Forest Carbon Assessment in Community-Managed Forest in the Nepal Himalayas: Strengthening Local Communities to Monitor Carbon Stocks under REDD+ Initiatives

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Introduction

Global climate change is a major global problem triggered principally by anthropogenic emissions of greenhouse gases (GHG). About 20% of GHG emissions come from forest carbon sources, in particular deforestation and degradation, thus forest carbon finance is at the centre of the future global GHG mitigation strategy. In view of the other environmental and social benefits of forests, initiatives have been proposed to consider co-benefits of forests when initiating forest carbon projects. REDD+ is one such initiative that has been under consideration globally; it supports the idea that forests should not only be considered as carbon storage, but also for their potential to supply co-benefits such as biodiversity conservation, conservation of carbon, and other associated social and environmental goods and services. Engaging local people in carbon monitoring could provide a cost-effective approach for REDD+ (Burgess et al. 2010; Phelps et al. 2010; Skutsch 2010). At the 15th Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC) in Copenhagen in December 2009, an agreement was drafted which proposed stabilizing global greenhouse gas concentrations in the atmosphere at a level that keeps the global temperature increase below 20°C in the coming century (UNFCCC 2010a).

Forests cover 31% of the world's surface area; and more than 22% of the total forest area is owned and/or managed by indigenous people and local communities (White and Martin 2002). According to the latest National Forest Inventory (NFI 1999), about 39.6% of the total land area of Nepal is covered with forests and shrubland (MOFSC 2010). In terms of physiographic regions, the hills have 35.3% of forests, the Siwaliks 22.8%, and the mountains (including the high Himalaya) 33.5%. As per the NFI (1999), the average annual rate of deforestation in Nepal was 1.6%, with the highest rate in the Terai (1.7%), followed by the Siwaliks and high Himalaya. Though, there is no reliable estimate of CO_2 emissions from deforestation and forest degradation in Nepal, based on 1994/95 data, the National Communication Report (2004) estimated 22,895 Gg emissions from the land-use sector (18,547 Gg from forest and grassland conversion and 4,948 Gg from soil). Thus there is scope for introducing forest carbon initiatives such as REDD+ for the conservation of forests and thus a reduction in CO_2 emissions from deforestation and forest degradation in Nepal.

REDD+ can be an opportunity for developing countries like Nepal to receive payments from developed countries for their performance in REDD+ activities, which include reducing emissions from deforestation; reducing emissions from forest degradation; conservation of forest carbon stocks; sustainable management of forests; and enhancement of forest carbon stocks. An operational REDD+ policy will require monitoring of deforestation and forest degradation across a whole country, not only to quantify the carbon savings in a particular area, but also to account for any compensatory increase in loss of forest biomass ('carbon leakage') elsewhere within the country (Mollicone et al. 2007). There are gaps in knowledge about monitoring in practice, but it is needed for effective implementation of REDD+.

The Asia Network for Sustainable Agriculture and Bioresources (ANSAB), International Centre for Integrated Mountain Development (ICIMOD), and Federation of Community Forest Users Nepal (FECOFUN) are implementing a project on 'Design and setting up of a governance and payment system for Nepal's community forest management under reducing emissions from deforestation and forest degradation (REDD)'. This pilot project aims to demonstrate the feasibility of a REDD payment mechanism in community forest by involving local communities, including marginalized groups, so that deforestation and forest degradation can be reduced by linking sustainable forest management practices with economic incentives. Further, the project focuses on the concerns of indigenous and marginalized people and local communities dependent on forests by involving them in the design and functioning of a national-level REDD governance and payment mechanism that supports community forestry at the grassroots level. One of the most contentious debates during the recent climate talks centred on the possible use of forests as credit towards REDD, thus for the success of REDD programmes there is a need for a reliable, accurate, and cost-effective methodology for measurement and monitoring of forest carbon. This is still lacking in the context of developing countries like Nepal. With the aim of overcoming the technical difficulties, ANSAB's technical team have developed and tested 'Forest Carbon Stock Measurement: Guidelines for measuring carbon stocks in community managed forests', in consultation with various experts, together with key stakeholders, and following various standards like the Voluntary Carbon Standard (VCS), IPCC, and Climate Community and Biodiversity Alliance (CCAB). The main points of the carbon monitoring process are described briefly in the following sections.

Methods and Approach for Forest Carbon Assessment

The methods for carbon measurement in community-managed forests focus on two aspects: capacity building and measurement on the ground. First, forest technicians, local resource persons (LRPs), and local people were trained in carbon measurement, and the carbon in the community forest was then measured with their support. The steps in the carbon measurement process are shown in Figure 16.

Boundary mapping and stratification

A participatory map of each community forest was prepared with the help of local people, as they are familiar with important characteristics of the forest

Figure 16: **Forest carbon measurement process in community-managed forests**

1. Capacity building of forest technicians, LRPs, and local users
2. Delineation of project boundaries
3. Stratification and boundary mapping of forest blocks
4. Pilot inventory for variance estimation
5. Field measurements in the permanent plots (AGB, BGB, soil, dead wood, herbs and litter)
6. Data analysis (calculation of carbon stock density)
7. Leakage analysis belt and monitoring
8. Report preparation

such as species distribution, age class, and crown density. The boundary of the community forest was mapped jointly by the researcher and community members using GPS and ArcGIS. For this, the entire forest boundary was visited and coordinates marked.

In order to increase the accuracy of carbon measurements, the forests were divided into two major strata: sparse (less than 70% crown canopy) and dense (more than 70% crown canopy) using ArcGIS software with high resolution remote sensing images, ERDAS Imagine, and Definiens Developers. For each of the selected forests, variance analysis was carried out to determine the number of permanent plots needed to achieve a confidence level of 90%, as explained below.

Variance estimation for sampling intensity

Ten to 15 temporary plots with a radius of 8.92 m (an area of 250 m^2) were randomly selected across all sites (Figure 17). Diameter at breast height (dbh, 1.3 m above the ground) of all trees equal to and greater than 5 cm was measured to determine variance in tree stocking. All research sites in this study have a moist climate with annual rainfall between 1,500 and 4,000 mm, so the equation suggested by Brown et al. (1989) was employed:

Tree biomass (kg) = 38.4908 – 11.7883*dbh + 1.1926*dbh²

$$\text{Tree biomass (kg)} = 38.4908 - 11.7883 \cdot dbh + 1.1926 \cdot dbh^2$$

The tree biomass in the temporary plots was converted into carbon by multiplying by 0.47 (IPCC 2006) and the mean tree carbon per hectare was estimated. The total number of permanent plots required was calculated using the following equation (MacDicken 1997):

$$N = \frac{(CV * t)^2}{E^2}$$

Where

N = maximum number of sample plots

CV = coefficient of variation of biomass

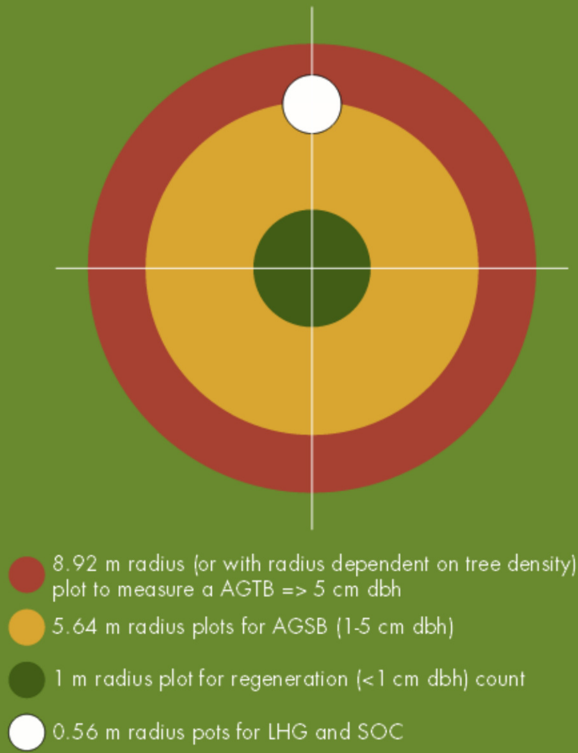
t = value of t obtained from student's t-distribution table at n-1 degrees of freedom of the pilot study. at 10% probability

E = sampling error at 10%.

Distribution of permanent sampling plots

The analysis showed that 481 permanent plots would be required across the three watersheds, 89 more plots were added to enhance the reliability of the results. Circular plots were used because they are easier to establish and it is less problematic to determine whether trees are inside or outside than in rectangular plots. Hawth's ArcGIS analysis tool was employed to distribute the plots randomly across the forests, and the coordinates of the plot centres were loaded into the GPS (Garmin Map 60CSx). The centre of each plot was marked in the field using a reinforced concrete cement pillar.

Figure 17: **Sampling design of the circular plots**



AGTB = above-ground tree biomass; AGSB = above-ground sapling biomass; LHG = LEAF litter, grass, and herbs; SOC = soil organic carbon; DBH = diameter at breast height

Pool-wise carbon inventory

Five different carbon pools were measured to estimate the total forest carbon stock and annual changes: above ground tree biomass, below ground tree biomass, above ground sapling biomass, leaf litter, grass and herb biomass, and soil carbon. The process and methods used in the study are described below.

Above-ground tree biomass (AGTB)

All trees equal to or above 5 cm dbh were measured for diameter and height using a dbh tape and Vertex and clinometers. Data were recorded in a spreadsheet and a simplified standard regression model based on dbh, height, and wood density was used to calculate the biomass of the trees as suggested by Chave et al. (2005). A number of regression models have been developed to estimate forest biomass in Nepal; however, these models are based on a small number of harvested trees, do not represent trees of higher diameter class, and are available only for a few species. We chose Chave's model because it takes into account the wood-specific gravity of each plant species, one of the important variables in the biomass function, and it gave the most accurate results in tests with five other models carried out in Uttar Pradesh in India under similar climatic conditions and vegetation types to those in Nepal. Cheve's model follows the equation:

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

Where,
$AGTB$ = above ground tree biomass (kg)
ρ = wood-specific gravity (kg m-^{3});
D = tree dbh (cm); and
H = tree height (m)

Above-ground sapling biomass (AGSB)

Saplings with a diameter between 1 and 5 cm were measured at 1.3 m height. AGSB was analysed using a site and species-specific national allometric regression model, which was developed jointly by the Department of Forest Research and Survey, Tree Improvement and Silviculture Component, and the Department of Forest, Nepal (Tamrakar 2000).

$$\text{Log (AGSB)} = a + b \log (D)$$

Where,
Log = natural log (dimensionless)
$AGSB$ = above ground sapling biomass (kg)
a = intercept of allometric relationship for saplings (dimensionless)
b = slope of allometric relationship for saplings (dimensionless)
D = sapling dbh(cm)

Leaf litter, grass, and herbs (LGH)

Destructive sampling was applied to estimate the biomass of the pool of leaf litter, grass, and herbs. Forest floor litter materials (dead leaves, twigs, fruit, flowers) were collected from a 1 m^2 area, avoiding contamination with soil and stones. The living components, mainly grass and herbs, were also harvested and weighed. Dry weight was analysed in samples of the materials in the laboratory. The leaf litter, grass, and herb (LGH) biomass per hectare was calculated using the following formula, and carbon content was determined by multiplying with the IPCC (2006) default carbon fraction of 0.47.

$$LHG = \frac{W_{field}}{A} \cdot \frac{W_{subsample,\ dry}}{W_{subsample,\ wet}} \times \frac{1}{10000}$$

Where
LHG = biomass of leaf litter, herbs and grasses (t ha^{-1})
W_{field} = weight of fresh sample of leaf litter, herbs, and grass, destructively sampled within area A (g)
A = size of area in which leaf litter, herbs, and grasses were collected (ha)
$W_{subsample,\ dry}$ = weight of oven dried sub-sample of leaf litter, herbs, and grass, taken to laboratory to determine moisture content (g)
$W_{subsample,\ wet}$ = weight of fresh sub-sample of leaf litter, herbs, and grass, taken to laboratory to determine moisture content (g)

Below-ground tree biomass (BGTB)

Methods for estimating below ground biomass (biomass of the roots) for different land use systems are still not standardized (IPCC 2006). The methods commonly used to estimate this pool are excavation of roots, root-to-shoot ratio, and allometric equations. Destructive excavation is very complex, time consuming, and expensive (MacDicken 1997), whereas the available allometric equations are not suitable for this study as they are mostly based on native forests (Ravindranath and Ostwald 2008) and the forests in our research sites are of mixed natural and plantation types. Therefore, a conservative root-to-shoot ratio value was used to calculate the root biomass. As most of the research sites are similar to tropical moist deciduous and sub-tropical humid forests, a 0.20 fraction was used to estimate the below ground carbon as recommended by IPCC (2006) and MacDicken (1997 p. 14).

Soil organic carbon (SOC)

Soil organic carbon is an important carbon pool as it contains 81% of the total carbon of terrestrial ecosystems (WBGU 2000). The soil carbon stock in forests may vary substantially: from 54 to 84% of total carbon (Bolin et al. 2000).

Soil samples were collected at depths of 0–10, 10–20, and 20–30 cm. Samples of exactly 100 cm^3 were taken and transferred to pre-weighed sampling bags. The wet weight of samples was determined in the field with 0.1 g precision. Samples were then oven dried (70°C) in the laboratory to constant weight to determine water content. Samples from each of the three depths were then combined and a well-mixed sample per sampling plot prepared for carbon measurement by removing stones and plant residues >2 mm and grinding the sample. Carbon concentration was determined by flash combustion in a total carbon analyser. The carbon stock density of soil organic carbon was calculated from the formula:

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

Where

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

ρ = soil bulk density ($g\ cm^{-3}$)

d = total depth (30 cm) over which the sample was taken

%C = carbon concentration in percentage total carbon

Total forest carbon

The forest biomass in all pools was converted into forest carbon by multiplying by the default value 0.47 (IPCC 2006). The carbon stock density of each stratum at the beginning of the project period (t=0) was calculated by summing the carbon stock densities of the individual carbon pools of that stratum using the formula given in the following equation. Any individual carbon pool in the formula can be ignored if it doesn't contribute significantly to the total carbon stock.

$$C(LU) = C(AGTB)+C(AGSB)+C(BB)+C(LHG)+SOC$$

Where

C (LU) = carbon stock density for a land use category ($t\ C\ ha^{-1}$)

C (AGTB) = carbon in above ground tree components ($t\ C\ ha^{-1}$)

C (AGSB) = carbon in above ground sapling components ($t\ C\ ha^{-1}$)

C (BB) = carbon in below ground components ($t\ C\ ha^{-1}$)

C (LHG) = carbon in litter, herbs, and grass ($t\ C\ ha^{-1}$)

SOC = soil organic carbon ($t\ C\ ha^{-1}$)

Carbon was summed, and the total was then multiplied by 44/12 (3.67) in order to convert to the carbon dioxide equivalent.

The forest carbon assessment in the community forests enabled members of the local community in the three watersheds to quantify the carbon stocks and carbon increment in their forests for a given interval of time. The results are summarized in Table 19.

Conclusion and Recommendations

Community-based forest management in Nepal effectively enhances biomass and carbon. Thus community forest management could be a good contributor to a REDD+ programme in the future. Strengthening communities to own and monitor carbon stocks could provide a rapid and cost-effective way of estimating carbon dioxide emissions and contributing to local livelihoods and forest biodiversity conservation. By involving local people, it is possible to carry out repeated monitoring of data of relevance to REDD+ – which would be logistically impossible for professional surveys – that could provide a fair basis for estimating payments to communities for carbon savings. This could in turn provide an incentive for their engagement with REDD+ monitoring and forest management. The approach also enhances ownership over the process. The grouping of scattered community forests into a single unit, institutionalized community carbon registration and monitoring (by incorporating the provisions of REDD+ in community forest management plans and constitutions), and locally-based approach in monitoring may in fact provide a good way of addressing some of the social issues that have been raised in connection with the implementation of REDD+. Based on field experience,

Table19: **Forest carbon stock (t/ha) in the project area in 2010, 2011, and 2012**

Watershed	Total forest area (ha)	Area in the strata (ha)		Forest carbon					
				2010		2011		2012	
				t C ha-1	total carbon stock (t C)	t C ha-1	total carbon stock (t C)	t C ha-1	total carbon stock (t C)
Kayar Khola	2,382	1,903	dense	296	564,042	298	567,029	300	572,174
		479	sparse	256	123,008	257	123,338	258	123,831
Ludhikhola	1,888	1,635	dense	216	353,507	221	362,514	224	367,009
		253	sparse	162	41,217	166	42,226	170	43,215
Charnawati	5,996	3,899	dense	228	891,212	231	902,091	233	911,488
		2,097	sparse	166	349,674	168	352,862	171	359,908

in order to conduct an effective assessment of forest carbon in community-managed forests, we need to train, educate, and build the capacity of local community people and forest technicians. This will help to maintain and assure the quality of the data and measured carbon stocks. There is a need for a database management and registration system for forest carbon from local to national levels. The forest carbon monitoring process should be recognized and mainstreamed in Nepal's national REDD policy. There is also a need for extensive research on biomass and carbon modelling, as the forest types in Nepal vary from tropical in the plains to temperate in higher mountain regions up to the timberline.

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