



ANALYZING THE BIOMASS AND SOIL CARBON STOCKS IN BLUE PINE (*PINUS WALLICHIANA*) OF MAKAWANPUR DISTRICT, NEPAL

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ABSTRACT

This study assesses the vegetation and soil carbon stocks in Pinus wallichiana forests of Nepal, goal of contributing to national carbon accounting and informing sustainable forest management practices. The carbon stocks on biomass and soil was quantified through field measurements and laboratory analysis, revealing significant carbon storage potential in both components. The total carbon stock in Pinus wallichiana forests was found 99.23 tha⁻¹ with above ground carbon stock 60.43tha⁻¹, leaf litters, herbs and grasses carbon stock 11.70 tha⁻¹ and soil carbon stock 27.10 tha⁻¹ respectively. Among the carbon pools carbon stock was found in the order of above ground carbon stock (60.90%) > soil organic carbon stock (27.30%)> below ground carbon stock (11.90%). These findings emphasizes the importance of protecting and managing Pinus wallichiana forests for climate mitigation and ecosystem services.

Keywords: Carbon pool, Climate change, Community Forest, *Pinus wallichiana*

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1. INTRODUCTION

One of the most important environmental issues facing human today is climate change on Earth. The reason for this is the increase in human-induced greenhouse gases (GHGs), which has led to health, ecological and humanitarian crises (Ghimire, 2001; IPCC, 2006). Response to this concern have focused on reducing emissions of GHGs particularly, carbon dioxide (CO₂) and on estimating carbon (C) absorbed by and stored in forest, soil and other pools (Lal, 2005; Ghimire et al. 2018).

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Forests play a critical role in the global carbon cycle, acting as significant carbon sinks by sequestering, large amounts of atmospheric carbon dioxide (CO₂) in plant biomass and soil (Zhao et al. 2019). C sequestration by growing forests has been found to be a cost-effective option for mitigation of global climate change (Lal, 2005). In Nepal, *Pinus wallichiana* (commonly known as Gobre Salla) are dominant tree species in temperate region, contributing to the country's 3.75% to total stem volume (DFRS, 2015; Jackson, 1994). *Pinus wallichiana* is a key species in Nepal's temperate region, thriving at altitudes between 1,800 and 3,600m, extending up to 3,700m. These forests are widely distributed throughout central Nepal and are critical to both ecological and socioeconomic systems (Jackson, 1994; MoFSC, 2014). Despite these roles, detailed researches focusing on the carbon sequestration potential of *Pinus wallichiana* forests are limited.

Carbon sequestration is the practice of removing carbon dioxide (CO₂) from the atmosphere and storing it in various carbon pools such as plants, soils, geologic formations, and the ocean, one of the many approaches being taken to combat climate change (Lal, 2005; Ghimire and Lamichhane, 2023). Carbon stock assessment in forests has become a global priority due to its critical importance for climate change mitigation strategies. Understanding the carbon stocks in vegetation and soil is essential for meeting the objectives of the United Nations Framework Convention on Climate Change (UNFCCC) and initiatives like Kyoto protocol, Reducing Emissions from Deforestation and Forest Degradation (REDD+) (Ghimire et al. 2018; Ghimire and Lamichhane 2023). In Nepal, the National Forest Inventory has highlighted the potential of forests to act as carbon sinks. However, specific studies on coniferous species such as *Pinus wallichiana* remain limited, particularly concerning the partitioning of carbon stocks between vegetation and soil carbon stocks, in particular, are often overlooked despite their significant contribution to the total carbon pool (Ghimire and Lamichhane, 2023). Hence, this study aims to quantify the vegetation and soil carbon stocks in *Pinus wallichiana* forests, assessing their contribution to carbon sequestration and implications for sustainable forest management.

2. METHODOLOGY

2.1 Study Area

The study was conducted in Siddhakali Community Forest (CF) from Makawanpur district, Bagmati Province Nepal. Siddhakali CF is a natural *Pinus wallichiana* forest which covers an area of 83.33 ha and lies at 1231-2300 msl in subtropical region (Operational Plan Siddhakali Community Forest, 2019).

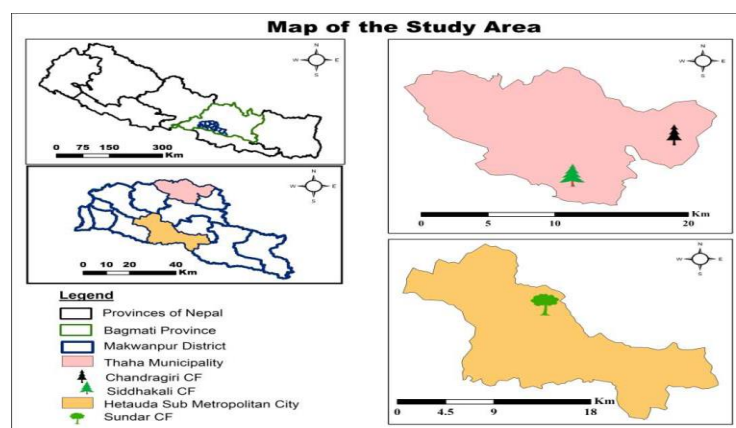


Figure 1: Map of the study area

2.2 Sampling Technique and Data Collection

Stratified random sampling was used to carry out forest inventory. 10 sample plots (of 500m²) were taken with the sampling intensity of 0.5%. The details of sampling for each forest types were taken according to Forest Carbon Measurement Guideline, Ministry of Forest and Environment, Nepal (MoFSC, 2010). The quadrat size was 20 m x 25 m for trees (>30 cm dbh):- nested quadrat size was 10 m x 10 m for poles (10-29.9 cm dbh), and 1m x 1m for leafs, herbs and grasses were laid out. Diameter at breast height (dbh) and height of each tree was measured by using diameter tape Abney's level. All the litters, herbs and grasses inside the 1m² plot were clipped and collected, and the fresh weights of the samples were recorded and representative subsamples were taken to the laboratory for oven drying. Forest biomass stocks were estimated by Forest Carbon Measurement Guideline of Ministry of Forest and Environment, Nepal (MoFSC, 2010). Then, biomass stocks were converted to carbon stock using the IPCC (2006) default carbon fraction of 0.47.

Soil profile was dug at center part of the each plot up to 20 cm depth of two different intervals (0-10 cm, and 11-20cm). A core ring sampler (5 cm diameter and 5 cm length) was used to take samples of soil for bulk density (BD) estimation. All the samples were bagged, labeled and sent to the soil laboratory for further analysis.

2.3 Data Analysis

Aboveground Tree/Pole Biomass and Carbon Analysis

The total above-ground tree biomass as calculated using the equations developed by 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)

The value of ρ for *Pinus wallichiana* is 0.480 gcm⁻³ (Jackson, 1994).

Leaf litters, Herbs and Grasses (LHG) Biomass and Carbon Analysis

To determine the biomass of LHG, collected samples were oven dried for 72 hours at 60 C and oven dry weight was recorded. The amount of biomass per unit area was then calculated by using the formula as suggested by Forest Carbon Measurement Guideline of Ministry of Forest and Environment, Nepal (MoFSC, 2010):

$$LHG = W_{\text{field}} / A * W_{\text{sub-sample dry}} / W_{\text{sub-sample wet}} * 1/1000$$

Where,

LHG = Biomass of leaf litter, herbs, and grasses (t ha⁻¹);

W_{field} = Weight of the fresh field sample of leaf litters, herbs and grasses, destructively sampled within an area of size A (g);

$W_{\text{sub-sample dry}}$ = Weight of oven dry sub sample of leaf litter, herb and grasses taken to the laboratory to determine moisture content (g);

$W_{\text{sub-sample wet}}$ = Weight of fresh sub sample of leaf litters, herbs and grasses taken to the laboratory to determine moisture content (g); and

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

Below ground Biomass and Carbon Analysis:

The following relationship was used to estimate the root biomass developed by MacDicken (1997).

Below-ground biomass = $0.20 \times$ above-ground biomass tree/pole biomass

Soil Organic Carbon (SOC) Analysis

The following formula as recommended by Pearson et al. (2005) was used to calculate the bulk density using stone correction:

Bulk density (gcm^{-3}) = Oven dry weight of soil (gm)/ Volume of the soil in (cm^3)

Where,

Volume of the soil = Volume of core – Volume of the stone

Soil organic carbon (SOC) was estimated by using following formula as suggested by (Chhabra et al. 2003).

$\text{SOC} = P \times d \times \%C$

Where,

SOC = Soil organic carbon stock per unit area (t ha^{-1})

P = Soil bulk density (gcm^{-3})

d = Thickness of horizon (cm)

%C = Organic carbon content %

3. RESULTS AND DISCUSSION

3.1 Above Ground Biomass and Carbon Stocks

The total above ground biomass stock (including tree/pole, and leaf litters, herbs and grasses) in *Pinus wallichiana* forest was found to be 128.86 tha^{-1} (Table 1). Accordingly, total above ground carbon stock (including tree/pole, and leaf litters, herbs and grasses) in *Pinus wallichiana* forest was found to be 60.43 tha^{-1} (Table 1). According to Sigdel (2013) the tree biomass carbon stock of 44.81 tha^{-1} in *Pinus wallichiana* forest of Manaslu conservation area in central, Nepal. Ghimire (2021) also reported 83.71 tha^{-1} of aboveground carbon stock in pine forest (*Pinus roxburghii* and *Pinus wallichiana*) of Makawanpur district Nepal.

Table 1: Distribution of aboveground biomass in *Pinus wallichiana* forest

Forest Type	Tree/pole biomass stock (tha^{-1})		Tree/pole carbon stock (tha^{-1})		LHG's biomass stock (tha^{-1})		LHG's carbon stock (tha^{-1})	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
<i>Pinus wallichiana</i>	124.38	17.74	58.45	9.42	4.22	0.60	1.98	0.30

3.2 Below Ground Biomass and Carbon Stocks

Below ground biomass and carbon stocks represent the biomass and carbon in the root portion of the forest. In this study belowground biomass was found to be 24.88 tha^{-1} . Accordingly, below ground carbon stock was found to be 11.70 tha^{-1} (Table 2). Ghimire (2021) also reported 26.65 tha^{-1} of belowground carbon stock in pine forest (*Pinus roxburghii* and *Pinus wallichiana*) of Makawanpur district Nepal.

Table 2: Distribution of below ground biomass in *Pinus wallichiana* forest

Forest Type	Below ground biomass stock (tha ⁻¹)		Below ground carbon stock (tha ⁻¹)	
	Mean	SD	Mean	SD
<i>Pinus wallichiana</i>	24.88	4.06	11.70	2.05

3.3 Soil Organic Carbon Stocks

In this study average soil BD ranges from 0.98 to 1.12 gmcm⁻³. Likewise, average carbon content ranges from 1.02 to 1.60%. The study found some variation in BD with respect to soil profile depth. There was a gradual increase in BD with increase in soil depth. Accordingly, carbon content was decrease with increase in soil profile depths (Table 3).

In this study total SOC stock up to 20cm soil profile depth was found to be 27.10 t ha⁻¹. Carbon stock was gradually decreased with increasing soil depth (Table 4). Higher SOC stock (15.68 t ha⁻¹) was found at the top soil layer (0-10 cm) and lower (11.42 t ha⁻¹) in 11-20 cm soil layer (Table 3). According to Sigdel (2013) the soil carbon stock of 24.85 tha⁻¹ in *Pinus wallichiana* forest of Manaslu conservation area in central, Nepal. Ghimire (2021) also reported 41.30 tha⁻¹ of soil organic carbon stock up to 30cm soil depth in pine forest (*Pinus roxburghii* and *Pinus wallichiana*) of Makawanpur district Nepal. Variations in findings may be attributed to differences in topographic and edaphic factors.

Table 3: Distribution of bulk density and soil carbon stock in *Pinus wallichiana* forest

Soil depths (cm)	Bulk density (gmcm ⁻³)		Carbon content (%)		Soil organic carbon stock (t ha ⁻¹)	
	Mean	SD	Mean	SD	Mean	SD
0-10	0.98	0.60	1.60	1.04	15.68	1.08
11-20	1.12	0.70	1.02	0.96	11.42	1.03
Total					27.10	

3.4 Total Carbon Stock

Total carbon stock in *Pinus wallichiana* forest of Siddhakali CF was found 99.23 t ha⁻¹ with total above ground, below ground and soil pool contributing 60.90%, 11.80% and 27.30% respectively (Figure 2). Sigdel (2013) reported the total carbon stock (including tree biomass carbon stock and soil carbon) of 69.66 tha⁻¹ in *Pinus wallichiana* forest of Manaslu conservation area in central, Nepal. Further, Ghimire (2021) also reported total carbon stock of 137.56 tha⁻¹ in pine dominated forest (*Pinus roxburghii* and *Pinus wallichiana*) of Makawanpur district Nepal. These findings highlight the potential of *Pinus wallichiana* forests for climate mitigation and ecosystem services.

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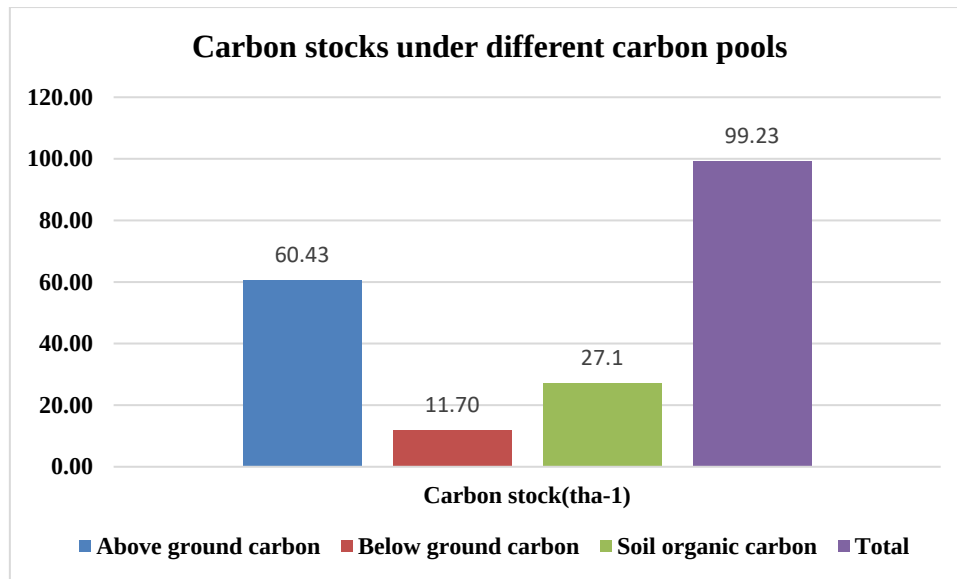


Figure 2: Distribution of total carbon stocks in different carbon pool

4. CONCLUSION

The study concludes that *Pinus wallichiana* forests are effective carbon sinks, storing an average of 99.23 tha^{-1} carbon stocks in vegetation and soil. Carbon stock distribution in *Pinus wallichiana* was found in the order of above ground carbon stock (60.90%) > soil organic carbon stock (27.30%) > below ground carbon stock (11.90%). Both vegetation and soil carbon stocks contribute significantly to the total carbon pool, underscoring the need for integrated forest-soil management strategies. Development of species-specific forest management practices recommended to optimize carbon sequestration.

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DECLARATION OF COMPETING INTEREST

The authors declare that they have no known conflict of interest associated with this publication

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