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Assessment of Carbon Stock in Community Forest (A Case Study from Barahi Community Forest)

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Abstract: Forests play a significant role in mitigating climate change by capturing carbon dioxide from the atmosphere and storing it in the form of biomass, deadwood, litter, and soils. Estimating the total carbon stock in any forest is crucial, as it provides both ecological and economic benefits through various environmental services. Given the recognised importance of community forests in mitigating the effects of climate change, and considering the scarcity of studies on carbon issues in the Nuwakot district, this research was conducted to determine the above- and below-ground carbon stocks in the Barahi community-managed forest, Nuwakot. The inventory of estimating above- and below-ground biomass of the forest was carried out using a stratified random sampling method. 17 plots were selected randomly. Forest biomass was calculated using standard allometric models. The below-ground biomass was estimated using a root-to-shoot ratio value of 1:5. The biomass stock density of a sampling plot was then converted to carbon stock densities after multiplication by the default carbon fraction of 0.47. The total above- and below-ground biomass was found to be 175.33 ± 18.75 t/ha and 34.38 ± 18.75 t/ha, respectively. The total forest carbon stock was found to be 98.57 ± 8.92 t/ha, with above-ground carbon stock 82.41 ± 8.92 t/ha and below-ground carbon stock 16.16 ± 8.92 t/ha, respectively. The study concluded that the studied CF has a high carbon sequestration potential and can serve as an important carbon sink contributing to climate change mitigation. Wise and sustainable management of the existing forest is highly recommended.

Keywords: *Environmental services, Forest biomass, Carbon sequestration, Climate change*

Conflicts of interest: None
Supporting agencies: None

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1. Introduction

Forest plays a vital role in the global carbon cycle, as they sequester a large amount of atmospheric carbon (Brown & Pearce, 1994). It acts as a natural storage for carbon at the global scale, contributing approximately 80% of terrestrial aboveground, and 40% of terrestrial belowground carbon storage (IPCC, 2001). However, growing deforestation and forest degradation threaten their ability to function as carbon sinks. In South Asia, forest conservation plays a crucial role in offsetting carbon emissions, particularly in Nepal, where land-use changes are a significant concern. Nepal's community forestry initiative has been internationally recognised as a successful model for sustainable forest management (Ghimire and Lamichhane, 2021). Currently, Nepal has approximately 22,519 community forests (CFs) covering approximately 2,312,545 hectares (Pandey and Pokhrel, 2021). These forests provide ecosystem services, including biodiversity conservation, hydrological regulation, and carbon sequestration. Research suggests that well-maintained CFs can lower emissions by reducing deforestation, strengthening carbon sinks, and promoting local livelihoods (K.C et al., 2018; Ingram & Fernandes, 2001).

Despite the known benefits of community forests, limited studies have assessed their carbon stock in the Nuwakot district of Nepal. Due to the lack of such assessments, the local people are unaware of the carbon reserves and the economic and environmental benefits they provide. This study aims to address this gap by evaluating the above- and below-ground carbon stocks in the Barahi Community Forest, highlighting its role in climate change mitigation and sustainable management.

2. Materials and Method

2.1 Study Area

Nuwakot is one of the seventy-seven districts of Nepal located in Bagmati Province. It lies from 84°58'00"E to 85°30'00"E longitude and 27°48'00"N to 28°06'00"N latitude with an area of 1121 km2 (433 sq. mi). The district headquarters is in Bidur Municipality. The altitude of the district ranges from 518 m to 4876 m above sea level. The temperature fluctuates between 35 °C during the summer and 15-20 °C during the winter season, and the climate zone varies from Upper tropical to subtropical to temperate. The annual rainfall of the district is 254.09 mm.

This study was conducted in the Barahi Community Forest, located in Bidur Municipality, Ward No. 2, Nuwakot District. The forest covers an area of 84.26 ha. This forest was handed over to the community on the 10th of Falgun, 2053 B.S. The forest has a subtropical climate, and the dominant tree species are *Pinus roxburghii, Shorea robusta, Schima wallichii*, etc. The majority of the trees are *Pinus roxbughii* species. This forest has grown through a natural regeneration system. There are 288 households and a population of 1523.

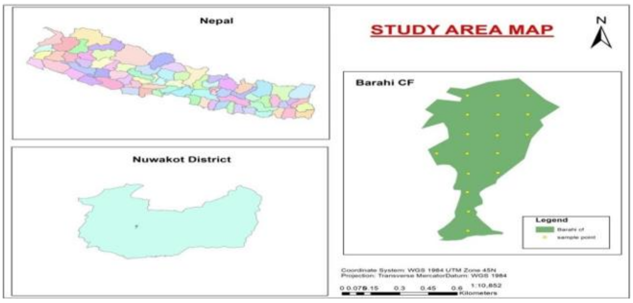

Figure 1: Study Area Map

2.2 Data Collection

The Barahi CF was delineated using GPS and ArcGIS 10.8. For this study, a 0.5% sampling intensity systematic random sampling was adopted (DoF, 2004). A total of 17 concentric circular plots, each covering 500m2 were randomly distributed across the forest to ensure representativeness. Trees (DBH ≥ 5cm) and Saplings (1cm < DBH < 5cm) in each sample plot were measured within a radius of 12.62 m and 5.64 m, respectively (Subedi et al., 2011). These sampling plots were strategically selected to capture variations in forest structure and biomass. Diameter tape was used for DBH measurement at a height of 1.3m above the ground, and a clinometer was used for tree height measurement. All the leaf litter (dead leaves, twigs, non-woody plants) within the 1m2 plots were collected destructively and weighed. Approximately 100g of sub-samples were collected and taken to the laboratory, where they were oven-dried until a constant weight was reached to determine the dry mass. For better understanding and interpretation, several scientific studies, articles, and other relevant literature sources related to carbon and biomass estimation were collected.

2.3 Estimation of biomass and carbon stock

To calculate the Above Ground Tree Biomass (AGTB), Chave et al. (2005), allometric equation was used.

$$AGBT = 0.0509\ x\ \rho\ x\ D^2\ x\ H \ldots\ldots\ldots\ldots\ldots\ldots eq(1)$$

where AGTB = Above ground tree biomass (KG), ρ = specific gravity of wood (g cm^3) (J.K. Jackson, 1994), D = tree DBH in cm and H = Height of tree (m).

To calculate aboveground sapling biomass (AGSB), the national allometric biomass tables developed by Tamrakar (2000), was used.

$$Log\ (AGSB) = a + b\log(D) \ldots\ldots\ldots\ldots\ldots\ldots eq(2)$$

where, AGSB = Aboveground tree biomass (KG), ρ = specific gravity of wood (g cm^3) (J.K. Jackson, 1994), D = tree DBH in cm and H = Height of tree (m).

To calculate aboveground sapling biomass (Kg), Log=natural log (dimensionless), a=intercept of allometric relationship for saplings (dimensionless), b=slope allometric relationship for saplings (dimensionless), and D=over bark diameter at breast height measured at 1.3 m above ground (cm).

For the forest herbs (herbs, grass and litter), the amount of biomass per unit area is given by:

$$LHGB = \frac{Wfield}{A} * \frac{Wsubsample\ dry}{Wsubsample\ wet} * \frac{1}{10000}$$

(Subedi et al., 2011)

Where, LHG = biomass of leaf litter, herbs and grass (t ha-1), Wfield = weight of the fresh field sample of LHG, destructively sampled within an area of size A, A = size of area in which LHG collected (ha), Wsubsample,dry = weight of the oven-dry sub-sample of LHG taken to the laboratory (g) and Wsubsample,wet = weight of the fresh sub sample of LHG taken to laboratory (g).

The below-ground biomass was estimated using a root-to-shoot ratio value of 1:5 (MacDicken, 1997). This ratio is widely accepted for tropical and subtropical forests and is supported by studies indicating that below-ground biomass contributes approximately 20% of total biomass (Djomo & Chimi, 2017; Sheikh et al., 2011; Batjes & Sombroek, 1997). Total biomass (Kg) was calculated by summing up above and below-ground biomass.

$$TB = AGTB + AGSB + LHG + BGB \ldots\ldots\ldots\ldots\ldots\ldots eq(3)$$

For each plot, the sum of all individual biomass in kilograms was divided by the sampling plot area to calculate biomass stock density in kilograms per square meter, and then simply multiplied by 10 to obtain biomass stock density in tons per hectare. The biomass stock density of a sample plot was converted to carbon stock densities after multiplying by the IPCC (2006) default carbon fraction of 0.47. Lastly, the carbon stock densities of various carbon pools were added up to estimate the carbon stock density of the overall CF.

$TC = C(AGTB) + C(AGSB) + C(LHG) + C(BGB) \dots\dots\dots\dots\dots\dots\dots\dots\dots. eq$ (4) (Subedi et al., 2011).

where, TC = total density of carbon stocks for a type of land use (ton ha-1), C(AGTB) = carbon in above-ground tree biomass (ton ha-1), C(AGSB) = carbon in above-ground sapling biomass (ton ha-1), C(LHG)= carbon in leaf litter, herbs and grasses (ton ha-1), C(BGB) = carbon in below-ground biomass (ton ha-1).

2.4 Statistical analysis

The data were analysed using Microsoft Excel 2010. To design a map, ArcGIS 10.8 was utilised. Descriptive statistical method was used to summarise the data. The results were presented in text, tables and figures interpreted accordingly.

3. Results

3.1 Measurement of tree and pole stand (>5cm DBH)

The mean diameter, mean height was found 17.5cm, and 9.68m respectively (Table 1).

Table 1: Characteristics of data of pole and tree stand

Statistical Characteristics	Diameter (cm)			Height(m)		
	Min.	Max.	Mean	Min.	Max.	Mean
Poles and Trees	5	48.5	17.50	1.3	18	9.68

3.2 Above Ground Biomass Estimation

The total above-ground biomass was found to be 175.33 ± 18.75t/ha, with tree biomass 171.93 t/ha, sapling biomass 1.46 t/ha and LHG biomass 1.94 t/ha (Table 2).

Table 2: Distribution of above ground biomass

Above ground tree biomass (t/ha)		Above ground sapling biomass (t/ha)		Leaf litters, herbs and grasses biomass (t/ha)		Total
Mean	SD	Mean	SD	Mean	SD	Biomass(t/ha)
171.93	18.2	1.46	0.22	1.94	0.33	175.33 ± 18.75

3.3 Above Ground Carbon Stock

The above-ground carbon stock included tree carbon stock, sapling carbon stock, leaf litter, and the carbon stock of herbs and grasses. The total above-ground carbon stock was found to be 82.41 t/ha, with tree carbon stock accounting for 80.81 t/ha, sapling carbon stock 0.69 t/ha, and leaf litter, herbs, and grasses carbon stock 0.91 t/ha, respectively (Table 3).

Table 3: Above ground carbon stock

Carbon stock (t/ha) by			Total aboveground
Tree	Saplings	Leaf litter, herbs and grasses	Carbon stock (t/ha)
80.81 ± 8.55	0.69 ± 0.22	0.91 ± 0.15	82.41 ± 8.92

3.4 Below Ground Biomass and Carbon Stock

The below-ground biomass was found to be 34.38 ± 18.75 t/ha, which is 20 % of the above-ground tree/pole biomass. The total below-ground carbon stock was found to be 16.16 ± 8.92 t/ha (Table 4).

Table 4: Below ground biomass and carbon stock

Belowground biomass (t/ha)	Below ground carbon stock (t/ha)
34.38 ± 18.75	16.16 ± 8.92

3.5 Total Carbon Stock

Within trees, saplings and LHG's, the highest carbon stock was found in trees with 80.81ton/ha, followed by LHG's and saplings with the corresponding stock density of 0.91 ton/ha and 0.69ton/ha. The below-ground carbon stock was found to be 16.16 tons/ha. Altogether, the overall carbon stock in CF was measured at 98.57 tons/ha.

Table 4: Total carbon stock in the CF

S.N.	Forest strata	Carbon stock (t/ha)
1.	Above ground	82.41 ± 8.92
2.	Below ground (root)	16.16 ± 8.92
Total		98.57 ± 8.92

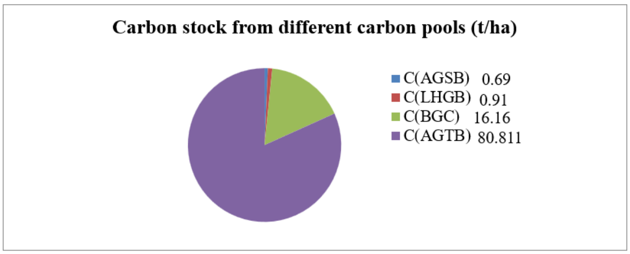

Figure 2: Total carbon stock by different pools

4. Discussion

The study found that the estimated total per ha biomass carbon of the selected community forest was 98.57 ± 8.92 t/ha. Based on a report published by the Department of Research and Survey, the estimated tree carbon (>10cm) was 108.88 tons/ha, which is slightly higher than the value reported in the present study. This discrepancy may be attributed to differences in forest type, age, and tree size, all of which influence the potential for carbon sequestration.

Compared to other studies, such as Ghimire (2019), which estimated an above-ground carbon stock of 140.56 t/ha in the Makwanpur district, the Barahi Community Forest had a lower value of 82.41 ± 8.92 t/ha. This variation may be due to differences in geographical location, plant species composition, stand age, site quality, climatic conditions, and past disturbances. Similarly, Pandey & Bhusal (2016) estimated the total carbon stock density of Shorea robusta forests in the Hills to be 123.15 t/ha, a value relatively close to this study's findings but still slightly higher, likely due to the exclusion of carbon stored in deadwood and stumps in the present study. The observed differences in carbon stock can be explained by several factors. Forest age and growth stage play a crucial role in carbon accumulation, with mature forests typically storing more carbon than younger stands. Additionally, the species composition has a significant impact on sequestration potential. Management practices also influence carbon storage; community forests with sustainable practices such as controlled harvesting, enrichment planting, and fire control tend to have higher carbon stocks, whereas forests subjected to frequent harvesting or lacking active regeneration efforts may exhibit lower values.

The estimated carbon stock in Barahi CF offers prospects for involvement in carbon trading schemes or Payment for Ecosystem Services (PES) initiatives, such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation). These programs promote climate change mitigation and sustainable forest management, offering financial incentives. Additionally, strengthening community forest user groups and implementing climate-smart forestry practices can enhance carbon sequestration while supporting biodiversity conservation and local livelihoods.

5. Conclusion

This study highlights the importance of Barahi CF in carbon sequestration, estimating its total carbon stock to be 98.57 ± 8.92 t/ha. Although this value is lower than that of other forests in Nepal, it highlights the need for enhanced forest management to maximise carbon storage. Sustainable forestry practices should be reinforced to optimise both ecological and economic advantages. Future research should refine biomass estimation techniques using remote sensing, and investigate potential carbon credit mechanisms to benefit the local communities.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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