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Evaluation of Biomass Stock in Two Differently Managed Forestsof Nepal: A Case Study from Sindhupalchok District, Nepal

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ABSTRACT

The study entitled "Evaluation of Biomass stock in two differently managed forests of Nepal (A case Sindhupalchok District Nepal)" aimed at to estimate the biomass stock of Selang Manju Community Forest and Lakpa Dorje Government Managed Forest of Sindhupalchok district, Nepal. Altogether there are 30 plots in the community forest and other 30 plots in the Government managed forest. Primary and Secondary data were collected and analyzed by using the t test. Total above-ground tree biomass of Government managed forest was found to be higher with 165.66 ton/ha than community forest with 158.27 ton/ha. The above ground sapling biomass of the community forest was found to be higher, with 2.07 ton/ha than Government managed forest is 1.95 ton/ha. The above ground LHG biomass of community forest with 2.47 ton/ha whereas the above ground LHG biomass of the Government managed forest was found to be 2.8 ton per ha. The dead wood biomass of the government-managed forest was found to be higher with 25.56 ton/ha than the community forest with 24.42. Total biomass stock of government managed forest was found to be higher with 231.24 ton/ha than community forest with 220.92 ton/ha including the above ground biomass, below ground biomass and dead wood biomass. The analysis of t test shows there is significant difference between mean above ground (shoot, LHG, dead wood) biomass of CF and GMF but there is no significance difference between mean above ground sapling biomass stock of CF and GMF at 5% level of significance.

Keywords: *Biomass Stock, Community Forest, Government Managed Forest*

1. Introduction

A carbon sink is a carbon pool from which more carbon flows in than out [1-3]. Forests can act as sink through the process of tree growth and resultant biological carbon sequestration. Activities like afforestation, reforestation (AR), sustainable forest management (SFM), and Conservation and Enhancement of forests acts as carbon sinks. Carbon source is a carbon pool from which more carbon flows out than flows in forests can often represent a net source of carbon due to the processes of decay, combustion, and respiration. Activities like deforestation, forest fire, and forest degradation acts as sources of carbon. Therefore, forests can switch between being a source and a sink of carbon over time depending on the type of activity they are experiencing. As both carbon sources and sinks, they have the potential to form an important component in efforts to combat global climate change. That is why forests play an important role in the global carbon balance [4-5]. Carbon pool is a system thathas the capacity to accumulate or release carbon. Examples of carbon pools are forest biomass, wood products, soils and atmosphere.Biomass is defined as mass of live or dead organic matter. It includes the total mass of living organisms in a given area or volume; recently dead plant material is often included as dead biomass. The quantity of biomass is expressed as a dry weight or as the energy, carbon, or nitrogen content. Therefore, a global assessment of biomass and its dynamics are essential inputs to climate change forecasting models and mitigation and adaptation strategies. Carbon sequestration is the removal of carbon from the atmosphere and long-term storage in sinks, such as marine or terrestrial ecosystems [6]. Carbon stock is the mass of carbon contained in a carbon pool. Biomass density is Changes in time of vegetation biomass per unit area and can be used as an essential climate variable, because they are a direct measure of sequestration or release of carbon between terrestrial ecosystems and the atmosphere [7-9]. Therefore, when using the term "biomass" we refer to the vegetation biomass density, that is mass per unit area of live or dead plant material.

Government managed forest is a national forest to be managed by the Nepal Government. Community Forest is a national forest handed over to a user group for its development, conservation and utilization for the collective interest. Community forestry management is considered as one of the popular models of decentralization in natural resource management. The program encompasses a set of policy and instrumental innovations that were especially designed to empower the local livelihoods through the proper management and utilization of forest products. Over the past three decades, the program has undergone a tremendous shift from state-centric and top-down to community-based participatory approach to forest governance by restructuring and reformulating plans and policies related to forest governance in Nepal [10]. Community forest management (CFM) essentially involves handing over of

the national forest to local people over the certain period for protection, management and utilization of the forest product. Local forest enterprises advise them on forest rehabilitation.

Participatory management is mostly practiced in forest management. Community forestry is found to be successful practice in management of forest in Nepal. Now-a-days forests are being managed scientifically.The stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfill, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems.SFM implementation plan was proposed by [11-12] DoF (Department of Forest) in 2069 with the objective of adoption of the principal of sustainable forest management while adopting the forest management techniques, and support to local and national economy. The objective of this study is to evaluate the biomass stock of two differently managed forests (i.e. Community managed forest and government managed forest).

2.Materials and Methods

2.1 Study area

Sindhupalchock is a geographically complex district which is located at 27° 36' N to 28° 13' N and 85° 27' E to 85º 85'E, and covers an area of 2542 km2 equaling 1.73 % of land mass of the entire nation. The mid-hill generally has complicated physiography with stepwise rise in altitudes from south to the north directions. This has led to the formation of deep river valleys below the elevation of 1000 m. The distribution of vegetation is remarkably displayed across south to the northern regions.The study area is situated at the Selang Manju Community Forest User Group, Selang 1, 8 and Syaule 3,4, Sindhupalchock and the Dorje Lakpa national forest.TheSelangManjuCommunity forest consists of plantation as well as natural forest but in the Dorje Lakpa Government managed forest all the forest is only Natural. Pinus patula, and Pinus wallichina are the main planted species and the *SchimaWalllichii* and *Alnus Nepalensis* are the main natural species of the Community Forest. The Community Forest covers an area of 196.16hec in the mid mountain region. Out of the total 196.16 ha 0.05 % Community forest area 1 ha was selected for the forest inventory. All together there are 20 plots in the Community forest and other 20 plots in the government managed forest.Both primary and secondary data were collected for the study purpose. The secondary data were collected from reviewing published and unpublished papers and reports of Governmental, Non-governmental and community-based Organization. For the collection of primary data, Group Discussion and Interviews, Field survey was applied. The data so collected from people perception was verified through field visits and triangulations.

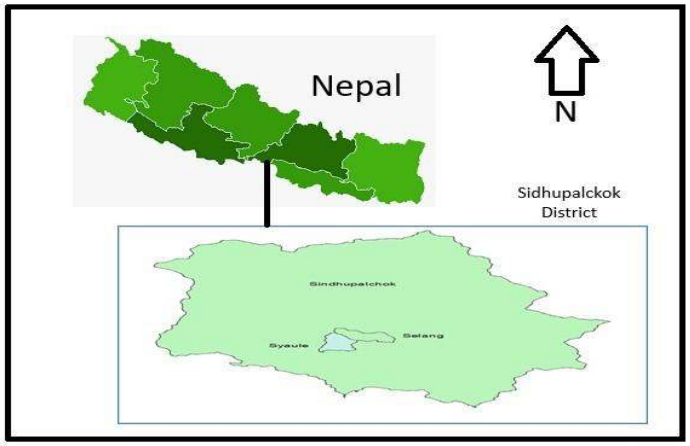

Figure 1: Map of Study area

2.2 Reconnaissance survey

Reconnaissance survey was done in both CF and GMF for the sample size and sample plot fixation. Then, according to the species area curve and survey 20*25 Sq. m. sample size was fixed. Sample plots were fixed to be 20 in each forest type. Both sample size and no. are the representative of the study area.

A preliminary survey was done to identify existing situation of the study area, location, ethnic composition of CFUGs and major species of CF. Rapport building with CFUG members, committee members and District Forest Office staff was made and informed about the research work.

2.3 Direct observation

Field observation was done with the help of forest guard. Thetotal area of the forest was divided into 5 blocks for the management of the forest. The study area was designed with respect to the systematic sampling techniques. Some photographs were taken from the forest as well as user group.

2.4 Forest sampling

The sampling wasdone by using the quadrate of 20*25 Sq. m. (CommunityForest inventory guideline, 2004.) The total number of tree species greater than 10 cm diameter at breast height belonging to quadrate was identified and noted. Plant greater than 10 cm DBH was regarded as tree and plant 4-10 cm DBH is regarded as Sapling Also the leaf litter from the ground was collected at 5 places in each 20*25Sq. m. quadrate with 1*1 Sq. m. quadrate. All the sample plots were taken on the equal distance of 100 m interval systematically [16-19] (Community Forest inventory guideline, 2004),Altogether40 quadrates are taken in the forest sampling.

2.5 Secondary data collection

Secondary data regarding this study was collected through literature survey. This included research reports and various published and unpublished documents available in the CFUGs, District development committee, Forest office, Village office, internets, and other sources.

2.6 Data analysis
The qualitative data was analyzed in descriptive texts while the quantitative data was analyzed by using Ms-excel and results was presented as pie chart, bar-diagram, mean, and tables.

2.6.1 Aboveground biomass estimation
The aboveground biomass included all parts such as stem, branches, foliage and undergrowth biomass. Biomass estimation of big trees is difficult to measure directly in situ. According to the objectives of the study only tree stem biomass and leaf letter biomass was predicted by the combination of measurement and models. Diameter at Breast Height (DBH) was measured by using DBH tape and height with the Clinometers.

Aboveground tree biomass
For the estimation of above-ground biomass of trees, DBH, wood specific density, and tree height were used. The algometric equation or model for estimating AGTB developed by ANSAB [9] was used, which is given below:
$AGTB = 0.0509 \times pD^2H$
Where,
AGTB = above ground tree biomass in kg
p = specific gravity (wood density) in kg/m^3
D = tree diameter at breast height in cm
H = tree height in m
Biomass stock was converted to carbon stock densities using the default carbon fraction of 0.47 (Forest carbon stock measurement, ANSAB [9].

Leaf litte biomass
To determine the biomass of leaf litter, samples was taken in the field within a small area of 1 m2. Fresh samples wasweighed in the field with a 0.1 g precision; and a well-mixed sub-sample wasthen placed in a marked bag. The sub-sample wasused to determine an oven-dry-to-wet mass ratio that will be used to convert the total wet mass to oven dry mass. A sub-sample was taken to the laboratory and oven dried until constant weight to determine water content. For the forest floor the amount of biomass per unit area is given byANSAB[9]:

$$\text{Leaf litter Biomass} = \frac{\text{Wfield} \cdot \text{Weight sub sample, dry}}{A * \text{Weight Sub sample, wet.} * 10000}$$

Leaf litter biomass = biomass of leaf litter [t ha-1];
Wfield= weight of the fresh field sample of leaf litter, sampled within an area of size A [g];
A = size of the area in which leaf litter, herbs, and grass were collected [ha];
Weight subsample, dry= weight of the oven-dry sub-sample of leaf litter, herbs, and grass taken to the laboratory to determine moisture content [g]
Weight Sub sample, wet = weight of the fresh sub-sample of leaf litter taken to the laboratory to determine moisture content [g].
Then,
Samples of undergrowth leaf litter were oven dried at a constant temperature of 70°C until the weight of the samples became constant [9] and the final constant weight was used as dry matter content. Dry biomass was converted to C content using an assumption that C content is approximately 47% of dry biomass.

Total above ground biomass organic carbon = (total above ground biomass of tree + total leaf litter biomass)* 47% (ANSAB, 2010, estimation of carbon in community forest ecosystem)

2.6.2 Underground biomass estimation
Root biomass
The measurements of root biomass were not a simple task. It wasrequired a lot of time as well as experience. Root biomass wasnot calculated in this study. [11-13] found 19.29% root biomass of total biomass. In a study by [14-17] for some temperate species, the root biomass was20 to 25% of the total aboveground biomass. Likewise [18-19] observed 9-22% of above ground biomass for different tropical species. The root biomass of trees varies according to species, age, microclimate and soil. On the basis of literature citing and forest type studied, the root biomass of tree has been assumed to be 18% of the above-ground biomass.

3. Result
3.1 Total aboveground biomass: Tree biomass
Total above ground tree biomass of Government managed forest was found to be higher with 168.34 ton/ha (From the analysis from the sample data, maximum tree biomass is 185.23 and minimum tree biomass is 145.23 ton/ha.)than community forest with154.67ton/ha. (From the analysis from the sample data, maximum tree biomass is 167.89 and minimum tree biomass is 129.54 ton/ha.). The standard deviation of the Above ground tree biomass in Government managed forest is 20.24 and the Community managed forest is 20.07.

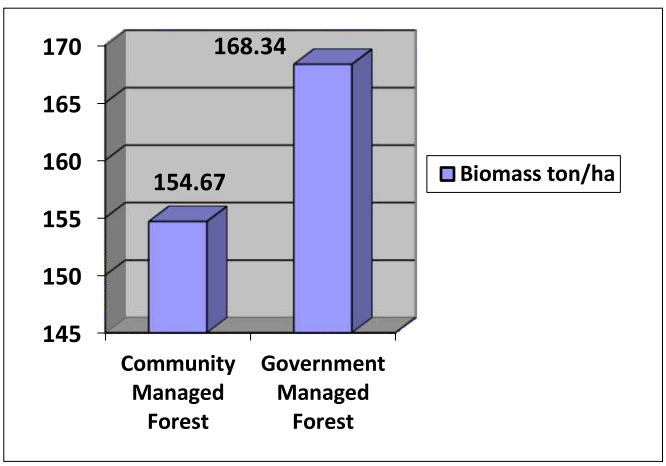

Figure 2: Above ground tree biomass

3.2 Aboveground sapling biomass
Total above ground sapling biomass of Community Forest was found to be higher with 2.80 ton/ha(From the analysis from the sample data, maximum sapling biomass is 3.30 ton/ha and minimum sapling biomass is 1.1 ton/ha.) thanGovernment Managed Forestis2.67 ton/ha.(From the analysis from the sample data, maximum sapling biomass is 2.91 ton/ha and minimum sapling biomass is 0.9 ton/ha.). The standard deviation of the Above ground Sapling biomass in Government managed forest is 1.26 and the Community managed forest is 1.25.

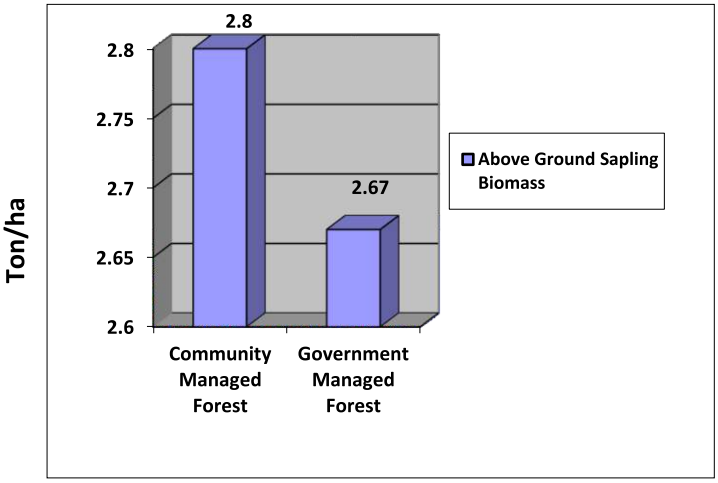

Figure 3: Above ground sapling biomass

3.3 Aboveground LHG biomass

Total above ground LHG biomass of community forest with 2.59 ton/ha (From the analysis from the sample data, maximum LHG biomass is 3.10 ton/ha and minimum LHG biomass is 1.9 ton/ha.) whereas the above ground LHG biomass of Government managed forest was found to be 2.79 ton/ha. (From the analysis from the sample data, maximum LHG biomass is 3.8 ton/ha and minimum LHG biomass is 2.2 ton/ha.). The standard deviation of the Above ground LHG biomass in Government managed forest is 0.82 and the Community managed forest is 0.61.

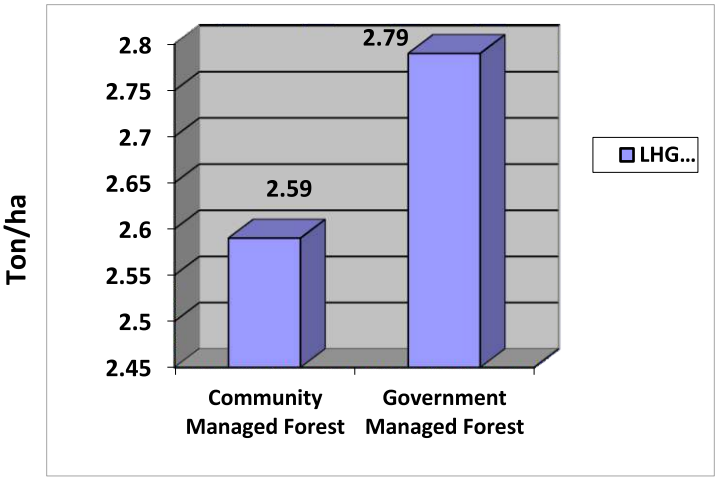

Figure 4: LHG biomass

3.4 Aboveground dead wood biomass

Dead wood biomass. (15% of the above ground biomass, Oli and Shrestha, Journal of Forest and Livelihood 8(1) Feb 2009). The dead wood biomass of Government managed forest was found to be higher with 26.07 ton/ha (From the analysis from the sample data, maximum Dead wood biomass is 28.79 ton/ha and minimum dead wood biomass is 22.25 ton/ha.)than community forest with 24.01. (From the analysis from the sample data, maximum dead wood biomass is 26.14 ton/ha and minimum dead wood biomass is 19.88 ton/ha.). The standard deviation of the Above ground dead wood biomass in Government managed forest is 3.32 and the Community managed forest is 3.29.

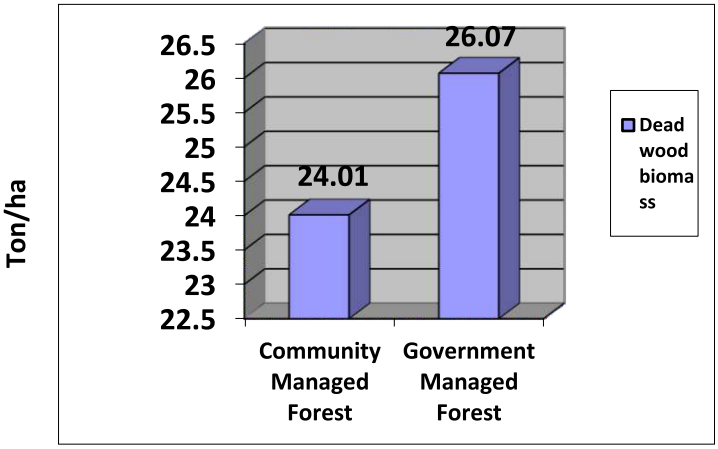

Figure 5: Dead wood biomass

3.5 Total above ground biomass

Total above ground biomass of community forest with 160.06 ton/ha (From the analysis of the sample data, maximum total above ground biomass is 200.43 ton/ha and minimum above ground biomass is 152.42 ton/ha.) whereas the above ground biomass of Government managed forest was found to be 173.8 ton/ha. (From the analysis of the sample data, maximum total above ground biomass is 220.73 ton/ha and minimum above ground biomass is 170.58 ton/ha.). The standard deviation of the total above ground biomass in Government managed forest is 33.26 and the Community managed forest is 29.05.

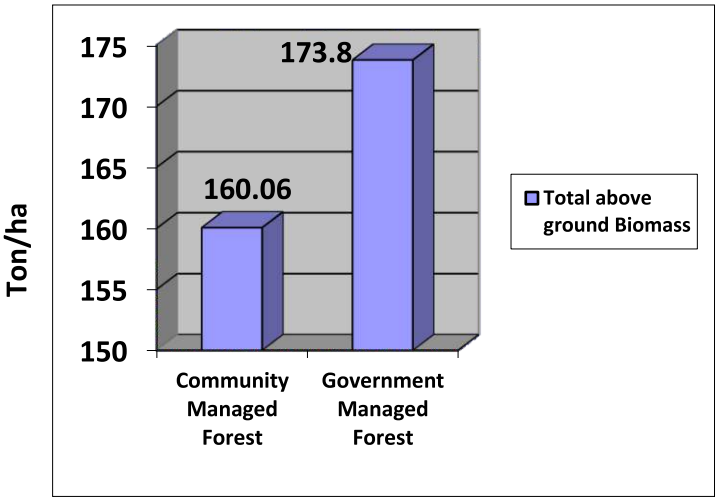

Figure 6: Total above ground biomass

3.7 Belowground biomass: Root biomass

The Below ground biomass consists of Root biomass (18% of the above ground biomass, from the analysis of the literature) The root biomass of Government managed forest was found to be higher with 31.28 ton/ha (From the analysis of the sample data, maximum total below ground biomass is 34.54 ton/ha and minimum below ground biomass is 26.69 ton/ha.)than community forest with 28.81. (From the analysis of the sample data, maximum total below ground biomass is 31.37 ton/ha and minimum below ground biomass is 23.85 ton/ha.). The standard deviation of the below ground root biomass in Government managed forest is 3.98 and the Community managed forest is 3.95.

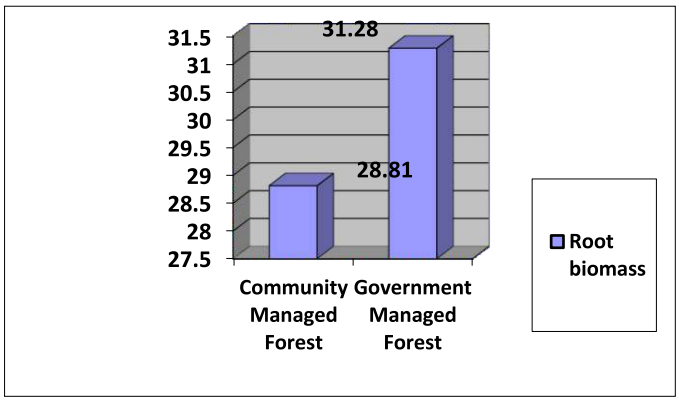

Figure 7: Root biomass

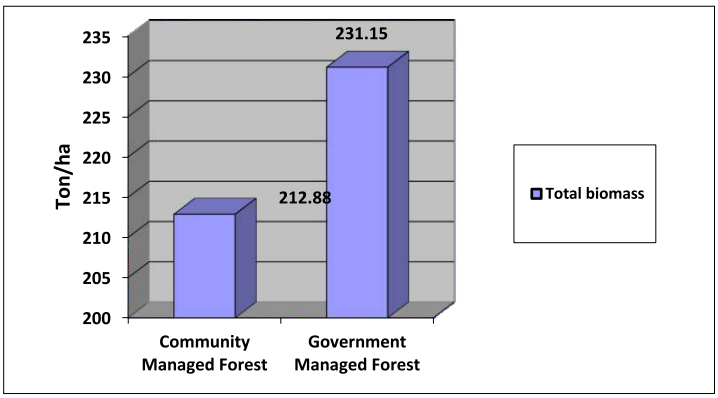

Figure 8: Total Biomass

3.8 Comparison of total biomass

Total Biomass stock of Government Managed forest was found to be higher with 231.15 ton/ha (From the analysis of the sample data, maximum total biomass is 255.27 ton/ha and minimum biomass is 197.27 ton/ha.) than Community forest with 212.88 ton/ha (From the analysis of the sample data, maximum total biomass is 231.8 ton/ha and minimum biomass is 176.27 ton/ha.) including the above ground biomass, below ground biomass and dead wood biomass. The standard deviation of the total biomass in Government managed forest is 29.41 and the Community managed forest is 29.14.

Table 1: Total Biomass Stock in the different forest

Total Biomass Stock in the different forest.				
Categories	Community Forest	Government managed Forest	Biomass Pool in CF (%)	Biomass Pool in GMF(%)
Above ground Tree Biomass	154.67	168.34	72.66	72.83
Sapling Biomass Stock	2.8	2.67	1.32	1.16
LHG	2.59	2.79	1.22	1.21
Below ground biomass	28.81	31.28	13.53	13.53
Dead wood biomass	24.01	26.07	11.28	11.28
Total	212.88	231.15	100	100.00

The table 1 shows the total biomass stock in the different forest types. The Above ground tree biomass contains the 154.67 ton/ha which is highest then the other categories and the LHG biomass stock is 2.59 ton/ha which is lowest among the categories in the community forest similarly in the Government managed forest above ground tree biomass contains the 168.34 ton/ha which is highest then the other categories and the LHG biomass stock is 2.79 ton/ha which is lowest.

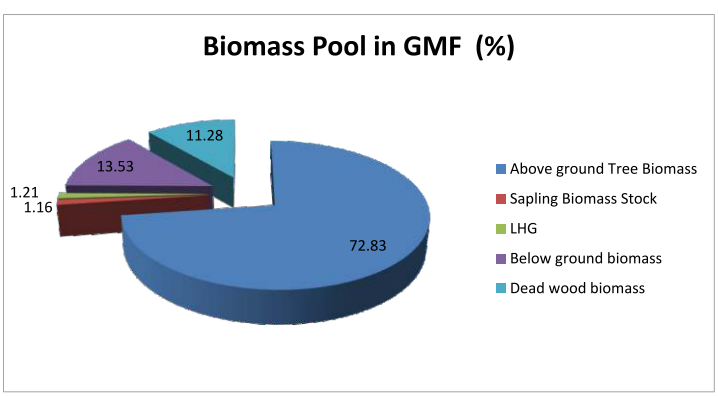

Figure 9: Biomass pool in GMF

The figure 9 shows total biomass pool in GMF. The 72.83 % of the total biomass is stocked in the above ground tree biomass and only 1.21 % biomass is stocked in the LHG.

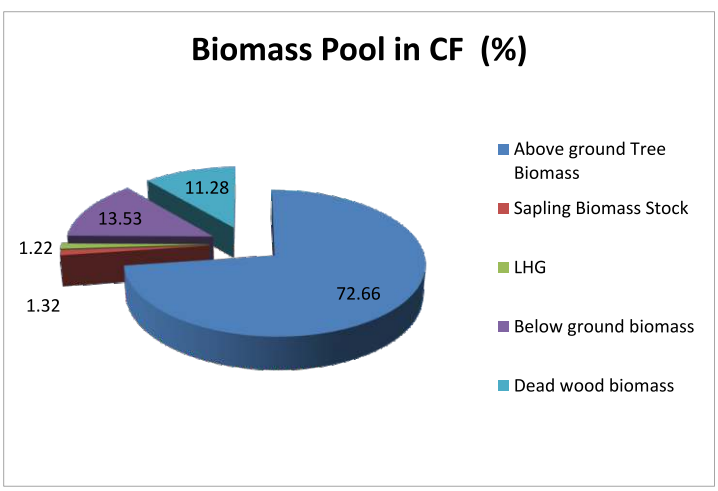

Figure 10: Biomass pool in CF

The figure 10 shows the total biomass pool in CF. The 72.66 % of the total biomass is stocked in the above ground tree biomass and only 1.22 % biomass is stocked in the LHG.

4. Discussion

Aboveground and belowground biomass and carbon of Trees are the plants that can develop a large biomass capturing a large amount of carbon over a growth cycle of many decades. So, forest can capture and retain a large volume of carbon for a long period of time.

The carbon sink and storage in the forest are dependent with each other. Many trees in the studied forests had the DBH of less than 30 cm. The biomass of Government managed forest is comparablewithother similar forests. [24-27] had carried out the study in *Betula utilis* forest in KCAP and found out that the tree biomass was 166.81 t/ha. In this study, the tree biomass is 168.34ton/ha. It seems that the tree biomass of the government managed forest is almost similar with the Betula utilis forest. [28-29] estimated 168.5 t/ha and 146.2 t/ha carbon stock in Jarneldhara CF and LipindeviThulopakho CF of Palpa but in this study area soil organic carbon of the Selang Manju Community forest is 271.95 ton/ha carbon it is quite higher because of the higher amount of the soil carbon in the study area.

Soil, being the largest carbon reservoir of the terrestrial carbon cycle, about three times more carbon is contained in soil than in the world's vegetation and soils hold double the amount of carbon that is present in the atmosphere [7-8; 30-38]. In my study area soil organic carbon is 173.94 ton per/ha in the government managed forest and 171.94 in communitymanaged forest. The total carbon content in the plant is only 100.64 ton/ha in the Community forest and only 108.63 ton per ha in the Government managed forest.So the result shows that 63.48 % of the total carbon is stored in the soil but only 36.51% of the carbon is stored in the plant in CF. In case of Government managed forest 61.55% of the total carbon is stored in the soil but only 38.44% carbon is stored in the plant. Similarly, [39] studied in two different forests and concluded that the soil carbon value is significantly higher than the biomass carbon stock. The soil carbon composition was 55% in Shorea Robusta forest and it was 74% in SchimaCastanopsis forest.

The average carbon stock in Community forestandGovernment managed forest was 273.98 tonC/ha and 282.57 tonC/ha respectively. The values of carbon stock of this study are higherthan the values obtained by ICIMOD, ANSAB and FECOFUN [9], inShorearobusta mixed sub- tropical hill deciduous forest in Ludikhola of Gorkhawas (165.91 tC/ha to 216.16tC/ha). It is because of the higher amount of organic matter in the forest floor, and most of the forest is virgin.Similarly, the C-stock densities estimated by different studies were different. Baraletal.[12] have calculated the Total Aboveground carbon stock of Pine forest 38.70 tC/ha only.

Total above ground carbon stock of Government managed forest was found to be 92.53 ton/ha FAO [18] but in my study area total above ground carbon stock of Government managed forest was found to be 93.93 ton/ha. It is because in Government managed forest of my study area old trees were present in more numbers. Total above ground carbon stock of community forest was found to be 92.53 ton/ha FAO[18] whereas in my study area total above ground carbon stock of community forest was found to be 86.5 ton/ha which is lower because of the application of the community forest management by the Community forest user group. An actively managed community forest in Kailali district has total carbon stock 139.96 ton/ha [34] but community forest in my study area has 86.5 ton/ha which is relatively less that may be due to presence of smaller sized tree in the community forest where my study was conducted.

FAO[18] reported that Government managed forest has 196.88 t/ha biomass. But in my study area, it is 231.15 t/ha because the government managed forest is not managed well large sized trees of greater diameter and height. Community forest has 196.88 ton/ha biomass FAO[18] whereas in my study area it was found to be 212.88 ton/ha which is almost similar.

Mishra [32] had found the biomass carbon of the Chapako community forest, Kathmandu is 119.742 t/ha. Out of which, aboveground biomass carbon and belowground biomass carbon were found to be 106.75 t/ha and 12.995 t/ha respectively. Mishra [32] estimated 32.29 t/ha soil organic carbon in the study area. Result of Mishra [32] showed that the soil organic carbon is decreasing with depth. She calculated total CO_2 stored in that forest is 557.465 t/ha. In this study area we found the biomass carbon 100.04 ton/ha.of which, aboveground biomass carbon and belowground biomass carbon were found to be 86.5 t/ha and 13.54 t/ha respectively.

Total above ground tree biomass of Government managed forest was found to be higher with 168.34 ton/ha than community forest with 154.67 ton/ha. Total above ground LHG biomass of community forest was lower with 2.59 ton/ha than Government managed forest with 2.79 ton/ha.

The dead wood biomass of Government managed forest was found to be higher with 26.07 ton/ha than community forest with 24.01. The root biomass of Government managed forest was found to be higher with 31.28 ton/ha than community forest with 28.81. Tree carbon stock in Government Managed Forest was found to be higher with 79.12 ton/ha than CF with 72.69 ton/ha. Tree carbon stock of Government managed forest is very high it's because in National forest there were lots of old trees which have carbon storage but they do not have sequestrating capacity anymore.LHG carbon was found to be higher 1.31 ton/ha in government managed forest than CF with 1.22 ton/ha. Dead wood carbon stock in Government Managed Forest was found to be higher with 12.25 ton/ha than CF with 11.28 ton/ha. The root Carbon of Government managed forest was found to be higher with 14.70 ton/ha than community forest with 13.54. The soil organic Carbon was found to be 171.94 ton/ha in Community Forest which is lower than government managed forest with 173.94 ton/ha. Total Biomass stock of Government Managed forest was found to be higher with 231.15 ton/ha thanCommunity forest with 212.88 ton/haincluding the above ground biomass, below ground biomass and dead wood biomass [35-42].

Total carbon stock of Government Managed forest was found to be higher with 282.57 ton/ha thanCommunity forest with 271.95 ton/ha including the soil carbon stock 10 cm below the ground level. The analysis of the data shows that community forest management should be encouraged to enhance the more carbon storage in the forest.

5. Conclusion

Total above ground tree biomass of Government managed forest was found to be highest with 168.34 ton/ha (From the analysis from the sample data, maximum tree biomass is 185.23 and minimum tree biomass is 145.23 ton/ha.) followed by community forest with 154.67 ton/ha. (From the analysis from the sample data, maximum tree biomass is 167.89 and minimum tree biomass is 129.54 ton/ha.) The standard deviation of the Above ground tree biomass in Government managed forest is 20.24 and the Community managed forest is 20.07.Total above ground sapling biomass of Community Forest was found to be highest with 2.80 ton/ha (From the analysis from the sample data, maximum sapling biomass is 3.30 ton/ha and minimum sapling biomass is 1.1 ton/ha) and Government Managed Forest is 2.67 ton/ha. (From the analysis from the sample data, maximum sapling biomass is 2.91 ton/ha and minimum sapling biomass is 0.9 ton/ha).

The standard deviation of the Above ground Sapling biomass in Government managed forest is 1.26 and the Community managed forest is 1.25.Total above ground LHG biomass of community forest with 2.59 ton/ha (From the analysis from the sample data, maximum LHG biomass is 3.10 ton/ha and minimum LHG biomass is 1.9 ton/ha.) whereas the above ground LHG biomass of Government managed forest was found to be 2.79 ton/ha. (From the analysis from the sample data, maximum LHG biomass is 3.8 ton/ha and minimum LHG biomass is 2.2 ton/ha.)The standard deviation of the Above ground LHG biomass in Government managed forest is 0.82 and the Community managed forest is 0.61.Dead wood biomass. (15% of the above ground biomass, Oli and Shrestha, Journal of Forest and Livelihood 8(1) Feb 2009). The dead wood biomass of Government managed forest was found to be highest with 26.07 ton/ha (From the analysis from the sample data, maximum Dead wood biomass is 28.79 ton/ha and minimum dead wood biomass is 22.25 ton/ha.) followed by community forest with 24.01. (From the analysis from the sample data, maximum dead wood biomass is 26.14 ton/ha and minimum dead wood biomass is 19.88 ton/ha.)The standard deviation of the Above ground Dead wood biomass in Government managed forest is 3.32 and the Community managed forest is 3.29.

Total above ground biomass of community forest with 160.06 ton/ha (From the analysis of the sample data, maximum total above ground biomass is 200.43 ton/ha and minimum above ground biomass is 152.42 ton/ha.) whereas the above ground biomass of Government managed forest was found to be 173.8 ton/ha. (From the analysis of the sample data, maximum total above ground biomass is 220.73 ton/ha and minimum above ground biomass is 170.58 ton/ha.) The standard deviation of the total above ground biomass in Government managed forest is 33.26 and the Community managed forest is 29.05.

The Below ground biomass consist of Root biomass (18% of the above ground biomass, from the analysis of the literature) The root biomass of Government managed forest was found to be highest with 31.28 ton/ha (From the analysis of the sample data, maximum total below ground biomass is 34.54 ton/ha and minimum below ground biomass is 26.69 ton/ha.) followed by community forest with 28.81. (From the analysis of the sample data, maximum total below ground biomass is 31.37 ton/ha and minimum below ground biomass is 23.85 ton/ha.)The standard deviation of the below ground root biomass in Government managed forest is 3.98 and the Community managed forest is 3.95.

Total Biomass stock of Government Managed forest was found to be highest with 231.15 ton/ha (From the analysis of the sample data, maximum total biomass is 255.27 ton/ha and minimum biomass is 197.27 ton/ha.) followed by Community forest with 212.88 ton/ha (From the analysis of the sample data, maximum total biomass is 231.8 ton/ha and minimum biomass is 176.27 ton/ha.) including the above ground biomass, below ground biomass and dead wood biomass. The standard deviation of the total biomass in Government managed forest is 29.41 and the Community managed forest is 29.14.

The table 1 shows the total biomass stock in the different forest types. The Above ground tree biomass contains the 154.67 ton/ha which is highest then the other categories and the LHG biomass stock is 2.59 ton/ha which is lowest among the categories in the community forest similarly in the Government managed forest above ground tree biomass contains the 168.34 ton/ha which is highest then the other categories and the LHG biomass stock is 2.79 ton/ha which is lowest.

The figure 9 shows total biomass pool in GMF. The 72.83 % of the total biomass is stocked in the above ground tree biomass and only 1.21 % biomass is stocked in the LHG. The figure 10shows the total biomass pool in CF. The 72.66 % of the total biomass is stocked in the above ground tree biomass and only 1.22 % biomass is stocked in the LHG.

6. Recommendations

The following recommendation has been made based on the study.

- **Expand research coverage:** Further studies on forest carbon stock and sequestration should be conducted across Sindhupalchok District and other regions of Nepal, representing different physiographic zones, forest conditions, and including both community-managed and government-managed forests to generate more generalized and representative results.
- **Strengthen forest management and monitoring:** Regular and systematic forest carbon inventories should be undertaken to improve forest condition, enhance carbon storage, and support sustainable forest management, with particular emphasis on promoting effective community forest management practices.
- **Support climate policy and carbon accounting:** In line with emerging climate policies such as REDD+, precise and accurate forest carbon assessments are essential to support carbon sequestration incentives, ensure reliable carbon accounting, and recognize the significant carbon reservoir potential of government-managed forests.

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Authors Contribution

D.H. and Y.H. designed the research plan, collected the required data, analyzed the data, prepared the manuscript and reviewed for final submission.

Declaration of Conflict of Interest

The authors declare that there is no conflict of interest with present publication.

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