THE GREENERY
A Journal of Environment and Biodiversity
Volume 7 (1) September, 2009

Carbon Sequestration in *Schima-Castanopsis* Forest: A Case Study from Palpa District

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Abstract:
Forests are natural carbon sink and play an important role in sequestrating the atmospheric carbon into biomass and soil. Estimation of total biomass and soil carbon sequestered in any forest is very important as it gives ecological and economic benefits to the local people. Schima-Castanopsis forests were selected for the study in Palpa district with the objectives of quantifying the total carbon sequestration, and evaluation of aspect and elevation on carbon storage. Stratified random sampling method was used for assessing biomass. Biomass was calculated using different allometric models. The biomass carbon content was taken 43% of the dry biomass. Soil samples were taken from soil profile up to 1 m depth for deep soils and up to bedrock for shallow soils at an interval of 20 cm. Walkey and Black method were applied for measuring soil organic carbon. Total biomass carbon in Schima-Castanopsis forest was found higher in northern aspect but soil carbon sequestration was higher in western aspect. Likewise, total carbon sequestration in western aspect was found 1.17 times higher compared to northern aspect at an elevation range 1100-1200m. Similarly, total carbon sequestration was found 1.13 times higher at an elevation range 1350-1500 m than 1100-1200 m.

Key words: *Carbon sequestration, Schima-Castanopsis forest, biomass carbon, SOC*

INTRODUCTION

Climate change and the escalating trend of the global warming have been triggered by human activities leading to elevated atmospheric carbon and greenhouse gas levels. Such change is unlikely to have occurred through natural forces alone. The biggest factor present concern is the increase in CO_2 levels due to emissions from fossil fuel combustion, followed by aerosols which exert a cooling effect and cement manufacture. Other factors, including land use, ozone depletion, animal agriculture, deforestation and land use change also impact climate. To control global warming there are many options such as the mitigative option-sequestration of CO_2 and reduction of emission; the adaptive option-adjustment in ways that reduce the negative impacts of temperature changes on the environment, and indirect policies-like controlling population growth or changing technologies. Among the options, forestry is one of the most cost effective mitigating options (IPCC, 1995). Forest cover more than one third of the world's land area and constitute the major terrestrial carbon pool (Roberntz et al, 1999). Carbon (C) storage in forest ecosystems involves numerous components including biomass carbon and soil carbon.

Thus, in addition to various goods and services being provided to human beings, forest act as natural storage for carbon at the global scale, contributing approximately 80% of terrestrial aboveground and 40 % of terrestrial belowground carbon storage (Kirschbaum, 1996). Overall, forest ecosystems store 20-100 times more carbon per unit area than croplands and hence play a critical role in reducing ambient CO_2 levels, by sequestering atmosphere C in the growth of woody biomass through the process of photosynthesis and thereby increasing the soil organic carbon (SOC) content (Brown and Pearce, 1994).

The main reason for forestry being of high interest is the flexibility provided by increased stocks of C in forest under the uncertainty regarding the impact of global warming (Solberg, 1997). Recognizing the importance of forest and soil in mitigating the greenhouse effect, an agreement was reached under the Kyoto Protocol (KP) to include forest and soil C sequestration in the list of acceptable offsets (UNFCC, 1997). KP under the UNFCC links the environment with economy by establishing a global carbon market. Fortunately, Nepal is first among the developing countries which have been selected by the World Bank as a member of the Forest Carbon Partnership Facility (FCPF), an innovative approach to financing efforts to combat climate change (www.worldbank.org). Nepal will receive initial funding from FCPF to reduce emissions from deforestation and forest degradation (REDD).

It is assumed that community forests play a critical role to reduce carbon in the atmosphere. However, the carbon sequestration potential in community forest has not so far been assessed in mid hills of Nepal. The Midhills of Nepal consists of large forest tract of *Schima-Castanopsis* forests at different aspect and elevations, which requires assessment of total carbon sequestration potential of such forest. Therefore, this study aims to establish the base line information for carbon sequestration potential of *Schima-Castanopsis* forest at different aspect and elevation.

MATERIALS AND METHODS

Study area

The study was carried out in two community forests (Bajha and Tinlankuri) of Palpa district. Palpa, a district of Lumbini Zone of Western Development Region of Nepal covers an area of 1366 square kilometer, lies between $27^0$14’ to $27^0$57’ N latitude and $83^0$15’ to $83^0$45’E longitude, and is 300 km west from the capital city, Kathmandu of Nepal. The district’s terrain lies in the Mahabharata (mid-hills) and Siwalik ranges. Bajha and Tinlankuri community forest lies in the central part (1.5 km west from district head quarter) of Palpa district. The forest is located in Bandipokhara VDC ward no 5, 9 and 13. It is natural *Schima-Castanopsis* mixed forest.

Sampling

Stratified random sampling was used for collecting data for plant biomass. Four sample plots of 20m x 25m for trees (>30cm dia), nested quadrate of size 10 m x 10 m for poles (10-29.9 cm dia), 5m x 5m for sapling (>5 cm dia) and 1m x1m for regeneration, grass and herb were laid out at different elevation ranging from 1200-1500 m and two aspects (north and west) for collecting data and measurement of individual trees, poles and shrubs lying within the plots were taken. Tree species whose height is below than 1 m and dia. less than 5 cm were considered as shrub (Shrestha and Singh, 2008).

Biophysical measurements

Diameter at breast height (Dbh) of each tree within each plot was measured using diameter tape (D-tape) and height of each tree was estimated using Sunto Clinometer and Abney’s level. For woody shrubs, diameter was measured at 15 cm above the ground level. All under storey bushes, grasses and herbaceous plants were clipped and the fresh weight of the samples were determined and representative sub sample of about 300 gm was taken to lab for oven drying.

Soil Sampling

Profile was dug at centre part of the plot up to 1m depth for deep soils and up to bed rock for shallow soils. Soil samples at different depths (0-20cm, 20-40cm, 40-60cm, 60-80cm and 80-100cm) were taken. A core ring sampler was used for bulk density.

Aboveground Biomass Estimation

The total stem volume of each tree was calculated using the relationship developed by Sharma and Pukkala (1990).

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

Where, V = the total stem volume with bark, d = the diameter at breast height (cm), h = the tree height (m), and a, b, & c are species specific constants shown in Table-1.

Table 1: Parameter a, b and c, and R^2 for major tree species

SN	Species	a	b	c	R^2
1	*Schima wallichii*	-2.7385	1.8155	1.0072	98.3
2	Miscellence in hills	-2.3204	1.8507	0.8223	97.7

(Source: Sharma and Pukkala, 1990)

After calculating volume of the tree, it was multiplied by the dry density of the wood (Chaturvedi and Khanna, 1982) of the species to get the above ground biomass (dry weight stem biomass). The biomass of branches and leaves were estimated using 45 and 11 % of the stem biomass respectively (Sharma, 2003).

Under-growth Biomass

Oven dry biomass values for litter, under storey bushes and grasses were calculated using the following formula (Lasco et al., 2005):

$$ODW\ (t) = TFW - \frac{(TFW*(SFW-SODW)}{SFW}$$

Where, ODW = Total oven dry weight, TFW = Total fresh weight
SFW = Sample fresh weight, SODW = Sample oven dry weight

The biomass of woody perennial shrubs was calculated using the equation developed by Hasse and Hasse (1995):

$Y = a\,D^b$

Where Y is the total dry biomass (kg), D is the dia. 15 cm above the ground (cm), and *a* and *b* are constants whose values were considered as -4.264 and 1.016 respectively, and with a correction factor of 1.0232 (Hasse ad Hasse, 1995).

Belowground Biomass estimation

Root biomass for broad leaved vegetation= 0.30 x aboveground biomass (FAO, 2000).

Soil Organic Carbon (SOC)

Collected soil samples were analyzed in soil laboratory and soil organic C percent were calculated. The Walkey-Black method was applied for measuring the soil organic carbon (McLean, 1982). Total soil organic carbon was calculated using the formula given below (Awasthi et al., 2005).

SOC= Organic carbon content % x soil bulk density (kg/m3) x thickness of horizon (m)

Bulk Density

Soil bulk density was determined using core sampling method (Blake and Hartge, 1986). Oven dry weight of soil samples will be determined for moisture correction. The dried soil then was passed through a 2 mm sieve, the sieved soil was weighed and volume of stones was recorded for stone correction. Following formula was used to calculate the bulk density using stone correction (Pearson et al., 2005).

$$Bulkdensity(g/cm3) = \frac{Ovendrymass(g/cm3)}{Corevolume(cm3) - \frac{Massofcoarsefragments(g)}{Densityofrockfragment(g/cm3)}}$$

Where, the coarse fragments are > 2mm. The density of rock fragments is 2.65 g/ cm^3.

Estimation of Net Carbon Content

Total carbon was taken to be 43% of the biomass (Negi et al., 2003). The following formulae were used for computing total above and below ground biomass organic carbon.

Total above ground biomass organic carbon= (total above ground biomass of tree +total branch and litter biomass + total under storey biomass + shrub biomass) * 43%
And
Total belowground biomass organic carbon= (total root biomass of tree) * 43% + total soil organic carbon.

RESULTS AND DISCUSSION

Properties of Forest Stand

Mean diameter of the stand was high in northern aspect (Table-2). At 1350-1500 m elevation, high mean diameter as well as larger tree (dbh. 25.8 cm and height 16.5 m) was observed. Similarly, tree density was high in western aspect (Table-2).

Table 1: Properties of *Schima-Castanopsis* forest in different aspect and elevation

Elevation (m)	Aspect	No. of stem/ha	Diameter (cm)			Height (m)			Remarks
			Mean	Min	Max	Mean	Min	Max	
1100-1200	West	1300	13.72	5.1	24.5	9.98	4.1	13.5	Bajha
	North	1175	14.82	5	24.5	10.09	4.5	13.5	Bajha
1400-1550	North	1150	14.78	5.2	25.8	11.01	3.5	16.5	Tinlankuri

Aboveground Biomass Estimation

It was found that aboveground tree biomass was higher in northern aspect (82.53 ± 15.78 t ha^{-1}) but tree biomass was found higher in 1350-1500 m elevation compared to lower elevation (Table-3). Undergrowth biomass was higher in northern aspect (4.12 ± 0.62 t ha^{-1}) compared to western aspect at elevation range 1100-1200 m.

Table 2 : Distribution of aboveground biomass in *Schima-Castanopsis* forest

Elevation (m)	Aspect	Tree biomass (t ha^{-1})				Undergrowth (t ha^{-1})		Total	Remarks
		Mean	SE	Min	Max	Mean	SE		
1100-1200	West	70.77	16.488	51.41	119.89	3.39	0.43	74.16	Bajha
	North	82.53	15.075	54.01	120.44	4.12	0.62	86.65	Bajha
	Mean	76.65	15.78			3.75	0.52	80.4	
1350-1500	North	91.77	22.09	52.49	154.94	2.38	0.35	92.29	Tinlankuri

Aboveground Carbon Sequestration

Aboveground carbon sequestration was high in northern aspect (37.26 ± 6.72 t ha^{-1}) followed by western aspect (Table-4). Undergrowth carbon sequestration was high in northern aspect and low in western aspect. High aboveground carbon sequestration was found at an elevation range 1350-1500 m. But undergrowth carbon sequestration was higher in 1100-1200 m elevation compared to 1350-1500 m (Table-4).

Table 43: Aboveground carbon sequestration in *Schima-Castanopsis* forest

Elevation (m)	Aspect	Carbon Sequestration (t ha^{-1}) by				Total above CS		Remarks
		Stem	Branch	Leaf	Under growth	Mean	SE	
1100-1200	West	19.50	8.77	2.14	1.46	31.89	7.10	Bajha
	North	22.74	10.23	2.50	1.77	37.26	6.72	Bajha
	Mean	21.12	9.50	2.32	1.61	34.57	6.91	
1350-1500	North	25.29	11.38	2.78	1.02	40.48	9.50	Tinlankuri

Root Biomass and Carbon Sequestration

It was found that root carbon sequestration was found high in northern aspect (10.64 ± 1.94 t ha^{-1}) followed by western aspect (Table-5). High root carbon sequestration was found in 1350-1500 m.

Table 5: Root biomass and carbon sequestration in *Schima-Castanopsis* forest

Elevation (m)	Aspect	Root biomass (t ha^{-1})	CS by root (t ha^{-1})	SE mean	Remarks
1100-1200	West	21.23	9.13	2.12	Bajha
	North	24.75	10.64	1.94	Bajha
	Mean	22.99	9.88	2.03	
1350-1500	North	27.53	11.83	2.85	Tinlankuri

SOIL CARBON SEQUESTRATION

Bulk Density

The minimum Bd (0.834 ± 0.037 t m^{-3}) was found at the top soil (0-20 cm) in northern while maximum Bd (1.193 ± 0 t m^{-3}) was found at the depth of 80-100 cm in western aspect (Table-6). Similarly, the minimum Bd (0.834 ± 0.037 t m^{-3}) was found at the top soil (0-20 cm) at an elevation range 1100-1200 m while maximum Bd (1.116 ± 0 t m^{-3}) was at the depth of 80-100 cm at 1350-1500 m elevation (Table-6).

Table 64: Bulk density (t m^{-3}) in *Schima-Castanopsis* forest

Soil depth (cm)	1100-1200 m				1350-1500 m	
	Bajha				Tinlankuri	
	West		North		North	
	Mean	SE mean	Mean	SE mean	Mean	SE mean
0-20	0.963	0.077	0.834	0.037	0.963	0.028
20-40	1.073	0.090	0.890	0.082	1.008	0.050
40-60	1.090	0.059	0.943	0.114	1.021	0.014
60-80	1.180	0	0.950	0	1.069	0.035
80-100	1.193	0			1.116	0

Soil Organic Carbon (SOC)

The maximum SOC (50.25 ± 4.33 t ha^{-1}) was found at the top soil (0-20 cm) in northern aspect at an elevation range of 1000-1200 m while minimum SOC (16.98 ± 0 t/ha) at the depth of 60-80 cm in the same aspect (Table-7). At an elevation range 1350-1500 m, maximum SOC (52.45 ± 8.84 t ha^{-1}) was found at the top soil (0-20 cm) while minimum SOC (33.37 ± 0 t ha^{-1}) at the depth of 80-100 cm in the same aspect (Table-7).

Table 7: Soil organic carbon (t ha^{-1}) in *Schima-Castanopsis* forest

Soil depth (cm)	1100-1200 m		1350-1500 m
	Bajha		Tinlankuri
	West	North	North
0-20	44.26 ± 1.47	50.25 ± 4.33	52.45 ± 8.84
20-40	44.26 ± 2.90	26.23 ± 2.63	40.05 ± 9.74
40-60	20.93 ± 3.20	20.87 ± 3.50	38.57 ± 11.79
60-80	20.30 ± 0	16.98 ± 0	39.47 ± 24.96
80-100	19.09 ± 0		33.47 ± 0

Total Carbon Sequestration

Total carbon sequestration was found high in northern aspect (162.26 t ha^{-1}) followed by western aspect at an elevation range 1100-1200 m (Table-8). Total carbon sequestration was higher in 1350-1500 m elevation

(183.407 t ha^{-1}). Carbon sequestration in *Schima-Castanopsis* forest was found 74% in soil, 20% in aboveground and 6% in root (Figure-1).

Table 8: Total carbon sequestration (t ha^{-1}) in *Schima-Castanopsis* forest

Carbon sequestration in	1100-1200 m		1350-1500 m
	Bajha		Tinlankuri
	CS (t ha^{-1}) in		
	West	North	North
Aboveground carbon	31.89486	37.26249	40.48836
Root carbon	9.130017	10.64676	11.83867
Soil carbon	148.8767	114.3516	131.0808
Total	189.9016	162.2608	183.4079
Mean	178.5234		

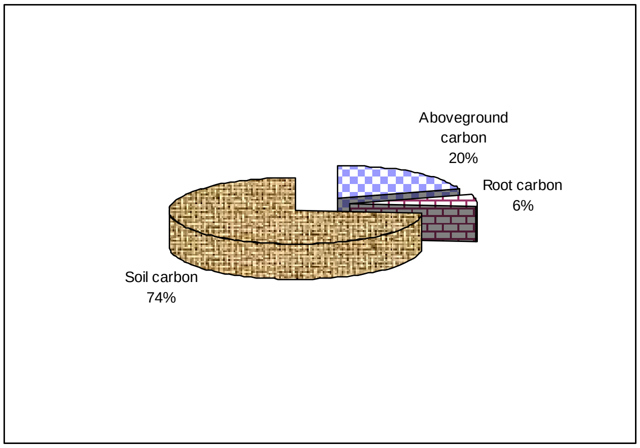

Figure 1: Carbon Sequestration in *Schima-Castanopsis* forest

CONCLUSION

Total carbon sequestration in *Schima-Castanopsis* forest is 178.52 t ha^{-1}. Carbon sequestration in *Schima-Castanopsis* forest is high in northern aspect followed by western aspect. Thus, study showed that *Schima-Castanopsis* prefers northern aspect. Similarly, it is found that carbon sequestration is high in higher elevation. Study found that aspect and elevation play an important role on total carbon sequestration.

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