Comparison of Carbon Stock in Chure, Bhawar and Terai, Nepal (A study from Mahottary district)

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The forests have been playing vital role in carbon sequestration but its rate is varying place to place and time to time. The Teria, Bhavar and Churiya areas have varying nature of vegetation in Nepal but carbon stock assessment was not so far done, here. Thus this study was objectively carried out to estimate the above ground carbon stock, assess the soil carbon and its trend according to soil depth. Hence six community forests (CF) namely Indrakali CF and Newadanda from Plain region, Gal Tar and Rai Mandap CF from Bhabar region and Ratu Mahila and Markaura CF from Churia region of Mahottari district was selected for study. The forest survey was carried out using GPS receiver and maps were prepared. Then forests were stratified into three major strata namely regeneration, pole and tree. Altogether 91 sample plots were established in the field by navigating the GPS coordinates. There were 16 plots in Indrakali CF, 20 plots in Gal Tar CF and 20 plots in Ratu Mahila CF. The measurements were carried out in 20m x 25m plot for tree stratum, , in 10m x 10m plot for poles, in 5m x 5m plot for sapling and in 1m x 1m plot for seedling, litter, herbs and grasses. The samples of seedling, litter and herbs were collected and dried in the lab. The soil samples were collected from 0-10 cm, 10-20 cm and 20-30 cm depth below ground.

The collected data were analyzed using simple descriptive analysis and biomass equations. The collected samples of seedlings, litter, herbs and grasses were dried to get the dry biomass. The below ground (root) biomass was estimated by using default value as 0.125 multiplying the above ground biomass. Then, the biomass stocks were converted into carbon stock by multiplying with conversion factor of 0.47. Similarly, the soil samples were analyzed by applying Walkey and Black method to determine the soil organic carbon. All analyzed data were compiled to get total carbon stocks. Besides, the data collected regarding forest management activities was analyzed using descriptive analysis.

The highest above ground carbon stocks 104.03 t ha^{-1} was found in Ratu Mahila CF while it was the lowest 48.57 t ha^{-1} in Rai Mandap community forest. The soil organic carbon was found to be highest in 0-10 cm and the lowest in 20-30 cm in all the forests. The soil carbon was the highest 77.03 t ha^{-1} in Rai Mandap CF but it was lowest only 42.83 t ha^{-1} in Markaura CF. Hence, the community forests are potential in sequestrating carbon and such records of carbon stock play a vital role for REDD+ mechanism.

Key words: Carbon stock, Plain, Bhabar, Churia, community forests

Introduction

Healthy forests sequestrate and store more carbon compared to other terrestrial ecosystems and are considered as an important natural brake on climate change (Gibbs, et al., 2007). Currently world's forests and forest soils store more than one trillion tons of carbon, which is twice the amount found floating free in the atmosphere (FAO, 2008). Hence, reforestation, afforestation and avoiding deforestation are mechanisms to tackle against the impacts of climate change (Marklund & Schoene, 2006, Hunt, 2009). United Nations Framework Convention on Climate Change (UNFCCC) on 11 December 1997 adopted Kyoto Protocol (UNFCC, 2011), which sets binding targets to industrialized countries for reducing Green House Gases (GHGs) emissions. Thus, the Bali Action Plan opened windows opportunities for developing countries to participate in forest carbon financing through the mechanism of reducing emissions from deforestation and forest degradation (REDD) (MFSC, 2009). The Copenhagen Accord recognizes the crucial role of reducing carbon emission from deforestation and forest degradation, proper management of forest, and commits to provide funding for such actions in developing countries (UNFCC, 2009).

Forests cover nearly 40% of the total land area of Nepal (Oli & Shrestha, 2009) which signify the amount of carbon in the forests of Nepal. But national forest inventory data on changes in forest cover, biomass stocks, carbon emissions and carbon removals on a periodic basis are limited (Acharya, et al., 2009).

Terai region geographically, consists of Churia, Bhabar and Plain areas of Nepal. The Churia hills are the first and lowest ridges in the Himalayan mountain system. They rise abruptly from the Indo-Gangetic plains, and cover an area of about 1.349 million ha (CAPS, 2008). The Bhabar zone lies at the foothills of the Churia range in the form of fans and aprons, and covers about 14.9% of the total land of the Churia area. It is composed of boulders, cobbles and pebbles of rocks of the Churia hills or the Mahabharata range, deposited by rivers (CAPS, 2008). Terai region, which is a continuation of the Indo-Gangetic Plains, forms the southernmost part of Nepal, bordering India and is considered as food bowl (CAPS, 2008).

Community managed forests have been playing a crucial role to address deforestation and forest degradation in Nepal. The forest of Chure, Bhabar and Teria are important for climate change mitigation but carbon assessment was not so far done. Hence, this study was objectively done to assess the above ground carbon stock in community forests of Plain, Bhabar and Churia hill regions and soil carbon and its trend according to soil depth as well.

Materials and Methods

Study Area: Mahottari District is one of the Terai district of Nepal situated in Janakpur zone of central development region. Geographically the district lies between 26º36’ to 28º10’ North latitude and 85º 41’ to 85º 57’ East longitude. This district can be divided into two parts Bhabar-Churia in North and plain area in South. In the North, Bhabar-Churia occupies 14% and in the South, Plain Terai occupies 86%. There are many rivers and river belts as Rato, Marha, Ankusi, Bighi, Jangha, Bhabsi, Budhi, Thalhi, and Chhagar flowing from North to South.

Tropical, sub-tropical and lower-temperate climate is found with maximum temperature 42 ^{o}C and minimum temperature 5.6 ^{o} C. Average relative humidity is 87% and average annual rainfall is 1841.1 mm (District Profile, 2008).

The dominant tree species is Sal (*Shorea robusta*), and associate species are Saj (*Terminalia tomentosa*), Botdhairo (*Lagerstroemia parviflora*), Bajhi (*Anogeissus latifolia*), Teak (*Tectona grandis*), Sissoo (*Dalbergia sissoo*), Kurilo (*Asparagus racemosus),* Bel *(Aegal marmelos),* Barro *(Terminalia bellerica),* Harro *(Termenalia chebula),* Amala *(Phylanthus emblica),* Simal *(Bombax ceiba),* in this district. These plant species are common in all the community forests.

Six community forests namely Indrakali and Newadanda in plain region, Gal Tar and Rai Mandap CF in Bhabar region and Ratu Mahila and Markaura CF in Churia region were selected as the study site.

Methodology

Primary and secondary data were collected from different sources (Moore & Mc Cabe, 2003). Primary data were collected from field observation, direct measurement, group discussions and laboratory analysis while the secondary information were collected from internet surfing, books, reports, journals and community forest operational plan in order to meet the research objectives. The boundary survey was done to prepare the map of the community forest. The strata were delineated based on the stage of the plant. Total 101 sample plots were established in the field by navigating the GPS coordinates. Specifically, 16 plots in Indrakali CF, 15 plots in Newadanda CF, 20 plots in Gal Tar CF, 15 plots in Rai Mandap CF, 15 plots in Markaura CF and 20 plots in Ratu Mahila CF. The plots sizes were 20m x 25m plot for tree stratum, 10m x 10m plot for poles, 5m x 5m plot for sapling and in 1m x 1m plot for seedling, litter, herbs and grasses (DoF, 2005).

Data collection: The diameter at breast height (DBH at 1.3m height) and height of individual trees and pole greater than or equal to 5cm were measured and recorded. Only diameter was measured to collect the data of regeneration (sapling) having DBH<5cm. Sample of seedling, litter, herbs and grasses were collected. The destructive sampling was carried out for this so, the fresh weight was taken and their dry weight recorded in the lab.

The soil samples at depth 0-10 cm, 10-20 cm and 20-30 cm were collected from the sub plot of 1 m^2 using metal corer of known volume and placed in the labeled sample bag. The collected samples were brought to the laboratory to determine the carbon content. The soil samples were oven dried at 105^0 C in the laboratory until they reached a constant weight to estimate soil bulk density.

Primary and secondary data were collected to explore the forest management activities. The primary data were collected from interaction with users group and observation of the field in the forest. For this, check-list was prepared and group discussions were carried out with forest user committee in each community forest to record the management practice. In addition, the field observation was conducted to observe their adopted management practices in all selected community forests

The secondary data were gathered from records and related documents. Review of operational plan and constitution, documents such as operational plans of forest and CFs constitutions of all the selected community forests were collected. The desk top review was

carried out to review all these documents focusing on to explore the adopted forest management practices.

Data Analysis: The biomass, carbon and management activities data were analysed from the collected data set :
Above ground tree biomass calculation:_According to Practical action Nepal 2009, Mahottari district falls in moist area (1500-4000 mm annual rainfall). So, following equation was applied to calculate the above ground tree biomass (Chave et al., 2005).

Moist: Above ground tree biomass calculation, (1500-4000 mm annual rainfall)

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

Whereas, AGTB = above ground tree biomass (kg), ρ= dry wood density (gm/cm^3),
D= tree diameter at breast height (cm) and H= tree height (m)

The biomass values of saplings (AGSB), seedling, herbs, litter and shrubs (LHG) were analysed using unitary methods.

Belo ground biomass (BB): Default value i.e. root shoot ratio 0.125 was used (IPCC, 2006) to calculate the root biomass.

Carbon factor: The calculated all biomass was converted into carbon multiplying with universal conversion factor 0.47 (Andreae & Merlet, 2001).

Soil organic carbon: The soil samples was analysed by Walkley Black Method (Walkley & Black, 1958) by digestion using Sulphuric acid and oxidized by the Potassium dichromate in laboratory. The soil samples were oven dried at 105^0 C to obtain constant weight.

The bulk density of soil sample was calculated for each soil depth for which soil carbon was estimated. Then, oven dried soil sample was divided by its volume to estimate bulk density (Mishara, 1968).

Bulk Density in gm/cm^3 (ρ) = (oven dry weight of soil)/(volume of soil in the core).

SOC= Organic Carbon Content % * Soil Bulk Density (gm/cm^3)*thickens of horizon (d) and was expressed in tons per ha (Chabbra et. al, 2002).

Total Carbon = C (AGTB) + C (AGSB) + C (BB) + C (LHG) + SOC

Data related to management activities was done using descriptive analysis. Shapiro-Wilks and Kolmogorov-Smirnov was applied to test the normality of the data set. Data performed normal so One-way ANOVA was applied to compare the carbon stock in community forests of Plain, Bhabar and Churia. Tukey's b test was also applied to compare the carbon stock in community forests individually.

Result and Discussion

Carbon Stocks of Above Ground Carbon Pool in Community Forests

The above ground tree/pole carbon stock was found to be highest in Ratu Mahila community forest with 103.60 t C ha^{-1} because the presence of larger sized trees (DBH>30cm) in Ratu Mahila CF.

The present study was supported by the study conducted by Gupta (2012). The above ground tree/pole carbon stock in Pragatishil community forest of Kaski district was 91.04 t C ha^{-1} which is near to the carbon stock of Ratu Mahila and Indrakali CF but the carbon stock of Gal Tar was very low compared to Pragatishil community forest. The effective implementation of good management practices ensures the multiple functions of forests and can increase forest carbon stocks (FAO, 2010).

The above ground sapling carbon stock was found to be highest in Gal Tar community forest with 0.34 t C ha^{-1} because more saplings are present in this forest in comparison to other community forests.

The study was conducted by ICIMOD (2010) in community forest of Chitwan, Gorkha and Dolkha District. The above ground sapling carbon stock was found in Kayarkhola (Chitwan), Charnabati (Dolkha) and Ludikhola (Gorkha) community forest with 1.38, 2.49 and 3.85 t C ha^{-1} respectively. The sapling carbon stock of community forests was low compared to the study of ICIMOD which showed that there was low sapling stand in community forests.

The leaf litter, herb, regeneration and grass carbon stock was found to be highest in Gal Tar community forest with 0.44 t C ha^{-1}.

The study conducted by Lama (2011) in leasehold forest of Dolkha District. Leaf litter, herb and grass carbon stock was found to be highest in Srijana leasehold forest with 2.464 t C ha^{-1}. The removal of forest litters removes most of the nutrients that would otherwise add to fertility of forest bio-mass and increase carbon (Pimentel et al., 1981). However, these values are higher compared with the present study sites.

The total above ground carbon stock was found to be highest in Ratu Mahila with 104.03 t C ha^{-1} because of dominance number with larger diameter (40-76.5 cm) and height (22.4m) of *Shorea robusta* and associated species.

The study conducted by Mandal, et al. (2012) in Banke-Maraha, Tuteshwarnath and Gadhanta Bardibas collaborative forest of Mahottari district. The above ground carbon stock in Gadhanta Bardibas collaborative forest was found to be higher 274.66 t C ha^{-1} than Tuteshwarnath and Banke-Maraha (222.58 t C ha^{-1} and 197.10 t C ha^{-1}) due to the large tree density and higher biomass values. However, these values were higher compared to the current community forests.

Name of CF	Region	C(AGT/PB)	C(AGSB)	C(LHG)	Total
		t ha^{-1}	t ha^{-1}	t ha^{-1}	t ha^{-1}

Indrakali	**Terai**	101.96	0.18	0.24	102.38
Newdanda		56.68	0.2	0.12	57
Gal Tar	**Bhabar**	49.25	0.34	0.44	50.03
Rai Mandap		48.21	0.13	0.23	48.57
Ratu Mahila	**Chure**	103.6	0.05	0.38	104.03
Markaura		80.83	0.11	0.34	81.28

The One way ANOVA and Tukey's be test also showed that there was significant differences in carbon stock in community forests among Terai, Bhawar and Chure areas.

Soil Carbon in Community Forests

The soil carbon was the highest 77.03 t C ha^{-1} in Rai Mandap community forest in Bhawar, it may be due to undisturbed soil in this area. Controlled grazing was also adopted to conserve soil from disturbance of soil. The soil carbon recorded lowest around 42.83 in Markaura CF, it may because of disturbance. The SOC of forest depend upon various biotic and abiotic factors such as micro-climate, faunal diversity, land use, land management and crops (Shrestha & Singh 2008). The present study was supported by Mandal et al. (2012). Where the total soil carbon stock in Chure Parwati community forest Mahottari was found to be 74.42 t C ha^{-1} which was near to the value of Rai Mandap community forets. The difference in SOC pool can be related to geographic aspect also. Smith et al., (2002) reported that north facing sites are usually cool and moist so it contain higher amount of SOC. Similarly, according to the study conducted by Chhetri (2007) in assessment of soil quality index and soil organic carbon stock under different land use, elevation and aspect in Upper Harpan Sub-watershed, Kaski, the SOC content was found to be higher in the Northern aspect (71.2 t/ha) than the Southern aspect.
Table 3: Soil carbon in community forests

Community forests	Region	Soil carbon tha-1
Indrakali	Terai	62.48
Newdanda		62.88
Gal Tar	Bhabar	60.32
Rai Mandap		77.03
Ratu Mahila	Chure	63.5
Markaura		42.83

Trend of soil carbon with respect to soil depths

The clear trend was seen in soil carbon according to the soil depth. It was highest in 0-10 cm while lowest in 20-30 cm depth in all community forests (Table 4). The highest record of soil carbon was 32.68 t ha-1 in 0-10 cm depth in Rai Mandap community forest and lowest value of carbon was 8.04 t ha^{-1} in 20-30 cm soil depth in Markaura community forest.

Table 4: Soil carbon according to soil depth in community forests

Community forests	Soil carbon according to depth (t ha^{-1})		
	0 - 10 cm	10 - 20 cm	20 - 30 cm
Indrakali	25.09	19.73	17.66
Newdanda	30.63	27.19	26.19
Gal Tar	16.08	20.66	16.76
Rai Mandap	32.68	22.47	12.87
Ratu Mahila	26.14	18.89	15.29
Markaura	9.98	14.81	8.04

The soil carbon was decreased with respect to soil depth in all selected community forests. All the community forests contained greater SOC in the upper layer 0-10 cm followed by 10-20 and 20-30 cm depth. This may be attributed by the fact that higher amount of humus was present in the top layer of the soil profile in the community forest and decreasing the organic matter with the increase in soil depth. The significant decrease in soil carbon with the increase in soil depth was supported by Khanal (2008), Ale (2010), Bhatta (2010), Maharjan (2010), Ranjitkar (2010), Sharma (2010), Basnet (2011) and Dutta et al. (2011). They found the maximum amount of SOC in the upper layer 0-10 cm as compared to the lower layer 80-100cm.

Conclusion and Recommendation

The above ground total carbon stock was found to be highest in Ratu Mahila CF of Churia than others while it was the lowest in Gal Tar CF, which was associated with only pole size trees. Similarly the above ground tree/pole carbon stock was found to be highest in Ratu Mahila CF while the above ground sapling and leaf litter herbs carbon stock was found to be highest in Gal Tal CF.

The soil organic carbon (SOC) decreased with the increase in soil depth in all community forests. It was the highest in Rai Mandap community forest.

Estimated carbon stocks differed in community forests situated in Plain, Bhabar and Churia region of Mahottari district.
It is recommended to carry out the similar types of studies in other community forest situated in Plain, Bhabar and Churia.

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