Climate Change Mitigation Potential from Carbon Sequestration of Community Forest in Mid Hill Region of Nepal

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***Abstract*- Forest can capture and retain large amount of carbon over long periods. To estimate the climate change mitigation potential from carbon stock of the forest, the study was conducted in Ghwangkhola Sapaude Babiyabhir Community Forest (GSBCF) in SyangjaDistrict of Nepal. The total carbon stock of forest was measured from April 1-25, 2011 by following the Forest Carbon Measurement guideline. The forest was with Castonopsis-Scima lying at an altitude range of 970 to1320 masl. More than 90% of the trees having a diameter of less than 20 cm indicate high potential of increasing biomass in the future. The above ground tree biomass, above ground sapling biomass, biomass in herbs and litter and below ground biomass was 126.3, 2.88, 7.54 and 27.34 ton/ha, respectively. The total carbon stock, annual carbon sequestration rate and total CO_2 mitigation potential was 122.29, 0.45 and 1.64 ton/ha, respectively. Reduced emission from deforestation and degradation (REDD) should be implemented for getting monetary benefit of carbon dioxide mitigation that will help to conservation of forest.**

Keywords-Climate Change; Mitigation; Carbon Sequestration; Community Forest

I. INTRODUCTION

Forests are known to play an important role in regulating the global climate. They play a key role in both sinks and sources of carbon dioxide. Forest can capture and retain large amount of carbon over long periods [1]. These stocks are dynamic, depending upon various factors and processes operating in the systems; most significant ones are land-use changes, soil erosion, and deforestation [2]. It has been estimated that deforestation and forest degradation contribute up to 20 percent of global emissions of CO_2 annually. Moreover, forests are thought to provide a more cost-effective means of reducing global CO_2 emissions than other sectors. Thus, if incentives could be provided to curb the deforestation and forest degradation in many tropical countries, then forests could have a net positive impact on carbon sequestration and contribute substantially to mitigate climate change [3].

Within the last four decades, Community Forest Management (CFM) has been promoted in Nepal as an important step in common property resource management. To mitigate the growing deforestation and deterioration of the forest all over the country, the government of Nepal made a policy based on the 1976 National Forestry Plan to involve local communities in forest management [4]. Till April 1, 2012, there were 17,685 CFUGs with the total CF area of 1,652,654 ha. The total number of households involved was 2,177,858 [5]. Various studies have demonstrated that there is a significant increase in forest condition under CF showing that it is a proven model for controlling deforestation and forest degradation. [4] recorded a 29% increase in basal area for degraded community forests over 4 years. [6] Recorded a 21% biomass increase across community forests of all types and conditions measured over a 14 years period (1.5% yearly). CF also had benefits for reducing poverty, addressing social exclusion and creating rural employment. Biological sequestration of CO_2 by CF assists in reducing atmospheric CO_2. Estimates of the carbon stocks of forests undergoing deforestation, and the subsequent carbon dynamics are uncertain for many developing countries including Nepal [7]. Up to date information on forest clearing and carbon storage is required to estimate the deforestation and degradation, and to identify the reduced amount of carbon from abated deforestation and degradation [4].

The impact of climate change can be much greater for indigenous communities living in the more remote and ecologically fragile zones and relying directly on their immediate environments for subsistence and livelihood [8]. Climate change is a phenomenon due to emissions of greenhouse gases from fuel combustion, deforestation, urbanization and industrialization resulting variations in solar energy, temperature and precipitation [9]. Nepal has already encountered some of the adverse impacts of climate change. The recently observed extreme weather events between 2006-09 including droughts and floods have significantly affected food production in Nepal [10]. Lower level of awareness to disasters and climate change and its adaptation and mitigation options are associated with higher vulnerability [11].

Hence, there is a need of study which will help in accurate measurement of carbon stock for determining the change in carbon sequestration. The research questions addressed by this study are i) what is the vegetation structure of the studied CF? ii)

What is the biomass composition of the CF iii) what is the carbon stock, carbon sequestration rate as well as yearly carbon dioxide absorption potential in the studied forest for mitigating climate change?

II. MATERIALS AND METHODS

A. *Study Area*

The study was done in the community forest in the western hilly district of Nepal. GSBCF, with an area of 92 hectares in Putalibazar Municipality, ward number 8, in Syangja District was handed over to Community Forest Users Group (CFUGs) in 2000 (Fig.1). So, this study was conducted in GSBCF of hilly region of western Nepal due to the availability of growing stock biomass data measured in 2006 during renewal of CF Operational Plan (OP) for calculating the incremental carbon stock at five years interval.

Other description of the Studied CF:

Handover Year (Renewed Year): 2000 (2006)

Total household involved: 195 (Dalit-6; Janajati-70 and Higher caste-119)

Total Population: 1025

Committee members: 13 (Male-9, Female-4; Dalit-1, Janajati-2, Other-10)

Major caste in group: Brahmin, Chettri, Magar, Gharti, Kami, Newar

Vegetation Type: Temperate deciduous forest

Major tree species: *Castanopsis indica*, *Schima wallichi*

Source: Community Forest Operation Plan [12]

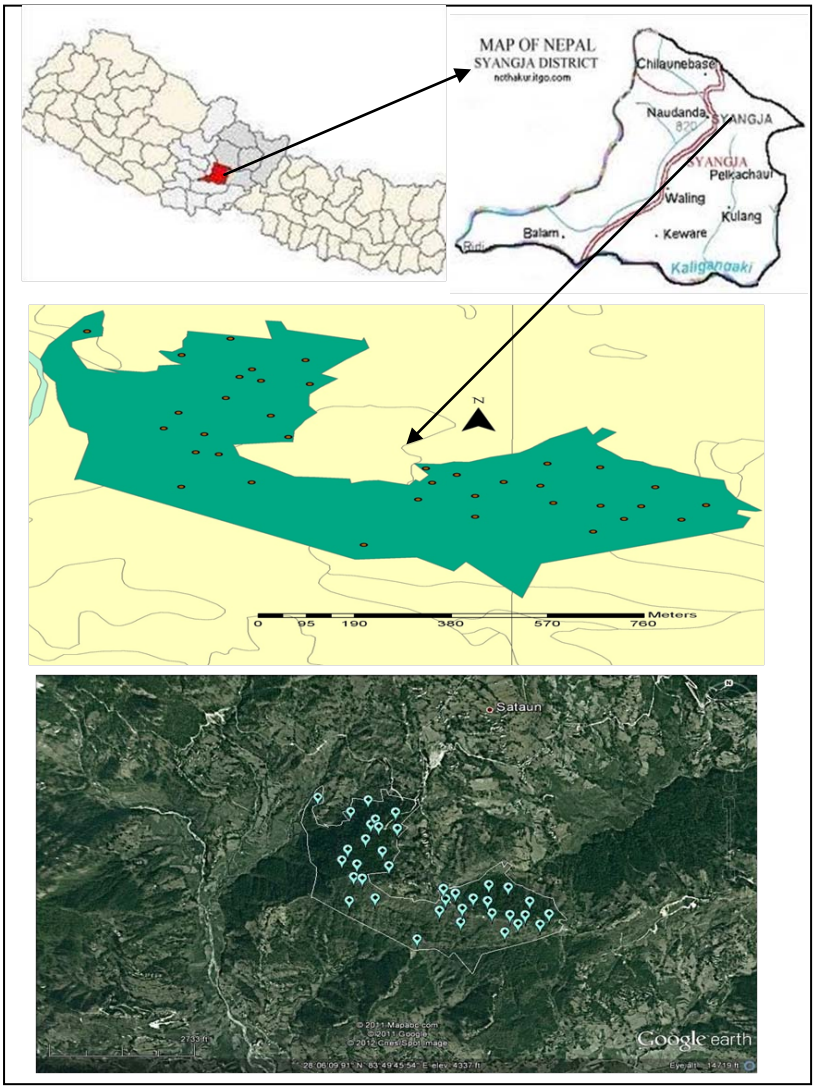

Fig. 1 a) Map of Nepal, Syangja district and CF with sample plots Source: Field Survey 2011, www.googleearth.com and www.google.com

B. Data Collection techniques

The primary data was collected from field observation, HH survey, KIS, FGD and transect walk. Secondary data was collected by literature review from journals, books, newspapers, research reports, expert consultation and Internet surfing.

Pilot inventory was done during October 5-20, 2010. During pilot inventory, one FGD was conducted with the CFUG executive committee members about their involvement in biomass measurement of the forest. The boundary of forest was tracked using GPS and block division of the forest was done for sample plot determination.

The field work for forest inventory was conducted from April 1, 2011 to April 25, 2011. Biomass measurement was directly done in the field for trees and sapling. For biomass measurement, guidelines prepared by [1] were followed. The samples of leaf litter, herbs, grasses (LHG) and soil were collected in the field. A total of 40 composite samples of LHG and soil were collected and brought to the laboratory for detailed analysis.

Stratified random sampling method was applied to determine the sample plot for biomass estimation in the forest. Altogether 40 sample plots of 250 m^2 each were taken for biomass estimation [13]. One hectare out of 92 hectares (1.09%) was selected as a sample for biomass measurement. In three different strata of forest, 19 sample plots were taken in Ghwangkhola block which has moderately dense forest, 10 sample plots were taken in Sapaude block which has dense forest and 11 sample plots were taken in Babiyabhir block which has very sparse trees with pastureland.

Soil samples brought to the lab were air-dried in dry lab in the beginning. Then, chemical analysis was done to find percentage organic carbon for determining SOC. The LHG sample was kept in hot air oven for 24 hours to remove the moisture for dry biomass calculation.

For above-ground tree biomass (AGTB), the diameter at breast height (DBH) (at 1.3 m) and height of individual trees (have a diameter of more than 5 cm) were measured in each circular plot of 250 m^2 having radius 8.92 m [14]. Diameter tape, clinometers and linear tape were used for this purpose. Each tree was recorded individually, together with its species' name. Trees on the border were included if more than 50% of their basal area falls within the plot and excluded if more than 50% of their basal area falls outside the plot. Trees overhanging into the plot were excluded, but trees with their trunks inside the sampling plot and branches outside were included.

For above-ground sapling biomass (AGSB) and regeneration, sub plots having a 5.64 m radius inside larger plots were established for sapling measurement. Smaller nested sub plots having a 1 m radius inside the larger nested plots were established for assessing regeneration. Saplings with diameters of more than 1 cm to less than 5 cm were measured at 1.3 m above ground level, while saplings smaller than 1 cm in diameter at 1.3 m above ground level were counted as regeneration.

For leaf litter, herbs, and grass (LHG), one circular sub plot of 1 square meter (0.56 m radius) in size was established at the center of each plot. All the litter (dead leaves, twigs, and so forth) within the 1 m^2 sub plots was collected and weighed. Approximately 100 g of evenly mixed sub-samples were brought to the laboratory to determine moisture content, from which total dry mass can then be calculated. Likewise, herbs and grass (all non woody plants) within the plots were collected in polythene bag by clipping all the vegetation down to ground level and brought to the lab.

Soil organic carbon (SOC) was determined through samples collected from the default depth prescribed by [15]. Near the center of all plots, a single pit of up to 30 cm in depth was dug to best represent forest types in terms of slope, aspect, vegetation, density and cover [16]. For the purpose of estimating bulk density, individual soil samples were collected with the help of a standardized 300 cm^3 metal soil sampling corer. Similarly, one composite sample was collected mixing soils from all the three layers in order to determine concentrations of organic carbon and then weighed at a precision of 0.1 g. Around 500 g of composite sample was collected from one plot. Composite soil samples were placed into sample bags by labeling. All samples were then transported to the laboratory for further analysis.

C. Data Analysis

The allometric equation (models) in estimating AGTB developed by [17] was followed. On the basis of climate and forest stand types, eq. (1) for moist forest stand was selected.

$$AGTB=0.0509*\rho D^2 H \quad \text{eq. (1)}$$

Where,

AGTB = above-ground tree biomass [kilogram (kg)];

ρ = wood specific gravity [g/cm^3] was used from guideline prepared by [1]

D= tree diameter at breast height measured [cm]; and

H = tree height [metre].

After taking the sum of all the individual weights (in kg) of a sampling plot and dividing it by the area of a sampling plot (250 m^2), the biomass stock density was attained in kg m^{-2}. This value was converted to ton/ha by multiplying it by 10.

To determine the AGSB (DBH less than 5 cm), national allometric biomass tables were used. These tables were developed by the Department of Forest Research and Survey (DFRS) and the Department of Forest, Tree Improvement, and Silviculture Component (TISC) [18]. The national allometric biomass table did not contain value for all species present in Nepal. So, values for related or similar species were used. The biomass values of saplings include foliage, branch, and stem compartments. The following regression model was used to calculate biomass.

$$\text{Ln (AGSB)} = a + b \ln (D) \quad \text{eq. (2)}$$

Where,

ln = natural log [dimensionless];

AGSB = above-ground sapling biomass [kilogram];

a = intercept of allometric relationship for saplings [dimensionless];

b = slope allometric relationship for saplings [dimensionless]; and

D = over bark diameter at breast height (measured at 1.3 m above ground) [centimeter].

To determine the biomass of LHG, samples were taken from sampling plot of 1 m^2. Fresh samples were weighed in the field with a 0.1 g precision; and a well-mixed sub-sample was then placed in a marked bag. The sub-sample was used to determine an oven-dry-to-wet mass ratio that was used to convert the total wet mass to oven dry mass. A sub-sample was taken to the laboratory and oven dried to determine water content. For the forest floor (herbs, grass, and litter), the amount of biomass per unit area is calculated as:

$$\text{LHG} = \text{Wfield} * \text{Wsubsample, dry} / (\text{A} * \text{Wsubsample, wet} * 100) \quad \text{eq. (3)}$$

Where,

LHG = biomass of leaf litter, herbs, and grass [ton/ha];

Wfield = weight of the fresh field sample of leaf litter, herbs, and grass, destructively sampled within an area of size A [g];

A = size of the area in which leaf litter, herbs, and grass were collected [m^2];

Wsubsample, dry = weight of the oven-dry sub-sample of leaf litter, herbs, and grass taken to the laboratory to determine moisture content [g]; and

Wsubsample, wet = weight of the fresh sub-sample of leaf litter, herbs, and grass taken to the laboratory to determine moisture content [g].

For below-ground biomass calculation, [13] root-to-shoot ratio value of 1:5 was used. It means that below-ground biomass was calculated as 20% of above-ground biomass.

Since the study area was part of the sub-tropical region, the biomass stock density of a sampling plot was converted to carbon stock densities after multiplication with the default carbon fraction of 0.47 [15].

Collected soil samples were analyzed in laboratory using special methods and organic carbon percentage were calculated. The titration method as developed by [16] was applied for measuring the percentage of organic carbon. The soil depth was measured in the field. Bulk density was calculated by dividing weight of the soil by the volume of the soil.

The soil organic carbon was calculated using the method developed by [19].

$$\text{Soil Organic Carbon (SOC)} = \%\text{C} \times \rho \times \text{d} \quad \text{eq. (4)}$$

Where,

%C = Carbon concentration (%)

d = soil depth (cm)

ρ = Bulk density (g/cm^3)

The total carbon stock density in 2011 was calculated by summing the carbon stock densities of the individual carbon pools of that stratum using the following formula.

Carbon stock density of a stratum:

$$\text{C Total} = \text{C (AGTB)} + \text{C (AGSB)} + \text{C (BB)} + \text{C (LHG)} + \text{SOC} \quad \text{eq. (5)}$$

Where,

C Total = carbon stock density for a land-use category [ton C/ ha],

C (AGTB) = carbon in above-ground tree biomass [ton C/ ha],

C (AGSB) = carbon in above-ground sapling biomass [ton C/ ha],

C (BB) = carbon in below-ground biomass [ton C/ ha],

C (LHG) = carbon in litter, herb & grass [ton C/ ha], and

SOC = soil organic carbon [ton C/ ha]

The total carbon stock was calculated by multiplying the C Total with area of forest (92 hectares).

Growing stock data in volume from the CF Operation Plan 2006 was used to calculate biomass.

Total biomass = Total Area × Volume × BCEFs × (1+0.2) …… eq. (6) [15]

Where,

Total biomass was measured in ton,

Total Area = Area of forest; 92 [ha]

Volume = Growing stock volume; 114.594 [m^3]

BCEFs = Biomass conversion and expansion factor for Temperate forest (0.9) [15]

Biomass was converted into carbon by using [15] default carbon fraction of 0.47.

Yearly Incremental Carbon stock = (Carbon stock in present inventory in 2011 – Carbon stock in 2006 inventory)/5

Yearly carbon dioxide mitigation potential = Yearly Carbon sequestration rate* 3.67 [19].

III. RESULTS AND DISCUSSIONS

A. *Vegetation Structure of the Forest*

The forest had the sapling of 828 per hectare which is much higher in comparison with trees as shown in Fig. 2. The tree with DBH class 10-20 had the highest density of 208 trees/ha. But, the density of tree with DBH greater than 50 is only 7 trees/ha. It shows that forest is dominated by newly grown trees after the implementation of CFM.

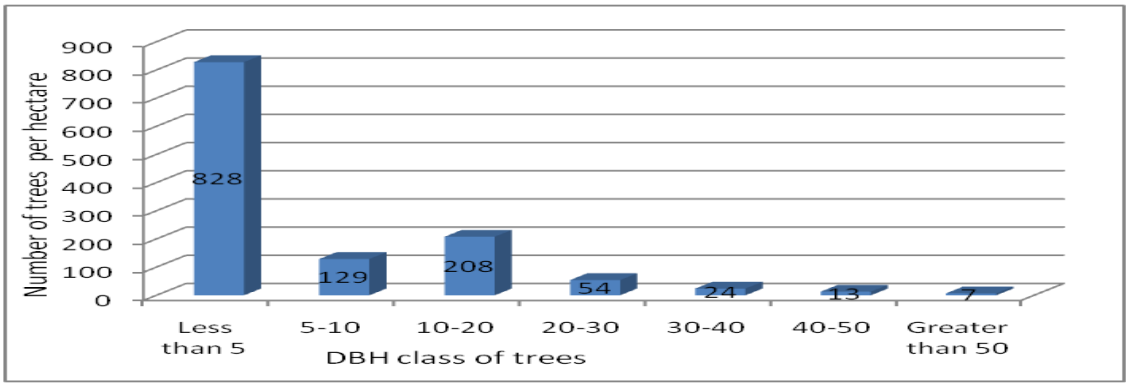

Fig. 2: Distribution of DBH Class of trees

TABLE I VEGETATION PARAMETERS OF THE FOREST

Name of the species	Regeneration/ha & %		Density/ha	% of trees	Sapling/ha
Castonopsis indica	504	36.42	15	36.63	304
Scima wallichi	486	35.12	160	27.65	304
Diospyros montana	192	13.87	120	2.99	41
Engelhardtia spicata	113	8.16	13	20.05	87
Others	89	6.43	87	12.68	67
Total	1384	100	40	100	817

It was Castonopsis-Scima forest having 72 % of the trees of these species which will also dominate in the future. The regeneration in the forest was 1384/ha as shown in Table-I. *Castonopsis indica* had the highest regeneration of 504 per hectare which was much less than that calculated by [20] in Nagmati watershed (4660 per ha). Similarly, *Schima wallichi, Diospyros montana* and *Engelhardtia spicata* had regeneration of 486, 192 and 113 per hectare, respectively. *Pinus roxburghi* were planted in regular interval in steep slope which might dominate the forest in the future. About 90% of the trees having DBH less than 20 cm shows that the forest was dominated by newly grown trees. The smaller trees would grow and increase the

biomass, carbon stock, forest cover and canopy cover in the future. The old trees being less in the forest shows that proper harvesting and thinning was done at regular interval by CFUG.

B. *Biomass Estimation of the CF*

From the current biomass inventory of forest, it was seen that shoot and root of the tree had biomass of 126.3 ton/ha and 27.34 ton/ha, respectively as shown in Table-II. Saplings, herbs and litter contribute very less biomass to the forest which was 2.88 ton/ha and 7.54 ton/ha, respectively. Species wise, biomass of the *Scima wallichi* was highest (63.40 ton/ha) followed by *Castonopsis indica* (57.66 ton/ha). Similarly, *Engelhardtia spicata* and other species had biomass of 13.62 and 20.34 ton/ha, respectively.

TABLE II BIOMASS ESTIMATION OF DIFFERENT SPECIES AND OF DIFFERENT CATEGORY

Name of the species	Biomass (ton/ha)	Category	Biomass (ton/ha)
Scima wallichi	63.4	Above Ground Tree Biomass	126.3
Castonopsis indica	57.66	Above Ground Sapling Biomass	2.88
Engelhardtia spicata	13.62	Herbs and litter	7.54
Others	29.38	Below Ground Biomass	27.34
Total	164.06	Total	164.06

By the application of biomass expansion factor, the total biomass of 2006 was calculated as 159.34 ton/ ha from growing stock data. The total biomass measured during field visit in 2011 inventory was 164.07 ton/ ha. From the calculation, net incremental biomass in 5 years was 4.73 ton/ ha. More than 77% of the biomass in the forest was contributed by above ground tree biomass. Shrubs, herbs and litter contribute very less biomass to the forest totaling about 7 % of total. The total below ground biomass was about 16%. The biomass in the forest was 164 ton/ha which was less than that reported by [15] in natural forest of Asian region (190 ton/ha). More biomass was contributed by *Scima wallichi* followed by *Catonopsis indica.* The slow incremental biomass might be due to harvesting and selective cutting of old and large trees for firewood and timber. Harvesting of firewood was done for the sustainable supply of cooking fuel by the CFUG. Yearly biomass increment was 0.95 ton/ha, which was less than that reported by [15] in natural forest of Asian region (8.4 ton/ha).

C. *Carbon Stock Estimation of the CF*

The conversion factor of 0.47 was used to convert biomass into carbon stock. Above ground tree carbon was highest (59.36 ton/ha) as shown in Fig.3. The SOC, above ground sapling carbon and carbon in herbs and litter was 45.18, 1.35 and 3.54 ton/ha, respectively. The carbon stock in sapling, herbs and litter was low compared to tree and soil carbon.

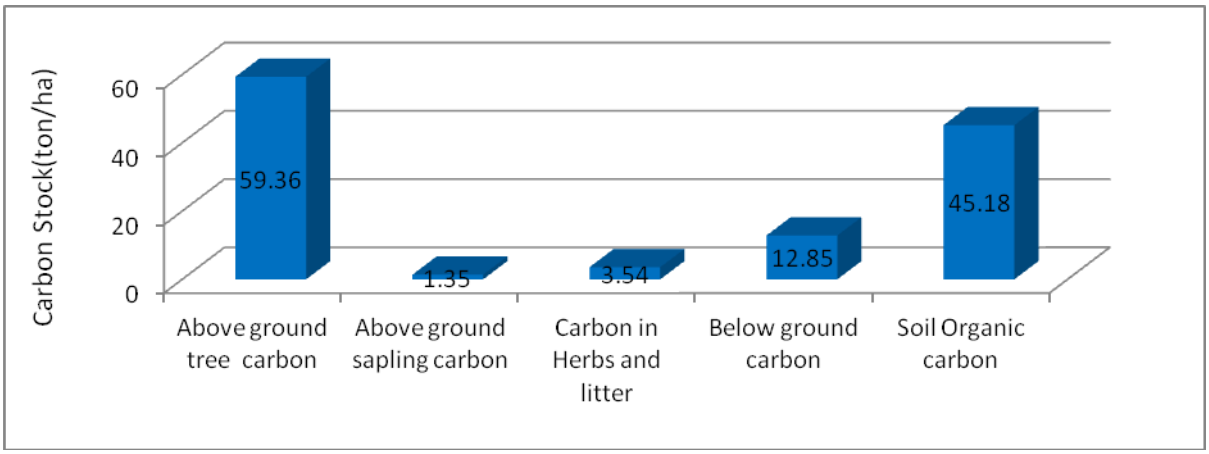

Fig.3: Carbon stock of studied CF

TABLE III CARBON STOCK OF DIFFERENT SPECIES OF TREES

Name of the species	Carbon stock (ton/ha)
Scima wallichi	29.80
Castonopsis indica	27.10
Engelhardtia spicata	6.40
Others	9.56
Total	72.86

Among the different species of plants, *Scima wallichi* and *Castonopsis indica* were dominant and had the carbon stock of

29.80 ton/ha and 27.10 ton/ha, respectively as shown in Table-III. *Engelhardtia spicata* had the carbon stock of 6.40 ton/ha. Other species had carbon stock of 9.56 ton/ha. The annual sequestration /mitigated rate of carbon by the forest was 0.45 ton/ hectare. The total sequestration/ mitigation potential of CO_2 by the forest was 1.64 ton/ hectare which shows that this forest is also helping in mitigating climate change. But it may contribute less to the carbon credit through REDD scheme.

The total carbon stock of the forest was calculated as 122.29 ton/ha, which was less than that estimated by [21] in Kayarkhola, Charnawati and Ludikhola watershed. The carbon stock in dense and sparse strata of Kayarkhola, Charnawati and Ludikhola watershed was 296.44 and 256.70 ton/ha; 228.56 and 166.75 ton/ha; 216.26 and 162.98 ton/ha, respectively. But it was more than that in Kathmandu where the biomass carbon and SOC of CF was 119.742 ton/ha and 32.29 ton/ha respectively [22]. Above ground trees, below ground roots and soil sequestered 48.54%, 10.51% and 36.94% of total carbon respectively. It shows that trees and soil are the main component in the forest for carbon sequestration. Carbon stock of *Scima wallichi* and *Castonopsis indica* was 40.9% and 37.20% of total carbon stock of the forest. Annual carbon increment was 0.45 ton/ha.

Nepal's share in climate change (CC) is negligibly small. Analysis of recorded temperature and precipitation data in Nepal are limited due to availability of data for only last 30 years. Studies have indicated that temperature in Nepal is increasing. The warming seems to be consistent and continuous after the mid-1970s [23].

Forest had lots of indirect and external benefits to the people other than the direct benefit. People were getting fresh air to breathe, fresh water supply for drinking, HH purpose and irrigation from forest and also it was mitigating climate change and natural disaster like landslide and soil erosion.

IV. CONCLUSION

The following points have been concluded from the above study.

1. The studied community forest was newly developed Castonopsis-Scima forest. More than 90% of the trees in the forest having DBH less than 20cm indicate high potential of increasing biomass in the future. To increase the regeneration of forest, forest should be protected from rearing of domestic animals.

2. Tree biomass in the forest was much more as compared to other parts resulting in higher carbon stock in trees. Soil was also contributing in absorbing carbon as SOC. Since the forest is dominated by newly grown trees, forest products should be harvested in sustainable manner without disturbing the young trees to grow and increase its biomass. Only old and dead trees should be cut down to fulfill the demand of firewood.

3. The annual sequestration rate of carbon by the forest was 0.45 ton/ hectare. In addition to the supply of forest products and other environmental benefits, community forest is also helping in mitigating climate change by sequestering 1.64 ton/ hectare of CO_2. To get the monetary benefit of carbon dioxide mitigation, efficient carbon trading mechanism through reduced emission from deforestation and degradation (REDD) should be implemented which can help in conservation and further enhancement of forest.

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