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Assessing the effect of aspect on carbon stock and biodiversity in community forests of Kavrepalanchok and Kathmandu, Nepal

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Abstract

Estimation of carbon stock is essential for understanding the global carbon cycle. Community Forest is one of the leading renewable resources which had provided safety nets for poor and vulnerable people. This study was rigorously conducted to thoroughly evaluate the effect of the aspect on carbon stock and biodiversity in three Community Forests, namely Jyalachity community forest of Kavrepalanchok and Bosan Danda and Pataleban community forest of Kathmandu district. As a primary source of data, a total of forty-five nested pattern blocks having 12.61m, 5.64m, and 2.82m for tree, pole, and sapling, respectively, have been installed in inventory. GPS, DBH, and height were recorded. Descriptive and statistical test like ANOVA, Tukey's b was performed in case of normal distribution with calculation of biomass, carbon stock, and the Importance Vegetation index. The North-East aspect was found maximum amount of carbon stock in trees, poles, and saplings. *Schimma wallichii* was the dominant species with the highest carbon stock mean of 29.56 tons/ha, species richness was 7, and Simpson's Diversity Index was 0.76 in the tree in Pataleban community forests. The highest tree Shannon-Weiner diversity index values were 1.01 in Jyalachity community forests, where Bosan Danda and Pataleban community forests bore 1.3 same value of index. Evenness of trees in the South-East aspects of Jyalachity community forests was 0.9, while Bosan Danda and Pataleban community forests bore 1 same value of evenness. One-way ANOVA showed no significant difference in the carbon pool in trees in Jyalachity, Bosan Danda community forests, but showed a significant difference in Pataleban community forests, where Bosan Danda community forests showed a significant difference (p=0.008) in poles at a 95% confidence level. Carbon storage is notably higher in the Northeast aspect, underscoring the need to protect these areas to mitigate deforestation-related carbon emissions. This research will provide significant insights and benefits to both the scientific community and policymakers.

Keywords: Biodiversity, Biomass, Carbon, Community Forest

Introduction

The role of carbon sequestration is vital to deal with climate change since the forests are both carbon sources and sinks. Besides, forests are important reservoirs of biological diversity. Therefore, forestry conservation serves as protection for both carbon storage and biodiversity. But on the other hand, deforestation adversely affects both the level of carbon dioxide and biodiversity. Forests play a critical role in reducing ambient CO_2 levels by sequestering atmospheric C into the growth of woody biomass through the process of photosynthesis and also by increasing the soil organic carbon (SOC) contents (Brown & Pearce, 1994). The rate of C sequestration is much faster in young and regenerating forests than the old and mature forests, but C stock is higher in old and mature forests (Luyssaert et al., 2008). Exchange of carbon compounds within the atmosphere, ocean, and ecosystem is a usual process that is modified due to human activities (Hairiah et al., 2001). Tropic forest holds a large amount of carbon (Chave et al., 2005). Carbon sequestration is the process of separating CO_2 from the atmosphere and storing it in a reservoir (plant biomass and soil) (Pan Y. et al., 2009). The world's forests store 1 trillion tons of carbon, twice the amount floating free in the atmosphere (Oli & Shrestha, 2009). Forests contain 80% of the live aboveground biomass in the world, with over 59% of the total live biomass residing in tropical forests (Dixon et al., 1994). The current estimate of the world's forests' C stocks is 861 ± 66 Pg. C (1Pg = 109 g, 1 Mg = 1015 g) with 363 ± 28 Pg. C (42%) in above- and belowground live biomass (Pan Y. et al., 2011). Forests not only store large amounts of carbon, but also cycle large volumes of CO2, tropical forests over a period of 25 years cycle a volume of carbon dioxide equal to the total amount in the atmosphere (GRACE et al., 1995). The following carbon pools are measured in forest carbon estimation. a) Above-ground tree biomass (AGTB) b) Below-ground biomass (BGB). If the neuromas portion of the carbon pool is not significant in the area due to frequent removal of dead wood for use as fuel by local communities, this pool should not be measured. Aboveground biomass includes all living biomass above the soil, including stems, stumps, branches, bark, seeds, and foliage. This category includes live understory. All living biomass with coarse living roots thicker than 2 millimeters in diameter is classified as belowground biomass. Carbon accounting in forests is one of the most crucial steps for the successful implementation of the Reducing Emissions from Deforestation and Degradation (REDD) projects. REDD+ scheme approved by UNFCCC for carbon accounting of developing countries, Nepal is concerned about the study of the potential to sequestration of carbon sequestration in community forests in the country (Thapa-Magar & Shrestha, 2015). In 1992, Nepal became a signatory to the UNFCC. In Nepal potential of REDD+ depends on the level of stock increases, typically due to community management (Bhattarai et al., 2012). Developing nations are fully committed to the global observance of REDD+ principles and the support of the Convention on Biological Diversity (Corson & MacDonald, 2012). As per the latest report, 83 countries from around the globe are actively taking part in the Forest Carbon Partnership Facility through the REDD+ initiative (Hernandez, 2020). Furthermore, a sum of 196 countries are parties to the Convention on Biological Diversity (McPherson, 2020; Woldegiorgis, 2020). Community forest management, which is a vital aspect of life for local populations in developing countries like India and Nepal, holds significant potential as a carbon sink under the Clean Development Mechanism (CDM). This approach not only contributes globally by helping to counteract deforestation and sequester carbon but also plays a local role in fostering rural development. It is estimated that at slightest 513 million ha of community forests universally store almost 38 billion Mg of carbon (Stevens et al., 2014). CF offers an impressive opportunity for nearby level community forest management groups to benefit from the deal of carbon sequestration by adjusting their management targets to extend carbon sequestration without jeopardizing their employment, but with a few trade-offs (Sharma et al., 2020). Forest management activities also affect the plant species diversity and their composition. The maximum number of flora and fauna is present due to the favorable climate and the topographic condition of this land, 3.2% of flora and 1.1% of fauna are found in the world. Globally, estimated annual deforestation was -0.13% between 2000 and 2010, but it was a positive change of 0.28% in Asia (Schmitt et al., 2009). Moreover, the annual forest area loss in Terai, Nepal, was 0.40% between 1991 to 2010 (Oli & Shrestha, 2009) and was about 1.7% between 1978 to 1994. Thus, the global deforestation contributes 18-20% of greenhouse gas emissions annually. Meanwhile, only tropical deforestation, including Nepal, shares about 25% of anthropogenic carbon emissions, which is the leading cause of species extinctions. Overall, this study was conducted in community forests of Kavrepalanchok and Kathmandu district of Nepal to assess the effect of aspect on carbon stock and biodiversity.

Material and methods

Study Area

Three community forests, namely Jyalachity, Bosan Danda, and Pataleban community forest of Kavreplanchok and Kathmandu district, Bagmati Province, Nepal. In Panauti Municipality, the Jyalachity community forest, located at 27°35´50´´N to 85°35´09´´E and 1531m above sea level, occupies 25.92 hectares. Bosan Danda Community Forest lies at 27°38´44´´N to 85°15´47´´ E, 1900m from sea level, occupying 57 ha within Dakshinkali Municipality, Kathmandu, and Pataleban community forest situated at 27°42´41´´N to 85°12´21´´ E with an elevation of 1576 m in Chandragiri Municipality of Kathmandu District. *Schima wallichii*, *Castanopsis indica*, *Rhododendron arboreum,* and *Alnus nepalensis* are common major species that are found in all three community forests (HMG, 2002) (Fig. 1).

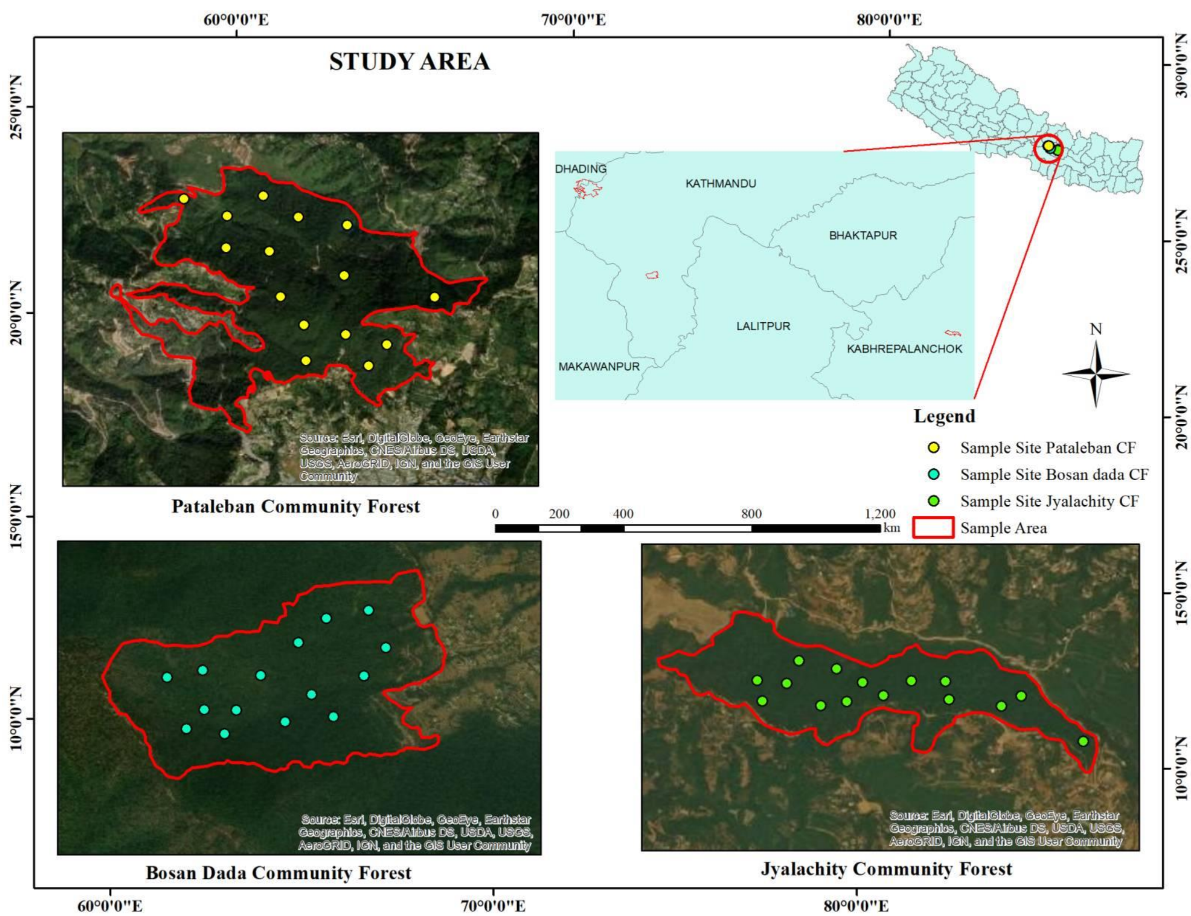

Figure 1. GIS Map of Study Area

Sampling design

To collect representative data, stratified random sampling was used, with trees grouped by growth stages: seedlings, saplings, poles, and mature trees. This method was chosen because each growth stage plays a unique role in the forest, contributing differently to biomass, carbon storage, and ecological functions. Grouping the trees by growth stage ensured that data from all stages were accurately represented. The forest areas were first surveyed and mapped to create a clear layout of the study sites. A total of 45 nested sample plots were then randomly distributed across the map, with 15 plots in each of the three community forests. This ensured that the data captured spatial variation across the forests while maintaining equal representation of growth stages within each forest. In the field, the sample plots were designed with different radii to match the size of the growth stages:

- 12.61 meters for trees,
- 5.64 meters for poles,
- 2.82 meters for saplings, and
- 1.87 meters for seedlings.

These plot sizes followed forest sampling guidelines (HMG, 2002), which recommend using sizes that fit the density and dimensions of the vegetation. This approach made the sampling process efficient and reliable for all growth stages.

Data collection

The diameter at breast height, height, and tree species were recorded from each aspect, i.e., North East, North West, South East, South West. Additionally, GPS coordinates, all the litter, herbs, and grasses inside a 0.56 m radius plot were clipped and collected.

Data Analysis

The data was processed, tabulated, and analyzed quantitatively. The biomass was calculated using the equation provided by Chave (Chave et al., 2005). $AGTB = 0.0509^* \rho D^2 H$, where AGTB = above-ground tree biomass (kg); ρ = wood specific gravity (g cm-3); D = tree diameter at breast height (cm); H = tree height (m). Calculated AGTB were summed up and divided by the area of the sampling plot (250 m²), giving biomass stock density in kg/m², and were multiplied by 10 to convert into tons/ha. Below Ground Tree Biomass (BGTB) was calculated using to shoot ratio, which is a standard method to estimate the below-ground biomass. The study used a root-to-shoot ratio of 1:5; below-ground tree biomass was assumed to be 20% of the above-ground tree biomass, following the standard value (Macdicken, 1997) and that root-to-shoot ratios can vary significantly between species and forest types. Above-ground tree biomass (AGTB) and below-ground tree biomass (BGTB) stocks were converted to carbon stocks using the IPCC (2006) default carbon fraction of 0.47. The carbon stocks were then expressed in carbon equivalents by multiplying the carbon stock values by 44/12. Leaf litter, herb, and grass (LHG) carbon stock per unit area was calculated by:

$$\text{LHG} = \text{W (field)} / \text{A} * \text{W (dry subsample)} / \text{W (wet sub sample)} * 10$$

Where:

LHG = biomass of leaf litter, herbs, and grass (t/ha)

W (field) = weight of the fresh field sample of leaf litter, herbs, and grass destructively sampled within an area of size A (g)

A = size of the area in which leaf litter, herbs, and grass were collected (ha)

W (dry subsample) = weight of the oven-dry sub-sample of leaf litter, herbs, and grass taken to the laboratory to determine moisture content (g)

W (wet subsample) = weight of the fresh sub-sample of leaf litter, herbs, and grass taken to the laboratory to determine moisture content (g).

The use of a single plot size (0.56 m radius) for collecting leaf litter, herbs, and grass was chosen to maintain consistency and efficiency during field sampling.

Calculation of the biodiversity index

The species diversity of the forest tree community was calculated to using different indices.

Species richness = n (number of species in the felling series was counted)

Shannon Wiener index (H') = $-\Sigma P_i \log p_i$

Where:

P_i is the relative abundance of each species, i.e., the proportion of individuals of a given species relative to the total no. of individuals in the community (Baumgärtner, 2006)

Simpson's diversity, (D) = $1 - \Sigma P_i^2$

Where:

Pi is the relative abundance of each species, i.e., the proportion of individuals of a given species relative to the total no. of individuals in the community.

Evenness E = H / log (N)

Whereas H' = Shannon-Wiener Diversity Index and N = number of species

Density represents the number of individual trees per unit area and reflects the numerical strength of a species within a community. (Odum et al., 1995)

$$\textbf{Density} = \frac{\text{Total number of individual of species in all plot}}{\text{Total number of plot sample x size of quadrate}} \text{x}100$$

$$\textbf{Relative Density (\%)} = \frac{\text{Density of a species}}{\text{Sum of Density of all species}} \text{ x } 100$$

Frequency represents the distribution of species within a community, reflecting the percentage of sampling units where a particular species is present.

$$\textbf{Frequency (\%)} = \frac{\text{Number of plots in which an individual species occurred}}{\text{Total number of plots sampled}} \text{ x } 100$$

$$\textbf{Relative frequency (\%)} = \frac{\text{Frequency of a species}}{\text{Sum of frequency of all species}} \text{ x } 100$$

Basal area refers to the ground actually penetrated by the stems (Hanson & Churchill 1961).

$$\textbf{Basal Area (BA)} = \pi \frac{(\text{DBH})^2}{4}$$

Where, DBH = Diameter at breast height

$\pi = 3.416$

$$\textbf{Relative basal area (\%)} = \frac{\text{Basal Area of a Species}}{\text{Total Basal Area of All Species}} \text{ x } 100$$

The dominance and ecological importance of a species was expressed by the IVI, was calculated (Curtis & Mcintosh, 1950).

IVI = Relative Density + Relative Frequency + Relative Basal Area

Statistical analysis

A normality test was conducted to assess the distribution of the dataset. Since the data were normally distributed, a one-way ANOVA test and Tukey's B test were applied to determine if there were significant differences in carbon stock among the community forests.

Results

Above and below-ground carbon stock according to aspect

The total carbon stock variations across the Jyalachity, Bosan Danda, and Pataleban Community Forests show distinct patterns of increase and decrease among different regions and categories. In Jyalachity, the total carbon stock decreases from 43.09±10.49 tons/ha in the northeast (NE) to 17.49±3.44 tons/ha in the southwest (SW), reflecting a significant reduction in both above-ground and below-ground carbon components. Bosan Danda exhibits a similar trend, with total carbon stock declining from 9.35±1.7 tons/ha in the NE to 2.18±0.336 tons/ha in the SW. The above-ground carbon stock in this forest also decreases notably, from 8.31±1.511 tons/ha in the NE to just 1.97±0.298 tons/ha in the SW. In contrast, Pataleban Community Forest shows relatively higher carbon stocks, though there is a clear decrease from 47.67±10.49 tons/ha in the NE to 11.43±1.71 tons/ha in the SW. The above-ground carbon stock follows a similar pattern, decreasing from 42.36±9.321 tons/ha to 10.14±1.514 tons/ha. The contributions of litter, herbs, and grass (LHG) also fluctuate, increasing in some cases, such as from 1.599±0.07 tons/ha in the NE of Pataleban to 2.6±0.33 tons/ha in the SE, while decreasing or remaining minimal in others. These trends highlight spatial differences in forest biomass and resource distribution (Table 1).

Table 1. Total carbon stock in the community forest

Carbon Stock tons/ha	NE±SE	NW±SE	SE*±SE	SW±SE	Mean Total carbon stock of forest (t/ha)
Jyalachity Community Forest					
Above Ground	38.22±9.33	23.52±5.654	20.84±5.64	15.55±3.06	27.65±6.655
Below Ground	4.87±1.16	2.94±0.71	2.72±0.692	1.94±0.38	
Total	**43.09±10.49**	**26.46±6.35**	**23.56±6.34**	**17.49±3.44**	
LHG	2.78±0.12	2.59±0.188	1.88±0.8685	2.88±0.063	
Bosan Danda Community Forest					
Above Ground	8.31±1.511	6.01±0.963	3.2±0.644	1.97±0.298	5.48 ± 0.88575
Below Ground	1.04±0.189	0.75±0.12	0.44±0.08	0.21±0.038	
Total	**9.35±1.7**	**6.76±1.083**	**3.64±0.424**	**2.18±0.336**	
LHG	3.85±0.372	1.672±0.568	0.37±0	0.38±0.14	

Pataleban Community Forest					
Above Ground	42.36±9.321	36.17±7.372	15.48±0.276	10.14±1.514	29.56 ± 5.275
Below Ground	5.31±1.169	5.31±0.921	1.93±0.33	1.29±0.196	
Total	**47.67±10.49**	**41.48±8.293**	**17.41±0.609**	**11.43±1.71**	
LHG	1.599±0.07	1.872±0.628	2.6±0.33	0.737±0.2	

NE: North East, NW: North West, SE*: South East, SW: South West, SE: Standard Error, LHG: Litter herbs and grass

Species-wise carbon stock in different aspects of community forests

The carbon stock in different aspects was varied according to species in the community forests. *Schima wallichii* was the dominant species in the Bosan Danda, *Castanopsis indica* in Pataleban community forests, where Jyalachity community forests bore *Alnus nepalensis* as the dominant species; thus, the carbon stock was the highest, around 45.022 tons/ha of *Alnus nepalensis* in Jyalachity, 10.87 tons/ha of *Schima wallichii* in Bosan Danda, and *Castanopsis indica* 36.79 tons/ha in Pataleban community forests. The estimated carbon stock was followed by *Schima wallichii* 39.029 in Jyalachity community forests, *Myrica esculenta* 5.11 tons/ha in Bosan Danda, and *Schima wallichii* with 35.24 tons/ha in Pataleban community forest. The proportion of carbon stock of *Alnus nepalensis* was 45.022 to 40.781 % in Jyalachity community forest, *Schima wallichii* was 10.87 to 49.52 % in Bosan Danda community forest, and *Castanopsis indica* was 36.79 to 31.39%, which can suppress other species from regenerating and growing. Users have no interest in promoting other species found in the community forests (Table 2). One-way ANOVA showed no significant difference (p=0.270) in the carbon pool in trees among the four aspects in Jyalachity community forests at a 95% confidence level. In four aspects of Bosan Danda community forests, One-way ANOVA showed no significant difference (p=0.287) in the carbon pool in trees but showed a significant difference (p=0.008) in the carbon pool in poles among the four aspects. Apart from this, in the Pataleban community forests, One-way ANOVA again showed a significant difference (p=0.027) in the carbon pool in trees among four aspects, and poles, One-way ANOVA showed no significant difference (p=0.180) in the carbon pool in poles among four aspects at a 95% confidence level.

Table 2. Species-wise carbon stock in different aspects of community forests

Jyalachity community forest						
Species Name	**NE t/ha**	**NW t/ha**	**SE t/ha**	**SW t/ha**	**Total t/ha**	**Percent**
Schima wallichii	3.49	15.16	9.31	11.069	39.029	35.353
Alnus nepalensis	39.51	0	0	5.512	45.022	40.781
Rhododendron arboreum	0.0345	0	0	1.36	1.3945	1.263
Myrica esculenta	0	0	0	0.003	0.003	0.003
Choerospondias axillaris	0	6.9	0	0	6.9	6.250
Pinus ruxburghi	0	4.38	13.67	0	18.05	16.350
Total					**110.40**	**100**
Bosan Danda community forest						
Schima wallichii	4.96	3.04	1.78	1.09	10.87	49.52
Alnus nepalensis	0	2.35	1.86	0	4.21	19.18
Rhododendron arboreum	0	0.76	0	0.85	1.61	7.33
Myrica esculenta	4.23	0.61	0	0.27	5.11	23.28
Castanopsis indica	0.15	0	0	0	0.15	0.68
Total					**21.95**	**100**
Pataleban community forest						
Schima wallichii	13.99	17.3	3.14	0.81	35.24	30.07
Alnus nepalensis	0	0.47	0	2.52	2.99	2.55
Rhododendron arboreum	0	0.36	0	1.32	1.68	1.43
Myrica esculenta	2.68	2.98	10.88	2.18	18.72	15.97
Castanopsis indica	21.49	13	0	2.3	36.79	31.39
Terminalia elliptica	9.51	7.36	0	3.01	19.88	16.96
Pinus roxburghii	0	0	0	1.89	1.89	1.61
Total					**117.19**	**100**

NE: North East, NW: North West, SE: South East, SW: South West

Biodiversity according to aspect in Community Forests

Species richness

The species richness was the good 6 in Jyalachity Community Forest which was 5 in Bosan Danda Community Forest and 6 tree species in Pataleban Community Forest. A total of 6 plant species were found in the Jyalachity community forest, out of which about 4 plant species were common in all three selected forests. *Schima wallichii*, *Alnus nepalensis*, *Rhododendron arboreum*, *Myrica esculenta.* Apart from this, *Pinus roxburghii* was found common in Jyalachity Community Forest and Pataleban Community Forest. *Castanopsis indica* was found common in Bosan Danda Community Forest and Pataleban Community Forest.

Simpson's diversity index (SDI) value, Shannon-Weiner diversity index (SWI), and Evenness (E)

The highest Simpson index of trees in the North-West aspect was 0.60, 0.70, and 0.90 in Jyalachity, Bosan Danda, and Pataleban community forests, respectively, while the highest tree Shannon-Weiner diversity index values were 1.01 in Jyalachity community forests, where Bosan Danda and Pataleban community forests bore 1.3 same value of index (Table 3). Besides this, Evenness of trees in the South-East aspects of Jyalachity community forests was 0.9 while Bosan Danda and Pataleban community forests bore 1 same value of evenness (Table 3).

Table 3. Biodiversity index value in community forests among the aspects

	NE			NW			SE			SW		
Jyalachity community forests												
Carbon pool	**SDI**	**SWI**	**E**	**SDI**	**SWI**	**E**	**SDI**	**SWI**	**E**	**SDI**	**SWI**	**E**
Tree	0.41	0.61	0.87	0.60	1.01	0.60	0.49	0.69	0.9	0.54	0.89	0.8
Pole	0.44	0.64	1	1	0	0	0.46	0.65	0.2	0.4	0.65	0.9
Saplings	0	0	0	0	0	0	0	0	0	0.44	0.64	0.9
Bosan Danda community forests												
Tree	0.48	0.67	0.9	0.7	1.3	0.9	0.6	1	1	0.5	0.6	1
Pole	0.5	0.6	0.6	0.32	0.50	1	0	0	0	0.4	0.6	1
Saplings	0	0	0	0	0	0	0	0	0	0	0	0
Pataleban community forests												
Tree	0.7	1.32	1	0.9	1.3	1	0.62	1.03	1	0.85	1.93	0.99
Pole	0	0	0	0.9	1.38	1	0.7	1.92	1	0.56	0.93	0.9
Saplings	0	0	0	0	0	0	0	0	0	0	0	0

Importance Value Index of Species according to the aspect

Ecological value in aspects of community forests

Curtis and McIntosh (1950) introduced the Importance Value Index (IVI) as a tool for measuring the dominance and ecological success of a species under focus. This index evaluates each participant in the community in the context of a particular channel's functioning and contributes to the overall ecosystem health. The results revealed that the Importance Value Index (IVI) of plant species varied across different study aspects or in community forests. Jyalachity community forests, *Alnus nepalensis* bore the highest IVI in North-East and in South-West aspects, where no consistency was found in other aspects. *Schimaa wallichii* consistently had the highest IVI in all community forests, with values ranging from 75.4 to 300 in Jyalachity community forests, 68.7 to 300 in Bosan Danda community forests, and from 30.05 to 300 in Pataleban community forests. Additionally, Jyalachity community forests bore 0 IVI in other species, with the exception i.e. tree and pole, and Bosan Danda and Pataleban community forests, except *Schimaa wallichii,* no consistent value was found in other species (Table 4).

Table 4. IVI of major species in different aspects of the community forest

Jyalachity community forests										
	NE		**NW**		**SE**			**SW**		
Species Name	**Tree**	**pole**	**Tree**	**Pole**	**Tree**	**Pole**	**Sap.**	**Tree**	**Pole**	**Sap.**
Schimaa wallichii	75.4	0	115.2	300	146.1	186	0	159.5	128	198.97
Alnus nepalensis	225	200	0	0	0	0	0	100.6	172	0
Rhododendron arboreum	0	100	0	0	0	0	0	39.89	0	0
Chorespondias axillaris	0	0	63.1	0	0	0	0	0	0	0
Pinus roxburghii	0	0	121.7	0	153.9	114	0	0	0	0
Myrica esculenta	0	0	0	0	0	0	0	0	0	101.02
Total	**300.4**	**300**	**300**	**300**	**300**	**300**		**299.99**	**300**	**299.99**
Bosan Danda community forests										
	NE		**NW**		**SE**			**SW**		
Species Name	**Tree**	**pole**	**Tree**	**Pole**	**Tree**	**Pole**	**Sap.**	**Tree**	**Pole**	**Sap.**
Schimaa wallichii	160	138	68.7	111	110.1	300	300	120.1	102	300
Alnus nepalensis	0	0	78.87	62.9	0	0	0	179.8	198	0
Rhododendron arboreum	0	0	97.41	62.9	129.6	0	0	0	0	0
Myrica esculenta	140	0	54.94	62.9	60.26	0	0	0	0	0
Castonapsis Indica	0	162	0	0	0	0	0	0	0	0
Total	**300**	**300**	**299.92**	**299.7**	**299.96**	**300**	**300**	**299.9**	**300**	**300**
Pataleban community forests										
	NE		**NW**		**SE**			**SW**		
Species Name	**Tree**	**pole**	**Tree**	**Pole**	**Tree**	**Pole**	**Sap.**	**Tree**	**Pole**	**Sap.**
Schimaa wallichii	100	67	108.8	73.6	135.3	300	300	30.05	300	0
Alnus nepalensis	0	0	0	80.2	0	0	0	41.87	0	0
Rhododendron arboreum	0	0	0	87.6	0	0	0	54.32	0	0

Myrica esculenta	72.1	67.3	42.81	58.6	85.78	0	0	40.35	0	0
Castonapsis Indica	77.7	132	93.49	0	78.95	0	0	41.53	0	0
Terminilia eliptica	49.8	0	54.87	0	0	0	0	46.85	0	0
Pinus ruxburghi	0	0	0	0	0	0	0	44.99	0	0
Mangiifera indica	0	33.7	0	0	0	0	0	0	0	0
Total	**299.6**	**300**	**299.97**	**300**	**300.03**	**300**	**300**	**299.96**	**300**	

NE: North East, NW: North West, SE: South East, SW: South West, Sap.: Sapling

Discussion

Total Carbon Stock

The total mean carbon stock was found to be 27.65±6.655, 5.48 ± 0.88575, and 29.56 ± 5.275 t /ha of Jyalachity, Bosan Danda, and Pataleban Community Forest, respectively. The carbon stock was found to be highest in the NE aspect with 43.09±10.49 t/ha, and lowest in the SW aspect with 17.49±3.44 t/ha. Next, the total mean carbon stock of the BCF was found to be 5.48±0.88575 t/ha. The carbon stock was found to be highest in the NE aspect with 9.35±1.7 t/ha and lowest in the SW aspect with 2.18±0.336 t/ha. Similarly, in PCF, the total mean carbon stock was found to be 29.56±5.275 t/ha, the carbon stock was found to be highest in the NE aspect, 47.76±10.49 t/hand lowest with 11.43±1.71 t/ha. The aboveground and belowground carbon stock was highest in the NE aspect and lowest in the SW aspect. *Shorea robusta* has a carbon stock of roughly 52.31 tons per hectare, according to (Mandal et al., 2016), which is slightly greater than the current study. The dominance of *Shorea robusta* in community forests was the main reason for the species' greatest carbon stock. This study was similar to one, found that maximum carbon stock (CS) was in the north aspect among all four aspects in the seven major forests of the Ghariwal Himalayan region of India. (Sharma et al., 2011). A similar result was due to *Pinus roxburghii* was found on the north aspect in both studies. Carbon stock in above-ground biomass varies from 76 tons per hectare in Terai to 37 tons in Middle Mountain in Nepal's forest (Oli & Shrestha, 2009). Therefore, the study CF has more CS than the national forest. Such types of studies are essential to link with the carbon trade potential under the REDD+ mechanism.

Above and below-ground Carbon Stock

The aboveground and belowground carbon stocks are varied in this community forest. The above-ground carbon stock includes trees, poles, saplings, herbs, and shrubs. The aboveground tree/pole carbon stock of JCF was found to be maximum in NE aspect with 38.22±9.33 t /ha, and the second highest was recorded in NW aspect with 23.52±5.654 t/ha. The carbon stocks of other aspects, like SE and SW of this community forest, were 20.84±5.64 t/ha and 15.55±3.06 t/ha. Similarly, the below-ground tree/pole saplings carbon stock of JCF was found to be maximum in NE aspect with 4.877±1.16 t/ha, followed by NW, SE, and SW with 2.92±0.71 t/ha, 2.72±0.692 t/ha, and 1.94±0.38 t/ha, respectively. Similarly, in the BCF, NE was found to be maximum for the both above and below ground carbon stock with 8.31±1.511 t/ha and 1.04±0.189 t/ha of carbon and followed by the NW, SE and SW aspect with 6.01±0.963 and 0.75±0.12 t/ha,3.2±0.664 and 0.44±0.08 t/ha and 1.97±0.298 and 0.21±0.038 t/ha of carbon stock, it may due to carbon stock of trees depends on types of climate, moisture, temperature and variation in species of plant (Shrestha & Singh, 2008). In the PCF, NE was found to be maximum for both above and below ground carbon stock, with 42.36±9.321 t/ha, 5.31±1.169 t/ha, for NW 36.17±7.372 and 5.31±0.921 for above and below ground carbon stock. 15.48±0.276 t/ha and 1.93±0.33 t/ha for SE and 10.14±1.514 and 1.29±0.196 for SW aspect for the above and below ground carbon stock. The biomass of *Alnus nepalensis* changes with elevation range and perspectives, according to (Baral et al., 2009). In the northern aspect, higher biomass was found at elevations of 1000-1100 m (4.96 t/plot), whereas lower biomass was observed at elevations of 1200-1300 m (2.604 t/plot). In the Southern aspect, higher biomass was detected at elevations of 1200-1300 m, whereas lower biomass was observed at elevations of 1400-1500 m. The CS of the root was estimated by assuming the root shoot value of 15%. Therefore, the carbon stock value of the root depends on the aboveground carbon stock value. The C (BB) was found maximum in the NE aspect, with, minimum in the SW. The aboveground carbon stock in the NE aspect was highest and minimum in the SW aspect, so the CS of the root was highest in the NE aspect and minimum in the SW aspect.

Carbon Stock in different carbon pools according to the aspect

For all three of the community forests, there were different carbon pools like trees, poles, saplings, and LHG. In all of the CF NE aspect has maximum carbon stock and minimum in the SW aspect. Among all of the carbon pool tree was found to be the maximum carbon stock, followed by the pole and saplings. According to a report issued by the Department of Research and Survey, tree carbon (>10cm) was assessed to be 104.47 tons/ha, which is slightly higher than the current study. This could be the case because the forest's ability to trap carbon is reliant on the type of forest and the size of trees (Khanal et al., 2010). Carbon stock values would differ on location, aboveground input, location, plant variety, age of the stand acquired from leaf litter, and fine root breakdown belowground. Other functioning ecological elements and management approaches (Nautiyal & Singh, 2013). For litter, herbs, and grass, JCF has 2.78±0.12 t/ha, 2.59±0.188 t/ha, 1.88±0.8685 t/ha, and 2.88±0.063 t/ha for NE, NW, SE, and SW, respectively. BCF has 3.85±0.372 t/ha, 1.672±0.568 t/ha, 0.37±0t/ha, and 0.378±0.14 t/ha of carbon stock in LHG for NE, NW, SE, and SW, respectively. PCF has 1.599±0.07 t/ha, 1.872±0.628 t/ha, 2.6±0.33 t/ha, and 0.737±0.2t/ha of carbon stock in NE, NW, SE, and SW, respectively. Since no study has been conducted on the sapling and seedling stage of plants, the carbon stock indicates is lack of studies on the carbon stock of saplings and, seedling stage of plants.

Biodiversity according to the aspect

The Simpson's Diversity Index was 0.51,0.57, 0.76 for tree, 0.57, 0.30, 0.54 for pole, and 0.44 for saplings in JCF, BCF, and PCF. The Shannon-Weiner Index was 0.79,0.89,1.3 for tree, 0.48,0.42,1.05 for pole in JCF, BCF, PCF, and Evenness 0.79,0.82,0.84 for tree 0.52,0.65,0.725 for pole, and 0.9 for saplings in JCF, BCF, and PCF. The lower the Simpson's index value higher the diversity, and the higher the Shannon's index value higher the diversity. The biodiversity indices values were slightly different between the forests. The study done by (Mandal et al., 2016) showed that the Shannon-Wiener Biodiversity Index was the highest, 2.33 in Banke-Maraha collaborative forest (CFM), and it was the lowest, 2.21 in Gadhanta-Bardibas CFM. Similarly, the Simpson index values were 0.39, 0.41, and 0.44 in Banke-Maraha. Tuteshwarnath and Gadhanta-Bardibas CFM, respectively (Mandal et al., 2016).

Species richness

The total no of tree was the highest 116 in Jyalachity community forest, 80 in Bosan Danda community forest and 96 no's of tree in Pataleban community forest. *Schimma walllichii* (Chilaune), *Alnus nepalensis* (Utish), *Castanopsis indica* (Katush), *Rhododendron arboreum* (Laligurans), *Myrica esculenta* (Kafal). These were some of the species that are common in all three Community forests.

Conclusion

The estimated total carbon stock was highest in the North East aspect and followed by the North west aspect, South east, and South west aspects, respectively. The tree and pole carbon stock were also highest in the Northeast aspect. Carbon Stock was also dominant in the carbon pool in

NE aspect, followed by C (AGT/P) and C (BB). Tree and pole contribute the maximum percentage in the total carbon pool facing the Northeast and the Lowest in the South West direction. Sapling, herbs, and leaf litter contribute a smaller percentage in all directions. *Schima wallichi* was found to be the dominant species, and it was followed by the *Alnus nepalensis* and *Castanopsis indica* on the NE aspect. Simpson's diversity, Shannon-Wiener index values, and evenness showed that the plant species diversity was not significantly different in the three community forests. From this, it can be concluded that the storage of higher carbon is on the North East aspect than the South West aspect, even in the micro climatic zone, and this would emphasize the importance of maintaining forests in the North East direction that reduce C emissions from deforestation.

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