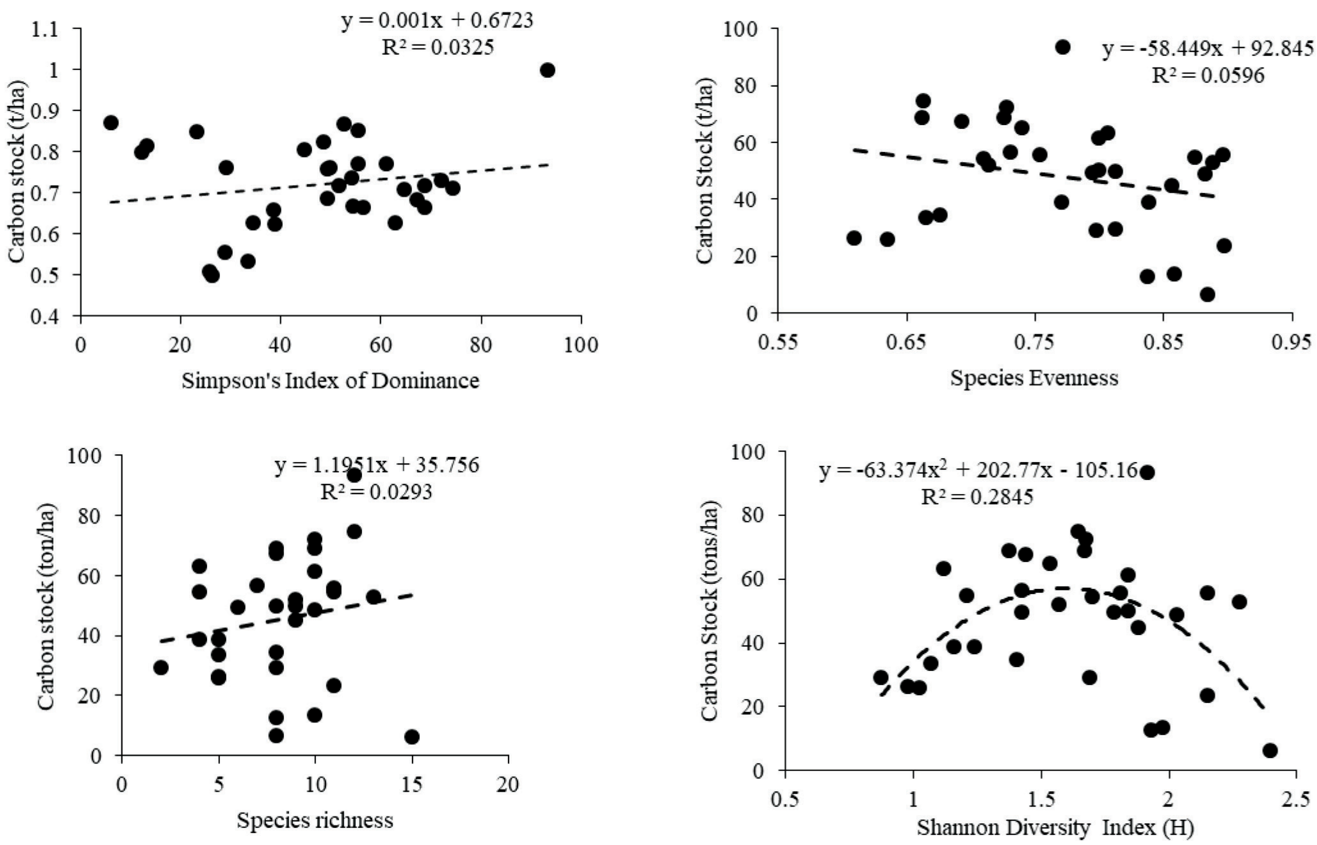

Figure 5: Scatter plot representing correlation between Diversity indices and Carbon stock

productive trees, and ultimately reduce the overall biomass of the forest (Franklin et al. 2002).

Relation between carbon stock and diversity indices

The diversity indices are major determinants for the regulating forest ecosystem's function and services. Results show varied relationship of carbon stock with diversity indices. The relationship between carbon stock and species evenness shows negative but insignificant (r=-0.24, p=0.17). However, positive and insignificant relationship was observed with carbon stock between Simpson's index of dominance (r=0.18, p=0.31) and species richness (r=0.17, p=0.34). Humped shaped but statistically insignificant (p=0.93) relationship was observed between carbon stock and diversity. The result showed the negative relation between carbon stock and species evenness which supports the finding of (Chalcraft et al. 2010), suggested that a few species become more dominant at high biomass, instead of the biomass being distributed evenly among all species. The study conducted by (Ayer et al. 2022) in Kanchanpur district also showed a negative relation between species evenness and carbon stock.

Conclusion

The Hasantar Community Forest is well stocked with mainly dominated by *Schima wallichi* followed by *Rhododendron arboretum*. The findings of this study indicate Shannon diversity and Simpson's index of dominance predominant at mid elevation whereas carbon stock was found high at lower elevation.

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