

Research

Effect of Altitude on Total Carbon Stock of Coniferous Forest (*Pinus wallichiana*) in Lete and Kunjo V.D.C of Mustang District, Nepal

Jyoti Bhandati^{1,2}, Dhruva Bijaya G.C.^{1,2}, Can Li^{1*}

¹Provincial Key Laboratory for Rare Animals and Economic Insects of the mountains of Guizhou Province, School of Biological and Environmental Engineering, Guiyang College, Guiyang 550005, China

²Institute of Forestry, Tribhuvan University, Pokhara Campus 43, Pokhara, Nepal

***Corresponding author:**

E-mail: lican790108@163.com

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Abstract : *Pinus wallichiana* forest is the most important vegetation type in Mustang, Nepal, with a significant potential to mitigate climate change issues through carbon storage. However, little is known about the carbon stock of these pine forests, particularly in remote areas of Nepal. Forests play an important role in regional and global carbon (C) cycles, and estimates of total carbon flux in forest systems are important for evaluating the ecological and economic benefits to local people. The aim of this study is the estimation of net carbon stock and the documentation of the effects of elevation on carbon storage in *Pinus wallichiana* forest. Total mean carbon stock for the forest as a whole was found to be 177.09 tC ha⁻¹. Total forest carbon stock was significantly higher at lower elevation range of (2200 – 2500 m) as compared to middle and higher elevation ranges. Soil carbon stock was 1.33 times higher than tree biomass carbon. Further research in different climate types, soil types and forest age should be conducted for carbon storage in *Pinus wallichiana* forests.

Key words: Carbon stock, biomass carbon, soil organic carbon, *Pinus wallichiana*

1. Introduction

Pinus wallichiana forest occurs in the Himalayas at between 1800 and 3600 m and sometimes rarely up to 4400 m in elevation (Jackson, 1994). Although it is a strongly light-demanding tree species, it can also grow in moderate shade. It is one of the important tree species used in afforestation projects at higher elevations in Nepal. Terrestrial ecosystems play an important role

in the global carbon cycle (Lal, 2005). Carbon sequestration from the atmosphere can be advantageous from both environmental and socioeconomic perspectives. The environmental benefits include the removal of CO₂ from the atmosphere, the improvement of soil quality, and an increase in biodiversity (Batjes and Sombroek, 1997), while socioeconomic benefits include increased timber yields (Sombroek et al., 1993) and potential monetary incomes from carbon trading schemes (McDowell, 2002).

Forest are estimated to cover 31% of the earth's land surface and to contain a total carbon content of 289 Gt in biomass (FAO, 2010), more than the amount of carbon in the entire atmosphere. Gorte (2009) reported that moist tropical forests are important for carbon sequestration, because they typically have high carbon contents. Tropical riverine forest, Pine and *Alnus nepalensis* are fast growing species with high carbon sequestration rates. Terrestrial carbon budgets are the result of complex interactions and feedbacks among many factors, including productivity, decomposition, climate, soil properties, and human activities (Bala et al., 2007; Chapin et al., 2006). To fully understand the causes and magnitudes of ecosystem carbon fluxes, and hence ecosystem carbon storage, it is necessary to study the systems in meaningfully large units and over sufficiently large-time scales (Zhao et al., 2009).

Studies of carbon stock and carbon sequestration in forests have been conducted in India and a few African countries, but there have been few studies in Nepal (Sigdel, 2013). Limited studies in Nepal have investigated the secondary benefits of forests carbon sequestration. After the ratification of Kyoto protocol, it is important for country like Nepal to estimate forest carbon stock in order to benefit from carbon trading mechanisms. This paper documents the effects of elevation on total carbon stock of coniferous forest (*Pinus wallichina*) in the Lower Mustang district of Nepal. Since data about carbon sequestration potential of *Pinus wallichina* forest are lacking, this study aims to estimate total carbon stock and elevation on total carbon stock variability by elevation in *Pinus wallichina* forests in the Lower Mustang district of Nepal.

2. Research Method

Study Area

Mustang District covers an area of 3,573 km², extending from 28°24' to 29°20' N latitudes and from 83°30' to 84°10' E longitudes. Elevation ranges from 1372 m to 8167 m, representing sub-tropical to alpine climate types (Rajchal, 2010). The study was carried out in Lete and Kunjo (Village Development Committees) V.D.Cs. of Mustang District. Average annual precipitation is

1242 mm (1978–2007) with a rainfall peak from June to September. The yearly average temperature is 12.3 °C (1978–2007) (Department of Hydrology and Meteorology, 2008).

Data Collection

The study was conducted during 2010. A stratified random sampling method was used for collecting tree and understory plant biomass data. Sampling intensity of 1% of the forest area of Lete V.D.C and 0.5% of the forest area of Kunjo V.D.C was taken. The study site was divided into 3 elevational categories. The low elevation category ranged from 2200-2500 m, middle elevation category ranged from 2500-2800 m, and the high elevation category ranged from 2800-3001 m. Twenty quadrates of 20m by 25m were laid out and individual trees in the plot were sampled. Diameter at breast height (DBH) was measured and height of each tree was estimated using Sunto Clinometer and Abney's Level. Soil samples were taken in each plot from the soil profile at 3 different levels (0-20 cm, 20-40 cm and 40-60 cm) up to 60 cm depth. A borer (4 cm in diameter and 10 cm length) was used to sample for bulk density.

Data Analysis

All parts of the tree, including stem, branches, roots, leaves and undergrowth biomass were used to estimate biomass. The logarithmic transformation of the algometric formulae was used in estimating volume and biomass. The following equation was used to estimate oven-dried tree biomass (Sharma and Pukkala, 1990):

$$\ln(V) = a + b * \ln(d) + c * \ln(h)$$

Where, V = total steam volume with bark

d = diameter at breast height (cm)

h = tree height (m)

And a, b, & c are species specific constants are shown in table 1

Table 1: Parameter a, b, c and R²

Species	a	b	c	R ²
Pinus wallichina	-2.8195	1.7250	1.1623	98.9

(Source: Sharma and Pukala, 1990)

To calculate total aboveground biomass (dry wood stem biomass), the volume of the tree was multiplied by dry wood density of the tree species. The dry wood density of *Pinus wallichiana* is 480 kg m⁻³. The biomass of branch and leaves were estimated using 45 and 11% of the stem biomass respectively (Sharma, 2003). Root biomass was estimated on the assumption that the belowground biomass was 25 % of total aboveground tree biomass (IPCC 1996; Mokany et al. 2006). Total carbon content is estimated to be 43% of dry biomass (Maclaren, 2001).

The formulas used to estimate organic carbon content of above and belowground biomass organic carbon are as follows:

Total aboveground biomass organic carbon = (total above ground biomass of tree) * 43%

Total belowground biomass organic carbon = (total root biomass of tree) * 43% + total soil organic carbon.

The Walkey-Black method was used to measure the soil organic carbon percent. Total soil organic carbon was calculated using the following formula (Awasthi et al., 2005; Tan et al., 2004; Chhabra et.al. 2002):

$$\text{SOC} = \% \text{ organic carbon content} * \text{soil bulk density (kg/m}^3\text{)} * \text{thickness of soil horizon (m)}$$

Ton of carbon ⁻¹ was also calculated.

All statistical analyses were performed by using software package of SPSS 14.0 (SPSS Inc., Chicago, and IL., USA).

3. Results

The aboveground carbon stock in this *Pinus wallichiana* forest was found to be higher (109.95 ± 16.09 tC ha⁻¹) at an elevation range of 2200 – 2500 m, and lowest (16.63 ± 5.22 tC ha⁻¹) at an elevation range of 2800 – 3100m. Root carbon stock was observed to be highest (32.30 ± 4.74 tC ha⁻¹) at an elevation range of 2200-2500 mand lowest (4.82 ± 0.44 tC ha⁻¹) at an elevation range of 2800-3100 m. Soil organic carbon was found highest (102 .94 ± 9.72 tC ha⁻¹) at an elevation range of 2200- 2500m and lowest (94.81 ± 10.48 tC ha⁻¹) at the highest elevation range of 2800– 3100 m. Total carbon was observed highest (243.98 ± 20.37 tC ha⁻¹) at lowest elevation range of 2200 – 2500m and lowest (116.07 ± 1.35 tC ha⁻¹) at highest elevation range of 2800-3100m. The

Pinus wallichiana-dominated forest of (I have to say, this is the first time you mention "P.w.-dominated". You should make it clear at the beginning of the paper where this is a monotypic forest type, or whether there are other species in there, and what they are) lower Mustang District had an average carbon stock of $173.09 \pm 20.90 \text{ tC ha}^{-1}$ (Table 1). The average aboveground carbon stock was estimated at $57.51 \pm 15.48 \text{ tC ha}^{-1}$, root carbon at $16.95 \pm 4.56 \text{ tC ha}^{-1}$ and soil organic carbon at $102.62 \pm 2.63 \text{ tC ha}^{-1}$. Aboveground tree biomass carbon, root carbon and total carbon present at lower elevation range was significantly higher than middle elevation range and high elevation range. Soil organic carbon, on the other hand, did not differ significantly between different elevation ranges.

Table1: Total Carbon Stock (tC ha^{-1})

Elevation range	Above ground carbon	Root carbon	Soil carbon	Total carbon	No of plots
2200-2500	109.56 ± 16.09	32.30 ± 4.74	102.12 ± 7.52	243.98 ± 20.37	11
2500-2800	46.63 ± 5.22	13.75 ± 1.54	100.94 ± 9.72	161.29 ± 20.37	11
2800-3100	16.63 ± 5.22	4.82 ± 0.44	94.81 ± 10.48	116.07 ± 1.35	12
Mean	57.51 ± 15.48	16.95 ± 4.56	99.29 ± 2.63	173.09 ± 20.90	11.3

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4. Discussion and Conclusions

Tree biomass varies in different plots of same forest due to the variation in tree size as well as tree density. Tree density and tree size (DBH and height) were greater in the low elevation range as compared to middle and high elevation range (Table 2). Similarly difference in biomass at different elevations appears to result from differences in soil moisture and other properties, temperature, and duration of sunlight and steepness of slope. Our results also show that total biomass gradually decreases with an increase in elevation. Variation in microclimate with elevation will also influence biomass. Carson (1992) reported that in the mountain regions of

Nepal, with each 100 m increase in elevation, temperature decreases by 10 C, influencing vegetation productivity accordingly.

Highest aboveground and belowground biomass carbon stocks were found in the low elevation range than in middle and high elevation range. Various factors affect ecosystem carbon stocks, including net primary productivity and decomposition rates (Shrestha, 2009 and Lal, 2005). Net primary productivity differs by vegetation type, stand age, and environment (Shrestha and Singh, 2008). Sigdel (2013) reported that total carbon stock of *Pinus wallichina* forest on the northern aspect of Manaslu was highest at the 2300m, i.e. 138.93 tC ha⁻¹ and lowest at 2700m i.e 80.25 tC ha⁻¹, a result consistent with our study findings.

On the other hand, Sigdel (2013) calculated the total carbon stock of *Pinus wallichina* forest on the northern aspect of Manaslu at 112.34 ± 13.87tC ha⁻¹ and on southern aspect was 58.04± 6.25 tC ha⁻¹ lower values than our results. This indicates that the *Pinus wallichina* forest at low elevations in Lower Mustang is well developed in terms of biomass stock. In support of our results, Shrestha (2009) found that total carbon stock in *Pinus roxburghii* forest was 278.25 t ha⁻¹ C. Similarly Aryal et al. (2013) found that total carbon stock in *Pinus roxburghii* forest was 217.73 t ha⁻¹. The amount of carbon stock in a forest changes over time due to climate conditions, vegetation succession, and disturbances (Brown et al. 1996; Lal 2005). Moreover, forest management (Jandal et al. 2007), as well as topographic (Prichard et al. 2000) and edaphic factors (Wang et al. 2001) also influence the total carbon stock.

The organic carbon in forest soil depends upon forest type, climate, moisture, temperature and soil type. Many environmental factors (e.g. temperature, precipitation, atmospheric pressure, solar and UV-B radiation, and wind velocity) change systematically with altitude (Gairola et al. 2011b). In our study, with an increase in elevation, there was decrease in soil organic carbon. Low biomass in higher altitude is likely to result in decreased soil organic carbon.

Pinus wallichina forests of Lower Mustang district have shown great potential for carbon storage at low elevation ranges. Establishing *Pinus wallichina* plantations at low elevation could be an important mechanism in capturing carbon. The conservation of *Pinus wallichina* forests at all elevations in the Mustang district of Nepal would play a key role in carbon storage in the region. (or something like that).

Table 2: Properties of Pinus wallichina Forest at Different Elevation of Lete V.D.C

Properties of Pinus wallichina Forest in Different Elevation

Elevation	No of plots	No. of stem per Ha	Mean Diameter (cm)	Mean Height(m)
2200-2500	11	340	32.66	18.79
2500-2800	11	220	26.66	17.24
2800-3100	12	155	22.17	13.27

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Dedication

Not mentioned.

Conflicts of Interest

There are no conflicts to declare.



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