Nep J Environ Sci (2018), 6, 61-67
https://doi.org/10.3126/njes.v6i0.30127
ISSN 2350-8647 (Print) 2542-2901 (Online)
Research Article

Carbon stock estimation of Shree Rabutar Forest of Gaurishankar Conservation Area, Dolakha, Nepal

Karishma Gubhaju[1], Dipesh Raj Pant[2] and Ramesh Prasad Sapkota[3*]

[1]*Department of Environmental Science, Padma Kanya Multiple Campus, Tribhuvan University, Kathmandu, Nepal*
[2]*Tri-chandra Multiple Campus, Tribhuvan University, Kathmandu, Nepal*
[3]*Cenral Department of Environmental Science, Tribhuvan University, Kathmandu, Nepal*

Abstract

Forests store significant amount of atmospheric carbon in the form of above and below ground biomass and the amount of carbon stored in forests differs along spatial continuum which provides important information regarding forest quality. This study was carried out to estimate the carbon stock of Shree Rabutar Forest of Gaurishankar Conservation Area, Dolakha, Nepal. In total, 20 circular sampling plots with an area 250 m^2 were randomly laid in the study area. Ten tree species were observed in the sampling plots laid in the forest. The higher values of density, frequency, abundance and basal area were observed for *Rhododendron arboreum, Alnus nepalensis, Pinus roxburghii and Pinus wallichian*a. On the basis of Important Value Index, the dominant tree in the forest was *Alnus nepalensis* followed by *Rhododendron arboreum* and *Pinus roxburghii.* Shannon Index of general diversity of trees in the forest was 0.74 with equal value of Evenness Index, whereas the index of dominance was low (0.22) in the forest. Mean biomass of the forest was 464.01±66.71 $tonha^{-1}$ contributed by above ground tree biomass (384.44 $tonha^{-1}$), leaf litter, herbs and grasses biomass (2.69±0.196 $tonha^{-1}$) and below ground tree biomass (76.88±11.13 $tonha^{-1}$). Mean carbon stock was 262.77±30.79 $tonha^{-1}$ including soil carbon stock 44.69±2.25 $tonha^{-1}$. Individuals of trees with 20-30 cm DBH class were observed in maximum number, which shows that the forest has high potential to sequester carbon over time. Carbon stock estimation and forest management can be one of the potential strategies for climate change mitigation especially through carbon dioxide absorption by the forests.

Keywords: Biomass, Carbon dioxide, Soil carbon

Introduction

Forests play an important role within the global carbon cycle, as they sequester large amount of atmospheric carbon in the form above and below ground biomass (Kriedemann & Unwin, 2000; Lal, 2008). The increasing concentration of greenhouse gases, particularly carbon dioxide (CO_2), in the atmosphere is emitted mainly from industries and other anthropogenic activities such as forest degradation, deforestation, burning of fossil fuels and forest fires (Dar & Sahu, 2018). CO_2 is the primary agent of global warming which contributes about 76% of the total anthropogenic greenhouse gases (GHGs) emission in the atmosphere (IPCC, 2014). About 20% of the total global GHGs emission is contributed by deforestation which is more than the entire transportation system (Stern, 2007). Therefore, forest carbon sequestration and its management are the low-cost option for mitigating of global climate change (Brown et al., 1996). Carbon stock is the absolute quantity of carbon held within a pool at a specific time (IPCC 2000), whereas, carbon sequestration is the rate of removing carbon from the atmosphere and storage in plants, soils, geological formations and ocean that reduce carbon level in the atmosphere (IPCC, 2006; Ghimire et al., 2018). Forests store 44% carbon in soil (to 1 meter in depth), 42% in live biomass (above and below ground), 8% in dead wood and 5% in litter (Pan et al., 2011). The soil stores atmospheric carbon in the form of soil organic carbon which is an important part of terrestrial carbon pool (Vashum et al., 2016; Dhakal et al., 2017). Temperate forests contribute about 25% of the world forest area and store 14% of the total forest carbon (Pan et al., 2011). Nepal's forest covers nearly 44.74% of the total area of the country and stores 1054.97 million ton of carbon stock (DFRS, 2015) under different forest management regimes.

Protected areas are designated with the objectives of biodiversity conservation and also play a significant role in maintaining climate regulation through carbon sequestration (Campbell et al., 2008).

*Corresponding author: rsapkota@cdes.edu.np

In Nepal, out of the total area of forest, 17.32% forest lies within protected area (DFRS, 2015) and these forests play important role in reducing carbon emissions by increasing the amount of carbon sink. Many tree species found inside forests of the protected areas have important role in maintaining carbon balance, but these forests are feebly considered in scientific studies. In this regard, the purpose of this study is to estimate carbon stock in the Shree Rabutar Forest of Gaurishankar Conservation Area of Dolakha District of Nepal. This study also identifies the status of forest in terms of carbon storing capacity of tree species and provides baseline data of carbon stock for the future references.

Methods and Materials

Study Area

The Shree Rabutar Forest lies in Ward No. 1 and 2 of Jiri Municipality, Dolakha District (Fig. 1). It covers an area of 41.12 hectares and situated between 27°38' to 27°39'N latitude and 86°17' to 86°19'E longitude with elevation ranging from 1400 to 2350 m. This North-East facing forest has been conserved by the Gaurishankar Conservation Area. *Alnus nepalensis*, *Rhododendron arboretum*, *Pinus roxburghii* and *Pinus wallichiana* are the major tree species found in this forest.

Sampling Design

The field study was carried out in October 2018. Field data for carbon stock calculation was collected using guidelines given by ANSAB et al. (2010). Twenty sampling plots (each of an area 250 m^2) were taken inside the forest using simple random sampling approach maintaining 1% sampling intensity. A circular plot of radius 8.92 m was taken for trees count and measurement. In the same plot, a radius 0.56 m was taken for leaf litter, herbs and grasses (LHG) biomass collection, and soil samples were collected for organic carbon determination. Diameter at Breast Height (DBH) and height of trees (≥5 cm DBH) were measured with the help of DBH tape and Silva Clinometer, respectively. LHG sample were collected by harvest method by oven drying at 80°C for 24 hours. Soil samples were taken at the depth 0-10 cm and 10-20 cm by using soil corer having diameter 5.08 cm.

Data Analysis

The collected data were analyzed to estimate vegetation composition of tree species and carbon stock of trees, LHG and soil.

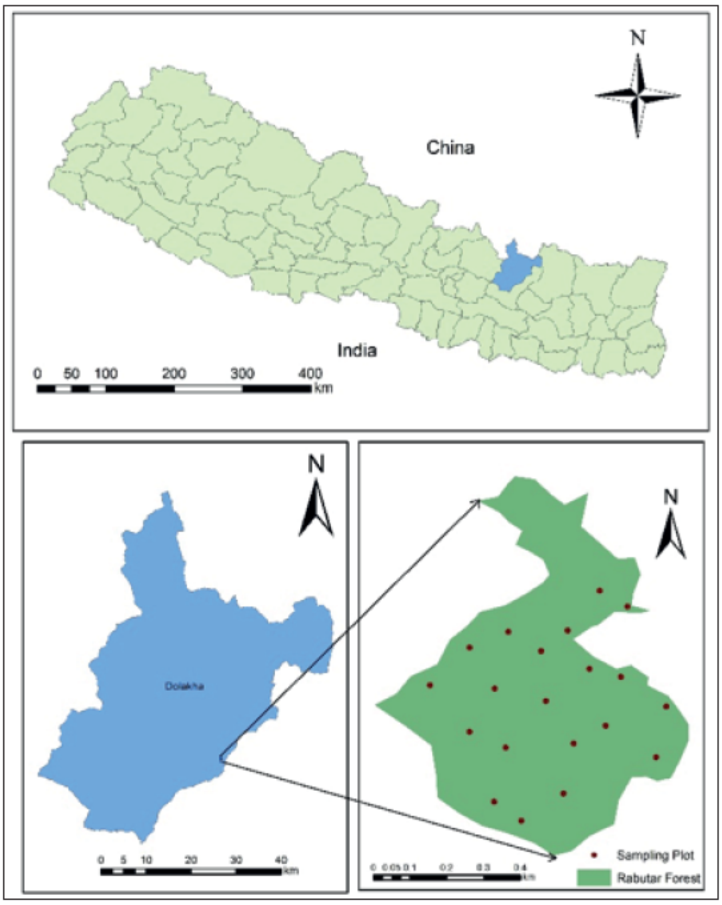

Figure 1: Location and sampling sites in the study area

Vegetation Analysis

Density, frequency and abundance of tree species were calculated from the collected data using respective formulas. Importance Value Index (IVI) was determined by using formula given by Curtice (1959):

$$IVI = \text{Relative Density (RD)} + \text{Relative Frequency (RF)} + \text{Relative Basal Area (RBA)}$$

Basal area of a tree species was determined by measuring the diameter of the trees at the breast height (1.37 m).

$$\text{Basal Area } (m^2) = \left(\frac{\pi * DBH^2}{4}\right)$$

Shannon Index of general diversity (H) was calculated using formula given by Shannon (1948):

$$H = -\sum\left[\left(\frac{ni}{N}\right) * \log\left(\frac{ni}{N}\right)\right]$$

Pielou´s Evenness Index (e) was calculated according to Pielou (1960):

$$e = \frac{H}{\log}, \ (0 \leq e \leq 1)$$

Index of dominance (C) was calculated according to Simpson (1949):

$$C = \sum\left(\frac{ni^2}{N}\right)$$

Carbon Stock Estimation

Above ground tree biomass (AGTB) was calculated by using the following allometric equation (Chave et al., 2005):

$$AGTB = 0.0509 \times \rho D^2 H$$

Where,

$AGTB$ = Above-ground tree biomass (kg)

ρ = Wood specific gravity (gm/cm^3)

D = Diameter at breast height (cm)

H = Total height of the tree (m)

The calculated AGTB (sum of all the individual weights) in each sampling unit was divided by sampling plot (250 m^2) to convert into kgm^{-2} and then this value was converted into $tonha^{-1}$ by multiplying it by 10. The leaf litter, grass and herbs biomass was calculated using USDA-NCRS (2013) formula:

$$LHG = \frac{\text{Oven dried weight of leaf litter, grass and herbs)}}{\text{(Area of the plot in which the biomass is sampled } (m^2)}$$

Below Ground Tree Biomass (BGTB) was calculated by using root to shoot ratio method in which root to shoot value is 1:5, i.e. the below ground biomass is 20% of the above ground tree biomass (MacDicken, 1997). All the biomasses were converted to carbon stocks using the IPCC (2006) default fraction of 0.47.

The soil bulk density was calculated from the soil samples of 2 stratums (0-10, 10-20 cm) using ANSAB et al. (2010). Percentage SOC was calculated following Walkley and Black (1934) method. The carbon stock of soil organic carbon (SOC) was calculated by using following equation (Pearson et al., 2007).

$$SOC = \rho \times d \times \%C$$

Where,

ρ = soil bulk density (gcm^{-3})

d = the total depth over which the sample is taken (cm)

$\%C$ = carbon concentration in percentage.

The total carbon stock (TCS) was calculated by summing carbon stock of the individual carbon pools of the stratum:

$$C(TCS) = C(AGTB) + C(BGTB) + C(LHG) + SOC$$

Where,

$C(AGTB)$ = Carbon stock for above ground tree biomass ($tonha^{-1}$)

$C(BGTB)$ = Carbon stock in below ground tree biomass ($tonha^{-1}$)

$C(LHG)$ = Carbon stock in leaf litter, herbs and grasses ($tonha^{-1}$)

SOC = Soil organic carbon stock ($tonha^{-1}$)

All the carbon stock was converted to tons of carbon dioxide equivalent by multiplying by 3.67 (Pearson et al., 2007). Carbon stock in dead wood and stumps, and carbon in above ground sapling biomass (≤ 5 cm DBH) were not considered in this study. As suggested by ANSAB et al. (2010) any individual carbon pool that does not contribute significantly to the total carbon stock can be ignored.

Results and Discussion

Vegetation Composition

In the sampling plots of the study area, 10 tree species were recorded with highest (224 $indm^{-2}$) density of *Rhododendron arboreum* followed by *Pinus roxburghii* (176 $indm^{-2}$) and the lowest value for *Pyrus pashia* (2 $indm^{-2}$) and *Prunus cornuta* (2 $indm^{-2}$). The frequency was found to be highest for *Alnus nepalensis* (85%) followed by *Lyonia ovalifolia* (75%) and lowest for *Pyrus pashia* (5%), *Rhus javanica* (5%) and *Prunus cornuta* (5%). Abundance of *Pinus roxburghii* was found to be highest (11.0) followed by *Rhododendron arboreum* (10.2) and lowest of *Pyrus pashia* (1.0) and *Prunus cornuta* (1.0). Likewise, IVI was found to be highest for *Alnus nepalensis* (60.72%) and lowest for *Pyrus pashia* (2.1%). The high IVI value for *Alnus nepalensis* indicates their dominance in the Shree Rabutar Forest (Table 1).

Table 1 IVI of tree species in the Shree Rabutar Forest

SN	Name of species	RD (%)	RF (%)	RA (%)	RBA (%)	IVI (%)
1	*Alnus nepalensis*	16.35	26.15	7.69	20.87	63.37
2	*Rhododendron arboreum*	30.52	16.92	22.21	6.55	53.99
3	*Lyonia ovalifolia*	18.26	23.08	9.74	2.10	43.44
4	*Symplocos ramosissima*	3.81	9.23	5.09	1.05	14.09
5	*Pinus roxburghii*	23.98	12.31	23.99	14.47	50.76
6	*Prunus cerasoides*	3.81	3.08	15.26	1.98	8.87
7	*Pyrus pashia*	0.27	1.54	2.18	0.25	2.06
8	*Pinus wallichiana*	1.91	4.62	5.09	39.21	45.74
9	*Prunus cornuta*	0.27	1.54	2.18	5.78	7.59
10	*Rhus javanica*	0.82	1.54	6.54	7.72	10.08
		100	**100**	**100**	**100**	**300**

Shannon Index of general diversity of the forest was 0.74 with equal value of Pielou's Evenness Index. Index of dominance of the forest was 0.22. Carbon stock in the forest vegetation depends on the DBH, height and age of trees, specific density and geographical location (Somogyi et al., 2007). Mean DBH (cm) of the species in the forest were observed to be 25.43 cm and mean height (m) to be 13.85 and mean basal area 801.88 cm^2 (Fig. 2). Basal area is an important parameter to determine the carbon content by the composition of species. In general, more basal area indicated more biomass and hence more carbon storage (Torres et al., 2012).

Individuals of trees with 20-30 cm DBH class were observed in maximum number. Out of 367 trees, the DBH classes of 263 trees (71.7%) were found between 5-30 cm and 104 trees (28.3%) were found greater than 30 cm (Fig. 3), which showed that the forest is in growing stage and could sequester more carbon in future.

Carbon Stock Estimation

The mean biomass of the forest was 464.01±66.71 $tonha^{-1}$ which was contributed by the above ground tree biomass (384.44±55.62 $tonha^{-1}$), leaf litter, herbs and grasses biomass (2.69±0.20 $tonha^{-1}$) and below ground biomass (76.88±11.13 $tonha^{-1}$) (Table 3). Forest plays an important role in storing large amount of carbon during the process of photosynthesis and tree growth which is a cost-effective way of mitigating climate change (FAO, 2000). Older forest stores higher carbon than younger forest (Bradford & Kastendick, 2010), however, young forest has more potential to sequester carbon than old forest.

Carbon stock in the soil depends on the land use pattern and management of the area. Forest soil stores greater carbon than the soil of other ecosystem because forest produces large amount of organic matter and adds litter to the soil. It also depends on microbial activities, climatic condition, topography and soil types (Shrestha, 2008). In the Shree Rabutar Forest, mean soil organic carbon was 44.69±2.25 $tonha^{-1}$ in 0-20 cm soil depth. Average organic carbon content was 51.44±2.31 and 37.93±3.04 $tonha^{-1}$ in soil depths 0-10 cm and 10-20 cm, respectively (Fig. 4). Similarly, soil bulk density determined was 0.80±0.02 $gmcm^{3}$ and 0.88±0.04 $gmcm^{3}$ in 0-10 cm and 10-20 cm depths from soil surface, respectively (Fig. 4). Bhushal et al. (2009) reported that the mean carbon content in the soil depth 0-20 cm was 32.57±3.63 $tonha^{-1}$ in Shivapuri Nagarjun National Park (SNNP), which was less than the value of the present study.

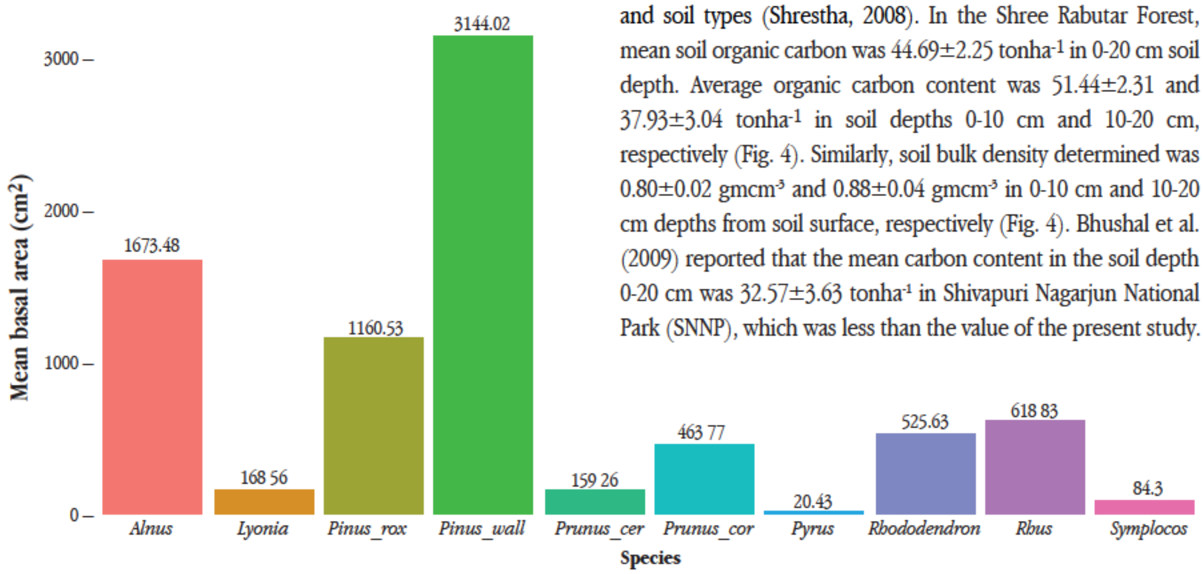

Figure 2 Mean basal area of the tree species in the Shree Rabutar Forest

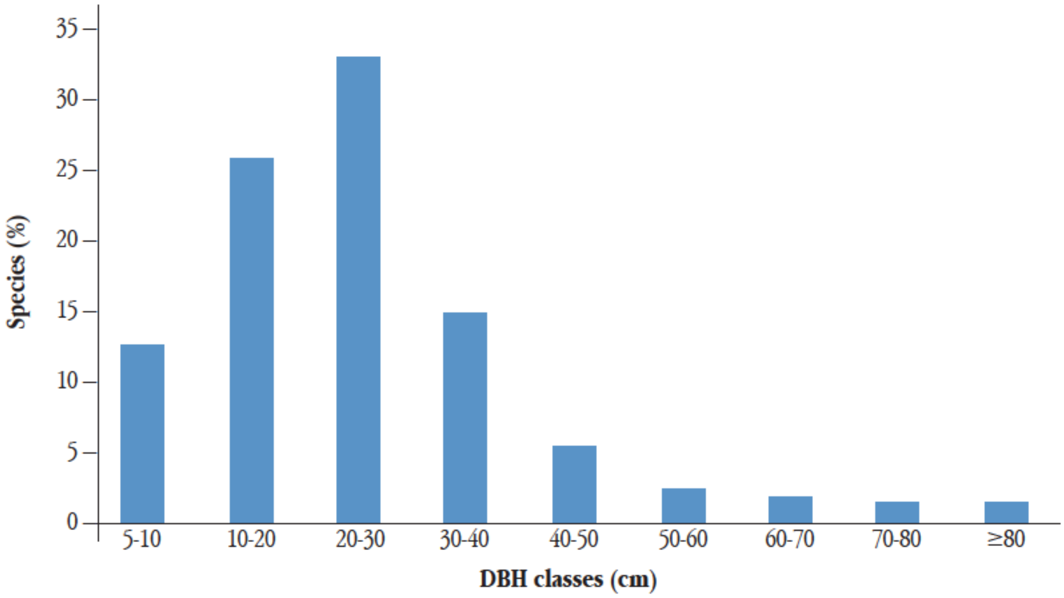

Figure 3 Percentage of tree species in different DBH classes

The mean carbon stock of the forest was found to be 263.32±30.89 $tonha^{-1}$ (Table 2). Bhushal et al. (2009) reported that mean total carbon stock of Nagmati Watershed Area of SNNP was 168.46±23.41 $tonha^{-1}$. The total free CO_2 fixed in the forest was greatly contributed by the above ground biomass carbon followed by soil organic carbon and below ground biomass. The protection and management of forest over time may increase the CO_2 absorbance by the trees of the forest of the present study.

In Shree Rabutar Forest, *Pinus roxburghii* and *Prunus cerasoides* were tree species planted in 2000 A.D., and other trees were naturally established. Among these trees, *Alnus nepalensis* contributed maximum carbon content (1318.41 $tonha^{-1}$ AGTB, 263.68 $tonha^{-1}$ BGTB) and followed by *Pinus roxburghii* (1153.05 $tonha^{-1}$ AGTB, 230.61 $tonha^{-1}$ BGTB) (Fig. 5). This indicates that natural forest stands store larger amount of biomass and carbon than planted stands.

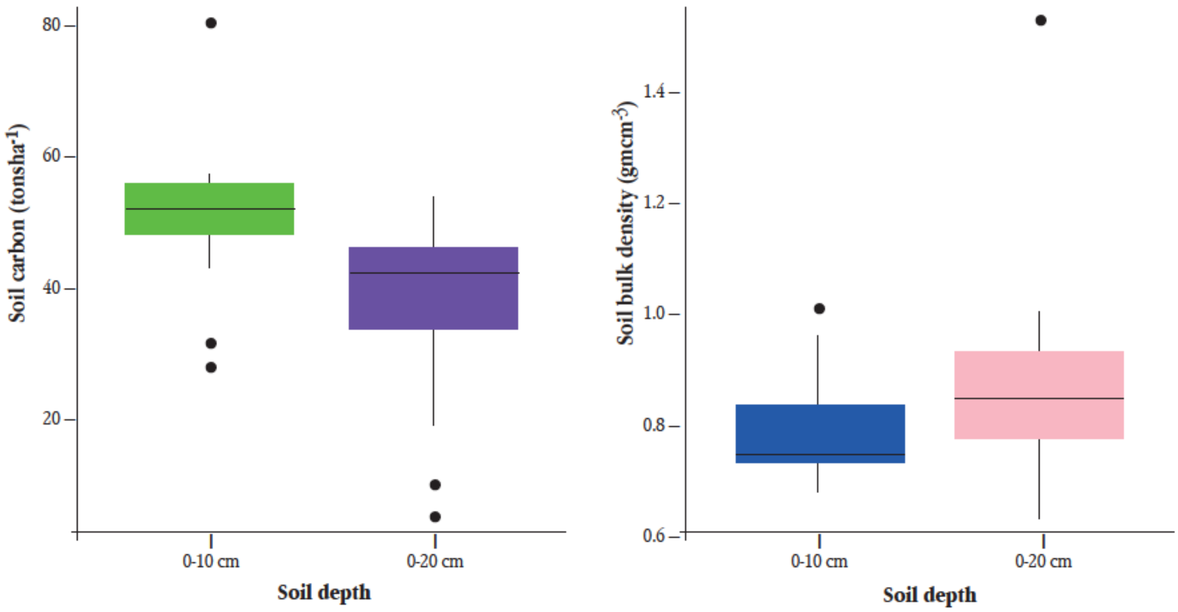

Figure 4 Soil carbon and soil bulk density in different depths

Table 2 Biomass and carbon content in different forest components

Components	Biomass (tonha^{-1})	Carbon Stock (tonha^{-1})
	Average±S.E.	Average±S.E.
AGTB	384.44±55.62	180.68±26.14
BGTB	76.88±11.13	36.13±5.22
LHG	2.69±0.20	1.26±0.09
SOC	-	44.69±2.25
Total	**464.01±66.71**	**262.77±30.79**

(S.E. represents standard error)

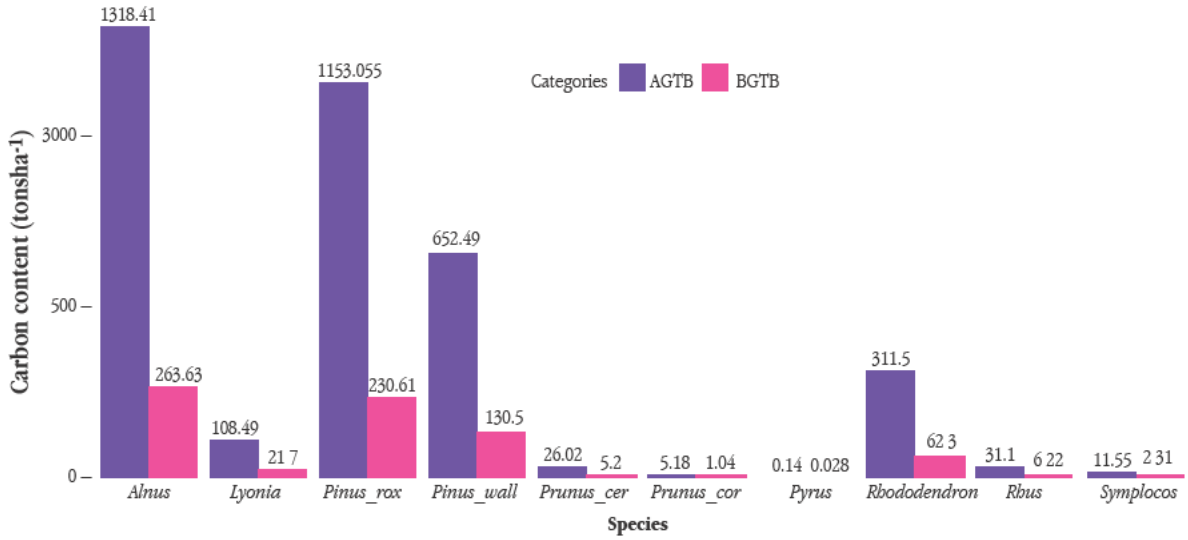

Figure 5 Carbon stock content by different tree species in the forest

Conclusion

The Shree Rabutar Forest is dominated by *Alnus nepalensis*. The mean carbon content of Shree Rabutar Forest is 262.77±30.79 tonha^{-1} contributed by above ground tree carbon (180.68 tonha^{-1}), leaf litter, herbs and grasses carbon (1.26 tonha^{-1}), below ground carbon (36.13 tonha^{-1}) and soil organic carbon (44.69±2.25 tonha^{-1}). The higher percentage of trees in DBH class 0-30 cm indicates that the forest is in growing stage, therefore could sequester more carbon in future. Management of the forest over time therefore may increase the CO_2 absorption and store huge amount of organic carbon and help mitigate climate change

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Acknowledgements

The authors would like to acknowledge Department of Environmental Science, Padma Kanya Multiple Campus for providing necessary equipment required for conducting field study. The authors would also like to thank Gaurishankar Conservation Area and Department of National Parks and Wildlife Conservation for providing permission to visit Gaurishankar Conservation Area and providing information related to the forest. All the authors would also like to appreciate the support and help from Ms. Sarishma Gubhaju and Ms. Aayasta Shakya.

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