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An assessment of Carbon stock variation in Chure area of Arghakhanchi District, Nepal (A Case study from Different CFs of Sitganga Municipality)

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Abstract

This study aims to assess carbon stock in different community forests of chure region. More importantly, it aims to compare carbon stock in three altitudinal zones of chure region. Four community forests namely Shree Banganga CF, Shree Sindhure CF, Shree Bhasme CF, Shree Bagar-Tilken CF were taken. The four CFs were equally divided into three strata each having 35 no of sample plots. Stratified random samplings with 1% SI was applied and total 105 nested plots for tree and sapling and LHGs having size 500, 100 and 1 m2 respectively were established altogether. The Chave et al. equation as in(ICIMOD WP,2016) was used to calculate the biomass and it was converted into carbon by multiplying with 0.47.

The per ha carbon stock in Banganga CF, Shree Sindhure CF, Shree Bhasme CF and Shree Bagar-Tilken CF was found to be 84.254 tons/ha, 86.90 tons/ha, 82.468 tons/ha and 85.575 tons/ha respectively. The highest quantity of carbon stock was found in Shree Sindhure CF followed by Shree Bagar- Tlken CF, Shree Banganga CF and lowest in Shree Bhasme CF.

The per ha carbon stock in lower altitude, middle altitude and upper altitude was found to be 84.254 tons/ha, 88.334 tons/ha and 81.99 tons/ha respectively. The highest quantity of carbon stock was found in middle altitude followed by lower altitude and lowest in the upper altitude. The difference in carbon stock between three altitudes was due to the different carbon sequestration potential of different species and also the ability of carbon sequestration varies according to the site, time and management intervention applied.

The total carbon stock and tree carbon stock showed weak negative relationship with altitude (R=-0.240; P=0.14) and (R=-0.238; P=0.14) respectively. The sapling showed positive relation with carbon stock (R=0.558; P=0.00) whereas the LHGs showed no relation at all with the altitude. The p-value (0.892) was found to be greater than the level of significance (0.05), thus the null hypothesis was retained and it was concluded that there was no significant difference in above ground carbon stock between lower, middle and upper altitudinal zones.

Keywords: Biomass, Carbon stock, Chure, altitudinal gradient

Introduction

Forests play an important role in the global carbon cycle as forest vegetation and soil can sequester the atmospheric carbon in the form of biomass and soil organic carbons (Ranjitkar, 2010). Forest plays a great role to absorb carbon dioxide (CO2) present in the air and store in its floral parts and the soil. The amount it sinks varies according to the time, type of vegetation, geographical area, and the management strategy applied on it (K.C,2019).

Forests and trees make vital contributions both to people and the planet, bolstering livelihoods, providing clean air and water, conserving biodiversity and responding to climate change. Forests act as a source of food, medicine and fuel for more than a billion people. In addition to helping to respond to climate change and protect soils and water, forests hold more than three-quarters of the world's terrestrial biodiversity, provide many products and services that contribute to socio-economic development, and are particularly important for hundreds of millions of people in rural areas, including many of the world's poorest (FAO, 2018).

The carbon sequestered or stored on the forest trees are mostly referred to as the biomass of the tree or forest. The Intergovernmental Panel on Climate Change identified five carbon pools of the terrestrial ecosystem involving biomass, namely the aboveground biomass, below-ground biomass, litter, woody debris and soil organic matter. Among all the carbon pools, the above-ground biomass constitutes the major portion of the carbon pool (T. Vashum, 2012). Forests sequester and store more carbon than any other terrestrial ecosystem and are an important natural 'brake' on climate change. When forests are cleared or degraded, their stored carbon is released into the atmosphere as carbon dioxide (CO2) (Gibbs et al., 2007). Plants store carbon for as long as they live, in terms of live biomass.

Global warming and climate change are perhaps the m ost pressing global issues these days.

Recent years have witnessed growing concern about th e accumulation of GHGs in the earth's atmosphere, which is significantly raising the global temperature (Oli & Shrestha, 2009).Anthropogenic activities released greenhouse gases such as carbon dioxide, nitrogen dioxide, methane, ozone, fluorocarbons, water vapour, sulphur dioxide, into the atmosphere. Among the gases, carbon dioxide is the main influencing gas for global warming (La, 2015).

Burden of deforestation and forest degradation is still very much challenging the living beings on Earth due to the increased production of greenhouse gases (GHGs) especially CO_2 (Mandal et al., 2016). The Global Forest Resources Assessment (FRA), coordinated by FAO, found that the world's forest area decreased from 31.6 percent of the global land area to 30.6 percent between 1990 and 2015, but that the pace of loss has slowed in recent years.

The overall deforestation rate of Nepal is currently 1.7 %, which is well above the Asian average (1%) and the global average (1.3%) (Chand, 2018).

Globally,deforestation results in the annual loss of 13 million ha of forests (Dhital, 2009). Nepal is one of the most vulnerable countries to climate change in the world. The data trend from 1975 to 2005 shows that the mean annual temperature has been increasing by 0.06 °C while the mean rainfall has been decreasing by 3.7 mm (3.2%) per month per decade (Chand, 2018).

Carbon sequestration is the process of removing additional carbon from the atmosphere and depositing it in other reservoir principally through changes in land use (Mandal & Laake, 2005). Carbon sequestration is one of the most important environmental issue of this century and is an extensively researched topic in the recent past (Jaiswal et al., 2014). Carbon sequestration through forestry has the potential to play a significant role in ameliorating global environmental problems such as atmospheric accumulation of GHG's and climate change (Girma et al., 2014). Trees act as a sink for CO2 by fixing carbon during photosynthesis and storing excess carbon as biomass (Jana et al., 2009).

Research Methodology

Study area

The study area is located in south of province no.5 of Arghakhanchi district. This district is located in the middle physiographical zone of Nepal and covers an area of 1193km² and has population of 197,632 according to 2011. It has altitude 305m to 2515m from sea level. 68% of the district is difficult mahabharatlekter rain 31% is covered by churia and 1% makes high mountain and terai. Its headquarter lies on Sandhikharka and it is surrounded by Palpain the east, Gulmi in the north, Kapilbastu in the south and Pyuthan in the east. Out of the total area, 40% of the area is forested. The GPS coordinates for Arghakhanchi are 28000'1.80''N latitude.

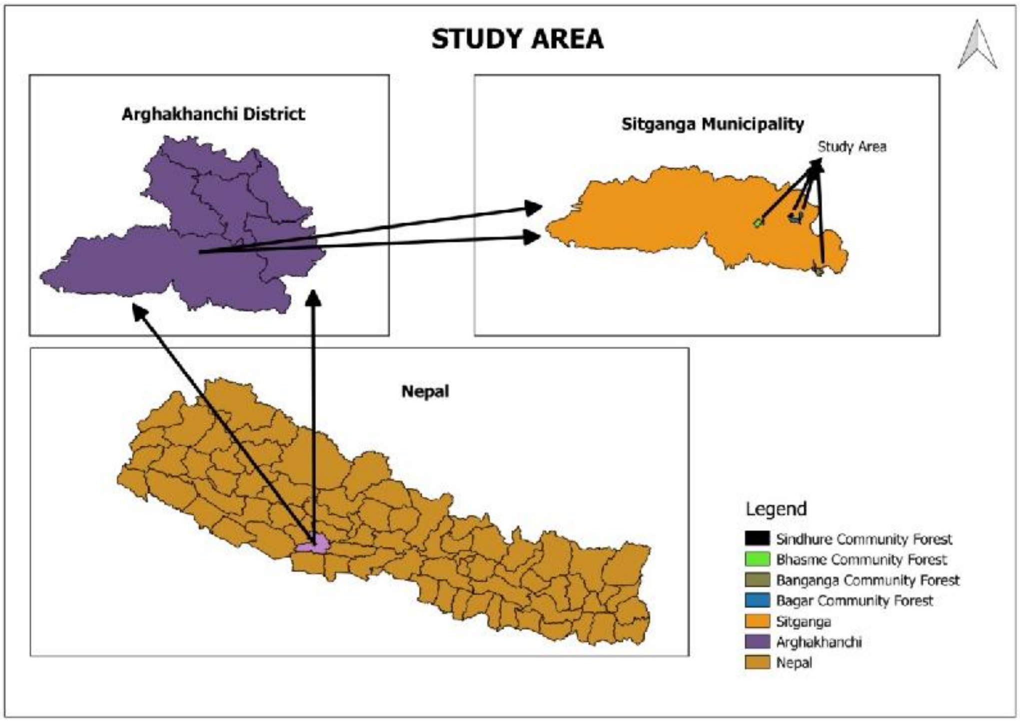


Figure 1: Map of study area

Physiography

Arghakhanchi district lies between 305m to 2515 m above mean sea level. The district can be broadly divided into two physiographic regions i.e. 68%Mahabharat hills and 32%Churia hills.

Geology and soil

Because of the topological structure, the Churia hills made mostly of soft lime stones and the Mahabharat region made of Phyllite, Schist, Quartzite, limestone etc.

Climate and season

Climatic variation in the district ranges from tropical to temperate. Tropical and subtropical climate exists in the southern part of the district whereas the temperate predominates the northern part. The district can be divided into three seasons: Hot, rainy and cold season. Hot season exists between March to June with the temperature up to 40°C. This season is the fire occurring season. Monsoon i.e. rainy season starts from July to September. The average rainfall in the district is 2,200 mm. Cold season exists between December to February with the temperature decreases up to 6.5°C.

Climate Zone	Elevation range	% of area
Lower Tropical	Below 300 meters	0.2%
Upper Tropical	300 to 1000 meters	50.5%
Subtropical	1000 to 2000 meters	49.1%
Temperate	2,000 to 3,000 meters	0.2%

("Arghakhanchi District," 2020)

Description of CFs

Table 1: Description of CFs

SN	Name of CF	Address	Area	Elevation	Major Species
1	Banganga CF	Sitganga-14, Bikram	176 ha	150m-400m	*Shorea robusta, Termanalia tomentosa, Anogeissus latifolia*
2	Shree Bhasme CF	Sitganga-13, Rikot	124.84 ha	440m-924m	*Shorea robusta, Termanalia tomentosa, Syzygium cumini, Rhus wallichi, Schima wallichi*
3	Shree BagarTilken CF	Sitganga-8	186.3 ha	550m-890m	*Shorea robusta, Termanalia tomentosa, Pinus roxburghii, Syzygium cumini, Rhus wallichi,*
4	Shree Sindhure CF	Sitganga- 1, Mandre	39.7 ha	850m-970m	*Shorea robusta, Termanalia tomentosa, Schima wallichi*

Data collection

Data collection techniques

Primary and secondary data were collected and used in this research.

Primary data: Primary data were collected from field observation, inventory and direct measurement, group discussions and laboratory analysis.

Secondary data: Secondary data and information were collected from internet surfing, books, reports, journals and community forest operational plan in order to meet the research objectives.

Sampling procedure:

Firstly, the entire boundary of CF was identified. The boundary survey was conducted using GPS. GPS co-ordinates were marked in the instrument as well as recorded in the field book. Later they were transferred/entered into Excel sheet. The map was prepared using Arc GIS and the area of CF was estimated.

The stratified random sampling with 1% sampling intensity was applied for the carbon inventory. Circular plot were applied for the study because of its easiness to layout especially in sloping terrain sand also to reduce the edge effect problem that normally occurs in rectangular plots. Following formulas were applied to determine the sample size and no of sample plots.

Sample size= Total area of the forest* sampling intensity (%)

Total no of plots= sample size/plot size

Sample plot layout in the field

A circular plot of 500 m2 with a 12.82 m radius was set up to measure the trees and poles(>5cm), while a nested circular plot of 100 m2, with a 5.64 m radius, was established for sapling measurement(1cm to 5cm).Likewise, a circular plot with a 1 m radius was used to count regeneration/seedlings(<1cm) and another plot of 0.56 m radius was set up to collect leaf litters, dead wood, debris, herbs and grasses. 105 sample plots were randomly overlaid to carry out the sampling in the field.

Data generation

Above ground tree:

The diameter at breast height (DBH) of trees standing at least a 1.3 m, and the height of individual trees greater than or equal to 5 cm DBH were measured in circular plots (each 500 m² in area) with radius 12.62m. The DBH and height were measured using a diameter tape and clinometers respectively. Identification of species was done with the help of local resource persons.

Above ground sapling

Saplings with a diameter >1 cm to <5 cm were measured in a nested sub-plot with a 5.64 m radius (each 100m²).

Leaf litter, Herbs and Grasses

All litter (dead leaves, twigs, etc.) and live components (herbs and grass) on the forest floor were collected in a destructive manner from a nested sub-plot of 0.56 m radius. The fresh weight of each item was recorded within 0.1 g precision and later transported to the laboratory for calculating oven dry weight/mass

Seedling regeneration

The status of forest regeneration was evaluated within a nested plot of 1 m radius. Seedlings with <1 m height were identified, and recorded in a field book.

Data analysis

The above ground biomass includes the above ground tree biomass (AGTB), above ground sapling biomass (AGSB) and leaf litter, herbs &grasses (LHG).

Above ground tree biomass (AGTB)

The equation developed by (Chaveetal.,2005) was applied to calculate the above ground tree biomass as in (ICIMOD WP,2016).

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

Where,
AGTB=above ground tree biomass (kg)
ρ = dry wood density (gm/cm3)
D=tree diameter at breast height (cm)
H=tree height (m)

After taking the sum of all the individual weight sin kg of a sampling plot and dividing it by the area of a sampling plot (m^2), the tree biomass stock was l be attained in kg/m2.The value was converted to t/ha by using unitary method.

Above ground sapling biomass (AGSB)

A national allometric biomass equation developed by the Department of Forest Research and Survey and the Department of Forests', Tree Improvement and Silviculture Component(Tamrakar, 2000) will be applied to determine the AGSB as in(ICIMOD WP,2016).

The following regression model was used for the calculation of sapling biomass:

$$Ln(AGSB) = a + bln\ (D)$$

Where,
Ln=Natural log; [dimensionless]
AGSB=Aboveground Sapling Biomass; [kg]
A=Intercep to fallometric relationship for saplings;[dimensionless]
B=Slope allometric relationship for saplings; [dimensionless]
D=Over bark diameter at breast height (measuredat1.3maboveground); [cm]

Litter, Herbs and Grass Biomass (LHGB)

As in (ICIMOD WP,2016), following formula was used to determine the Litter, Herbs and Grass Biomass,

LHGB=W field/A*W subsample DRY/W subsample wet× 1/10000

Where,
LHGB =Biomass of seedling, sapling, Litter, Herbs, and Grasses [t/ha]
W field=Weight of the fresh field sample of Leaf Litter, Herbs, and Grasses, destructively sampled within an area of size A; [gm]
A=Size of the area in which seedling, sapling, litter, Herbs, and Grasses will be collected;
W subsample, Dry =Weight of the oven-dry sub-sample of Seedling, Leaf Litter, Herbs, and Grasses to be taken to the laboratory to determine moisture content;[gm]
W SubSample, Wet= Weight of the fresh sub-sample of Leaf Litter, Herbs, and Grasses to be taken to the laboratory to determine moisture content;[gm]

Seedling/regeneration count

The status of forest regeneration was evaluated within a nested plot of 1 m radius. Seedlings with <1 m height will be identified, and recorded in a field book which provided idea about the regeneration status of forest.

Total above ground biomass

The total above ground biomass will be calculated as:

TAGB = AGTB+ AGSB+ LHGB

Where,

TAGB= Total Above Ground Biomass [t/ha]
AGTB= Above Ground Tree Biomass [t/ha]
AGSB= Above Ground Sapling Biomass [t/ha]
LHGB= Litter, Herbs and Grass Biomass [t/ha]

Carbon stock calculation

Biomass value will be converted into carbon stock upon multiplying by the default carbon fraction of 0.47 (IPCC, 2006) as in(ICIMOD WP,2016)

Total Carbon in Above Ground Biomass will be calculated by the formula:

C (TAGB) = C(AGTB)+ C(AGSB)+ C (LHGB)

Where,
C (AGTB) = Carbon in Above Ground Tree Biomass (tC/ha)
C (TAGB) = Total Carbon in Above Ground Biomass (tC/ha)
C (AGSB) = Carbon in Above Ground Sapling Biomass (tC/ha)
C (LHGB) = Carbon in Litter, Herbs and Grass Biomass (tC/ha)

Altitude wise carbon

The study area was equally divided into three altitudinal strata.

Lowe altitude (<400m)
Middle altitude (400-800m)
Upper altitude (>800m)

The above ground biomasses as well as the carbon stock in three altitudinal strata were calculated using the above formulas and the results were compared between 3 altitudinal zones.

Correlations between carbon stock and altitude

To find out the correlations between carbon stock and altitude, Spearman’s coefficient of correlation will be used which is as follows:

$$r_s = 1 - \frac{6\sum_{i=1}^{n} D_i^2}{n(n^2-1)}$$

Where,

(Dί = Xί-Yί) is the difference between the two ranks of each observation,

n = the number of observations.

Properties of Coefficient of Correlation

The value of the coefficient of correlation (r) always **lies between ±1**. Such as:

r=+1, perfect positive correlation
r=-1, perfect negative correlation
r=0, no correlation

By the help of correlation coefficient, the associations between the two variables i.e.
Carbon stock and altitude were identified.

Statistical analysis

The data were analyzed using Microsoft Excel and IBM SPSS statistics26. Before the test of hypothesis, the test for normality was carried out by non-parametric 1Sample K-S normality test to determine whether there is variation in total carbon stock along altitudinal zones or not, The data showed the non-normal distribution and the Kruskal-Wallis test was applied for hypothesis testing. Spearman’s coefficients of correlation were used to test the correlation between the carbon stock and altitudes. The level of significance used was α = 0.05.

Results

Biomass and carbon stock in different community forests

Table 2: Biomass and Carbon data from different CFs

Community Forest	Biomass (tons/ha)	Carbon stock (tons/ha)	Elevation(m)
Banganga CF	179.264(tons/ha)	84.254(tons/ha)	150-400
Shree Bhasme CF	175.464(tons/ha)	82. 468(tons/ha)	440-924
Shree Bagar- Tilken CF	182.075(tons/ha)	85.575(tons/ha)	550-890
Shree Sindhure CF	184.895(tons/ha)	86.90(tons/ha)	850-970

Biomass and carbon stock of Banganga CF

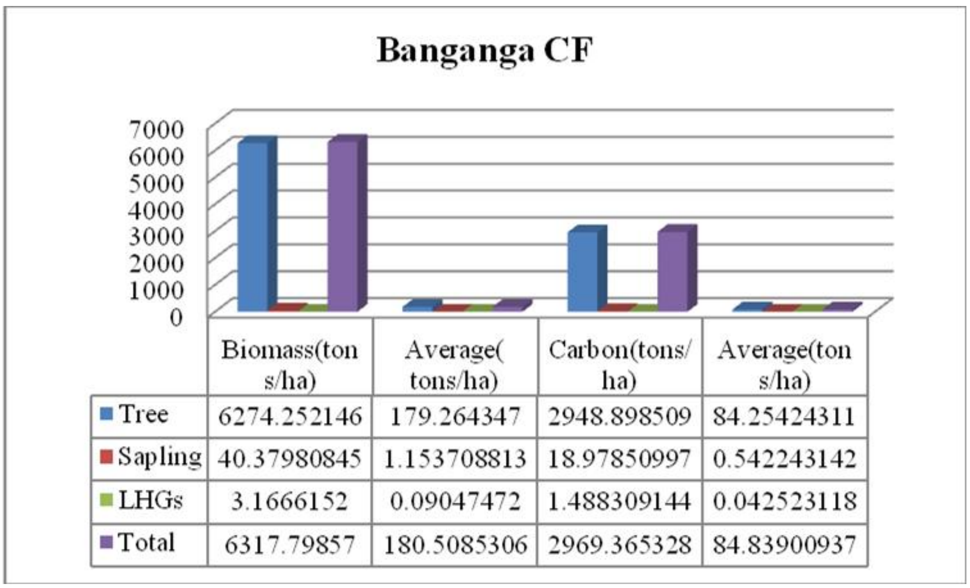
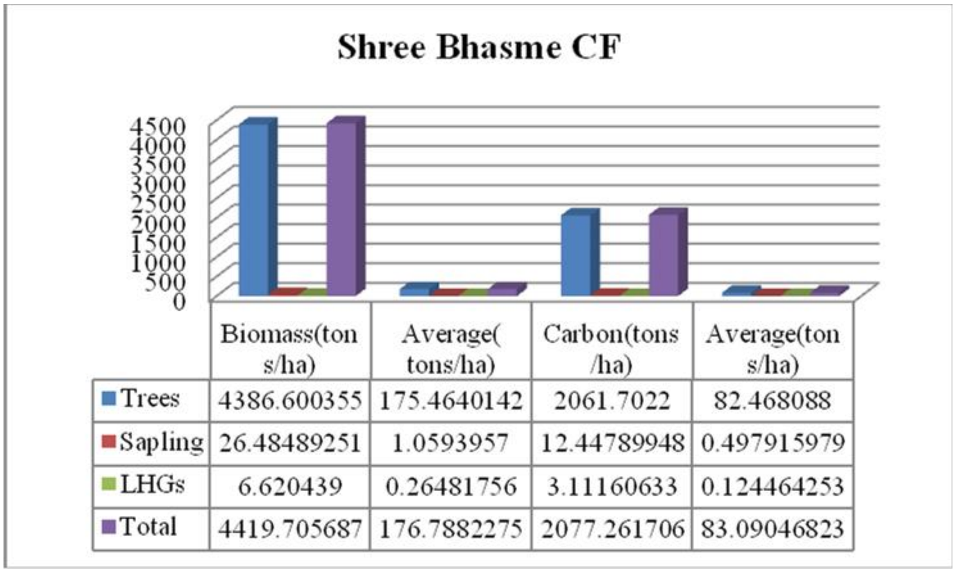


Figure 2: Above ground biomass and carbon

The average total above ground biomass of Banganga CF was found to be 180.509 tons/ha which includes tree biomass of 179.264 tons/ha, sapling biomass of 1.154tons/ha and LHGs biomass of 0.0905 tons/ha.
Likewise, the average total above ground carbon stock was found to be 84.839 tons/ha which includes tree carbon stock of 84.254 tons/ha, sapling carbon stock of 0.542 tons/ha and LHGs carbon stock of 0.043 tons/ha.

There was good regeneration of important species like *Shorea robusta*, *Termanalia tomentosa etc*. Other species like *Mallotus phillipensis*, *Lagostroemia parviflora*, *Rhus wallichi* etc were also regenerating well.

Biomass and carbon stock of Shree-Bhasme



	Biomass(tons/ha)	Average(tons/ha)	Carbon(tons/ha)	Average(tons/ha)
Trees	4386.600355	175.4640142	2061.7022	82.468088
Sapling	26.48489251	1.0593957	12.44789948	0.497915979
LHGs	6.620439	0.26481756	3.11160633	0.124464253
Total	4419.705687	176.7882275	2077.261706	83.09046823

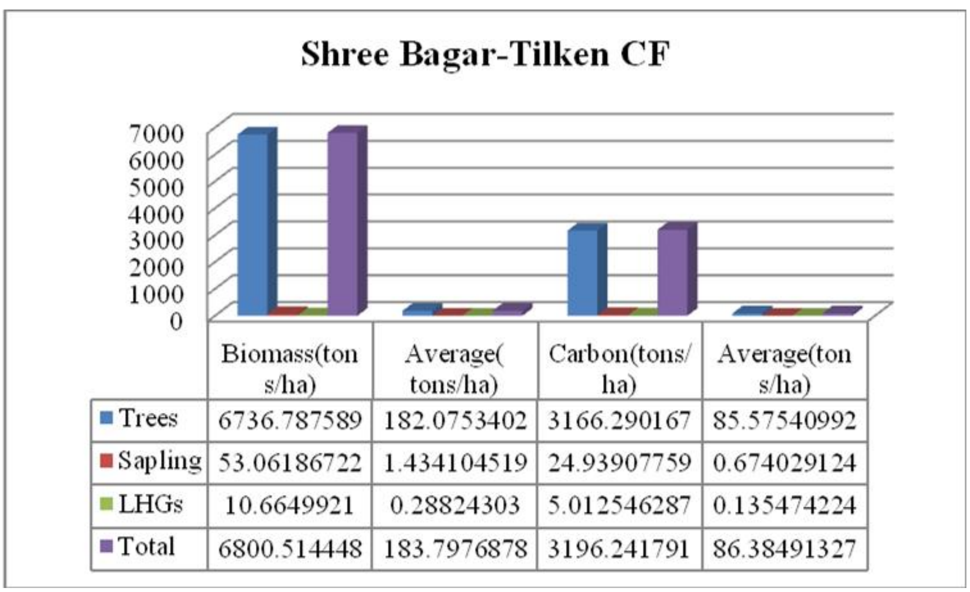
Figure 3: Above ground biomass and carbon

The average total above ground biomass of Shree-Bhasme CF was found to be 335.3995 tons/ha which includes tree biomass of 334.075 tons/ha, sapling biomass of 1.0594 tons/ha and LHGs biomass of 0.265 tons/ha.

Likewise, the average total above ground carbon stock was found to be 157.638 tons/ha which includes tree carbon stock of 157.0154 tons/ha, sapling carbon stock of 0.498 tons/ha and LHGs carbon stock of 0.0145 tons/ha.

Seedling of *Shorea robusta*, *Termanalia tomentosa* were found in higher quantity. Other species like *Rhus wallichi, Lagestroemia parviflora, Phyllanthus emblica, Schima wallichi* were also regenerating well.

Biomass and carbon stock of Shree Bagar-Tilken CF



	Biomass(tons/ha)	Average(tons/ha)	Carbon(tons/ha)	Average(tons/ha)
Trees	6736.787589	182.0753402	3166.290167	85.57540992
Sapling	53.06186722	1.434104519	24.93907759	0.674029124
LHGs	10.6649921	0.28824303	5.012546287	0.135474224
Total	6800.514448	183.7976878	3196.241791	86.38491327

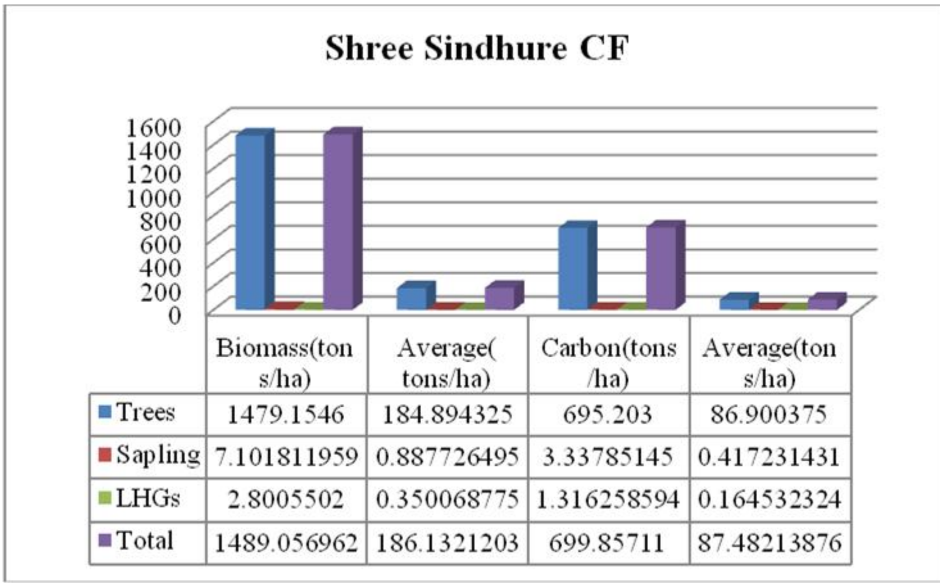
Figure 4: Above ground biomass and carbon

The average total above ground biomass of Shree Bagar- Tilken CF was found to be 183.798 tons/ha which includes tree biomass of 182.075 tons/ha, sapling biomass of 1.434 tons/ha and LHGs biomass of 0.288 tons/ha.

Likewise, the average total above ground carbon stock was found to be 86.3849 tons/ha which includes tree carbon stock of 85.575 tons/ha, sapling carbon stock of 0.6740 tons/ha and LHGs carbon stock of 0.01355 tons/ha.

Seedlings of *Shorea robusta*, *Termanalia tomentosa* were found in higher quantity. Other species like *Rhus wallichi*, *Lagestroemia parviflora*, *Castonopsis indica*, *Mallotus phillipinensis*, *Albizzia lebbeck*, *Schima wallichi*, *Syzigium cumini* were also regenerating well.

Biomass and carbon stock of Shree Sindhure CF



	Biomass(tons/ha)	Average(tons/ha)	Carbon(tons/ha)	Average(tons/ha)
Trees	1479.1546	184.894325	695.203	86.900375
Sapling	7.101811959	0.887726495	3.33785145	0.417231431
LHGs	2.8005502	0.350068775	1.316258594	0.164532324
Total	1489.056962	186.1321203	699.85711	87.48213876

Figure 5: Above ground biomass and carbon

The average total above ground biomass of Shree Sindhure CF was found to be 186.132 tons/ha which includes tree biomass of 184.894 tons/ha, sapling biomass of 0.888 tons/ha and LHGs biomass of 0.3501 tons/ha.

Likewise, the average total above ground carbon stock was found to be 87.482 tons/ha which includes tree carbon stock of 86.900 tons/ha, sapling carbon stock of 0.542 tons/ha and LHGs carbon stock of 0.165 tons/ha.

Seedlings of *Shorea robusta*, *Termanalia tomentosa* were found in higher quantity. Other species like *Rhus wallichi*, *Lagestroemia parviflora*, *Mallotus phillipinensis*, *Schima wallichi*, *Castonopsis tribuloides* were also regenerating well.

Carbon Stock Variation with altitude

LHGs biomass and carbon along altitudes

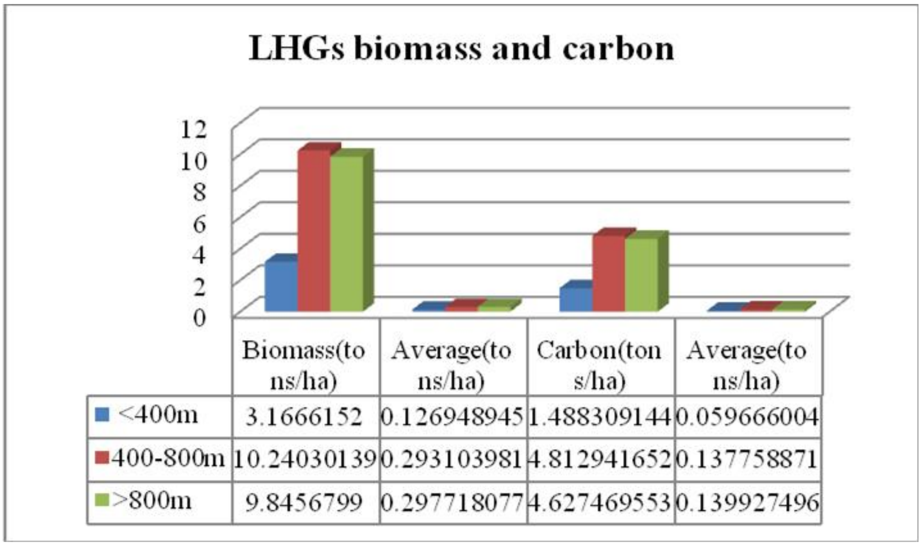


Figure 6: LHGs biomass and carbon

The average LHGs biomass of lower altitude was found to be 0.127 tons/ha, middle altitude was found to be 0.293 tons/ha and upper altitude was found to be 0.298 tons/ha. Upper altitude has the highest quantity of LHGs biomass followed by middle altitude and lower altitude respectively.

The average LHGs carbon of lower altitude was found to be 0.0597 tons/ha, middle altitude was found to be 0.1378 tons/ha and upper altitude was found to be 0.1399 tons/ha. Upper altitude has the highest quantity of LHGs carbon followed by middle altitude and lower altitude respectively.

Sapling biomass and carbon along altitudes

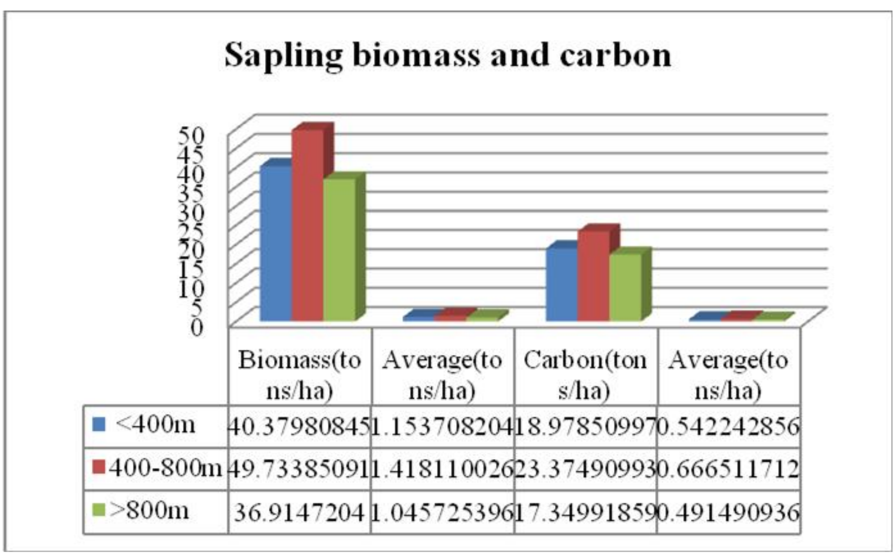


Figure 7: Sapling biomass and carbon

The average sapling biomass of lower altitude was found to be 1.1537 tons/ha, middle altitude was found to be 1.418 tons/ha and upper altitude was found to be 1.046 tons/ha. Middle altitude has the highest quantity of sapling biomass followed by lower altitude and upper altitude respectively.

The average sapling carbon of lower altitude was found to be 0.5422 tons/ha, middle altitude was found to be 0.667 tons/ha and upper altitude was found to be 0.4915 tons/ha. Middle altitude has the highest quantity of sapling carbon followed by lower altitude and upper altitude respectively.

Tree biomass and carbon along altitudes

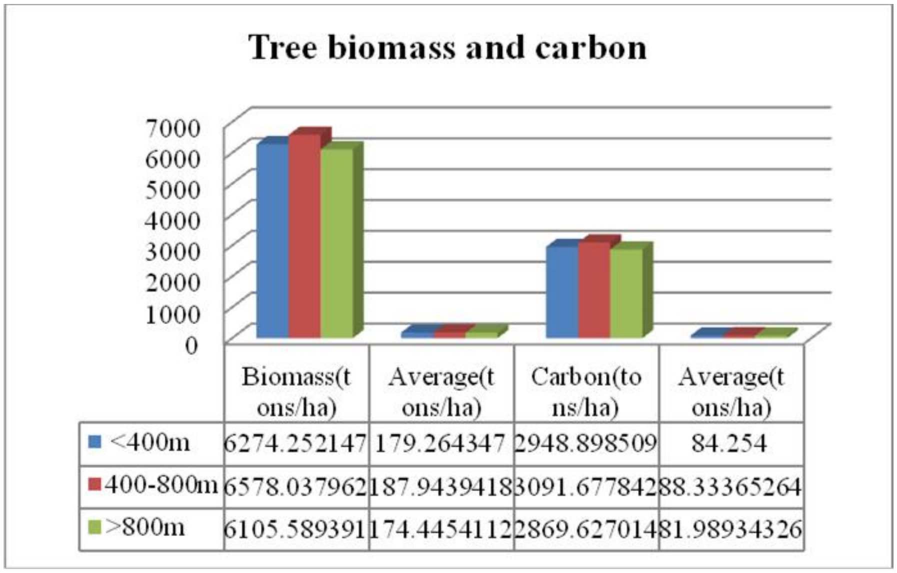


Figure 8: Tree biomass and carbon

The average tree biomass of lower altitude was found to be 179.264 tons/ha, middle altitude was found to be 187.944 tons/ha and upper altitude was found to be 174.445 tons/ha. Middle altitude has the highest quantity of tree biomass followed by lower altitude and upper altitude respectively.

The average tree carbon of lower altitude was found to be 84.254 tons/ha, middle altitude was found to be 88.334 tons/ha and upper altitude was found to be 81.989 tons/ha. Middle altitude has the highest quantity of tree carbon followed by lower altitude and upper altitude respectively.

Total above ground biomass and carbon stock along altitudes

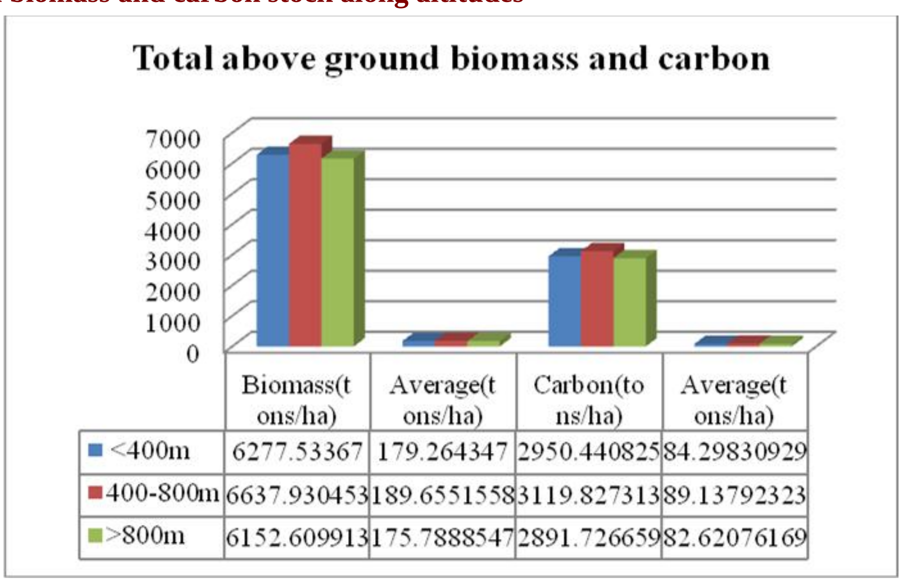


Figure 9: Total above ground biomass and carbon

The average above ground biomass of lower altitude was found to be 179.264 tons/ha, middle altitude was found to be 189.655 tons/ha and upper altitude was found to be 175.789 tons/ha. Middle altitude has the highest quantity of above ground biomass followed by lower altitude and upper altitude respectively.

The average above ground carbon of lower altitude was found to be 84.298 tons/ha, middle altitude was found to be 89.138 tons/ha and upper altitude was found to be 82.621 tons/ha. Middle altitude has the highest quantity of above ground carbon followed by lower altitude and upper altitude respectively.

Correlation of carbon stock with altitude

Correlation of LHGs carbon with altitude

Correlations- LHGs Carbon and Altitude

			Altitude	Carbon
Spearman's rho	Altitude	Correlation Coefficient	1.000	-.052
		Sig. (2-tailed)	.	.597
		N	105	105
	Carbon	Correlation Coefficient	-.052	1.000
		Sig. (2-tailed)	.597	.
		N	105	105

Figure 10: Correlation of LHGs carbon stock with altitude

The LHGs biomass showed no correlation with altitude. That means there is no any change in the LHGs carbon stock due to increase or decrease in altitude.

Correlation of sapling carbon stock with altitude

Correlations-Sapling Carbon and Altitude

			Altitude	Carbon
Spearman's rho	Altitude	Correlation Coefficient	1.000	.558**
		Sig. (2-tailed)	.	.000
		N	105	105
	Carbon	Correlation Coefficient	.558**	1.000
		Sig. (2-tailed)	.000	.
		N	105	105

**. Correlation is significant at the 0.05 level (2-tailed).

Figure11: Correlation of sapling carbon stock with altitude

The sapling carbon stock showed positive correlation with altitude (R= 0.558; P=0.000) at 0.05 level of significance. Thus, as the altitude increases the amount of sapling carbon also increases and vice versa.

Correlation of tree carbon stock with altitude

Correlations-Tree Carbon and Altitude

			Altitude	Carbon
Spearman's rho	Altitude	Correlation Coefficient	1.000	-.238*
		Sig. (2-tailed)	.	.014
		N	105	105
	Carbon	Correlation Coefficient	-.238*	1.000
		Sig. (2-tailed)	.014	.
		N	105	105

*. Correlation is significant at the 0.05 level (2-tailed).

Figure 12: Correlation of tree carbon stock with altitude

The tree carbon stock showed negative correlation with altitude (R= -0.238; P=0.014) at 0.05 level of significance. Thus, as the altitude increases the amount of tree carbon decreases and vice versa.

Correlation of total above ground carbon stock with altitude

Correlations- Total above ground carbon stock and Altitude

			Altitude	Carbon
Spearman's rho	Altitude	Correlation Coefficient	1.000	-.240*
		Sig. (2-tailed)	.	.014
		N	105	105
	Carbon	Correlation Coefficient	-.240*	1.000
		Sig. (2-tailed)	.014	.
		N	105	105

*. Correlation is significant at the 0.05 level (2-tailed).

Figure 13: Correlation of total above ground carbon stock and altitude

The total above ground carbon stock showed negative correlation with altitude (R= -0.240; P=0.014) at 0.05 level of significance. Thus, as the altitude increases the amount of total above ground carbon decreases and vice versa.

Statistical analysis of data set

Normality test

The data distribution of carbon stocks of sample plots of each altitude zone were tested for normal distribution. The Kolmogorov-Smirov and Sharpio-Wilk tests were applied for normality testing. The data showed the non -normal distribution. Later, the siginificance of carbon stock along three altitudinal zones was tested by using Kruskal-Wallis test.

Table 3: Hypothesis testing of carbon stocks

	Data- type	Test used	P-Value	Decision
LHGs	Non-normal	Kruskal-Wallis	0.892	Not-significant
Sapling	Non-normal	Kruskal-Wallis	0.74	Not-significant
Trees	Non-normal	Kruskal-Wallis	0.000	Not-significant

Kruskal Wallis was applied to test the variation of carbon stock among three altitudinal zones. The carbon stocks of different zones showed somehow different values. Thus test was applied to find whether there exist any significant differences or not.

Kruskal-Wallis test

H0: There is no significant difference in above ground carbon stock between lower, middle and upper altitudinal zones.

H1: There is significant difference in above ground carbon stock between lower, middle and upper altitudinal zones.

Test Statistics[a,b]

	Carbon
Chi-square	.228
Df	2
Asymp. Sig.	.892

a. Kruskal Wallis Test

b. Grouping Variable: Altitude

Figure 14: Kruskal-Wallis test

Critical value: The p value was 0.892 which was greater than the level of significance (α=0.05).

Decision: So the null hypothesis is accepted at 5% level of significance and it can be concluded that there was no significant difference in above ground carbon stock between lower, middle and upper altitudinal zones.

Discussion

Biomass and carbon stock in different CFs

The total above ground biomass was found to be in highest quantity in Shree Sindhure CF (184.895 tons/ha) followed by Shree Bagar-Tilken CF (182.075 tons/ha), Banganga CF (179.264 tons/ha) and Shree bhasme CF (175.464 tons/ha) respectively. Similarly, the above ground carbon in highest quantity was found in Shree Sindhure CF (86.90 tons/ha) followed by Shree Bagar-Tilken CF (85.575tons/ha), Banganga CF (84.254 tons/ha) and Shree Bhasme CF (82.468 tons/ha) respectively. The highest quantity of biomass and carbon in Shree Sindhure CF was due to the larger sized trees and dense vegetation. According to (Thapa, 2016), the total carbon stock in churia forest was found to be 160.65 tons/ha. Here, the contribution of tree component is equal to 84.73 tons/ha. The contribution of LHGs component is equal to 0.31 tons/ha. The slight difference in the above values might be due to the differences in species composition and tree density. The amount of carbon stock varies according to the time, type of vegetation, geographical area, and the management strategy applied on it (K.C,2019).

Biomass and carbon stock in three altitudinal zones

The highest amount of total above ground biomass and carbon was found at the middle altitude (400-800m), followed by lower altitude (<400m) and lowest at the higher altitude (>800m). The total above ground biomass at lower, middle and upper altitudes are 179.264 tons/ha, 187.94 tons/ha and 174.45 tons/ha respectively. Likewise, the total above ground carbon at lower, middle and upper altitudes are 84.254 tons/ha, 88.335 tons/ha and 81.99 tons/ha respectively.

In a study conducted by (Yohannes, 2015) , the highest amount of carbon stock was found in middle altitude followed by the lower altitude and lowest carbon stock was found in the upper altitude. . Rates of carbon fixation vary with forest age, species and site (Grierson et al., 1992)

The highest quantity of carbon stock in middle altitude was due to the larger sizes trees, maximum no of *Shorea robusta* and *Termanalia tomentosa* trees and their higher carbon sequestration potential than other species. The disturbance due to human and livestock was less in middle altitude and as compared to lower and upper altitudes which is also one of the reason for higher carbon stock in middle altitudinal zone.

Correlation of carbon stock and altitude

Table 4: Correlation of different carbon pools and altitude

Carbon pools	R-Value	P-value
LHGs	-0.52	0.597
Sapling	0.558	0.00
Tree	-0.238	0.14
Total	-0.240	0.14

*Correlation is significant at the 0.05 level (2-tailed)

The total carbon stock and tree carbon stock showed weak negative relationship with altitude (R=-0.240; P=0.14) and (R=-0.238; P=0.14) respectively. The sapling showed positive relation with carbon stock (R=0.558; P=0.00) whereas the LHGs showed no relation at all with the altitude. The study conducted by (Yohannes, 2015) found that altitude has inverse relation with aboveground biomass, belowground biomass, deadwood carbon and total carbon density. Altitude also has significant effect on all carbon pool except litter biomass and soil organic carbon. The degree of correlation of different carbon pools showed that the tree carbon and total carbon stock decreases as there is increase in altitude and vice versa, whereas the amount of sapling carbon goes on increasing with the altitude and vice versa. Also, there is no any effect in LHGs carbon stock due to increase or decrease in altitude.

Statistical analysis of data set

First of all, the test of normality of dataset was carried out to know whether the data is normally distributed or not. K-S test showed the non-normal distribution of the data. After that, the kruskal-wallis test was carried out to find out the variance of dataset among three altitudinal zones. The p-value (0.892) was greater than the level of significance (0.05), thus the null hypothesis was retained and it was found that there was no significant difference in above ground carbon stock between lower, middle and upper altitudinal zones.

Conclusion and Recommendation

Conclusion

- The per ha carbon stock in Banganga CF, Shree Sindhure CF, Shree Bhasme CF and Shree Bagar-Tilken CF was found to be 84.254 tons/ha, 86.90 tons/ha, 82.468 tons/ha and 85.575 tons/ha respectively.
- The highest quantity of carbon stock was found in Shree Sindhure CF followed by Shree Bagar- Tlken CF, Shree Banganga CF and lowest in Shree Bhasme CF.
- The highest stock of carbon in Shree Sindhure CF was due to larger sized trees and dense vegetation.
- The per ha carbon stock in lower altitude, middle altitude and upper altitude was found to be 84.254 tons/ha, 88.334 tons/ha and 81.99 tons/ha respectively.
- The highest quantity of carbon stock was found in middle altitude followed by lower altitude and lowest in the upper altitude.
- The difference in carbon stock between three altitudes was due to the different carbon sequestration potential of different species and also the ability of carbon sequestration varies according to the site, time and management intervention applied.
- The total carbon stock and tree carbon stock showed weak negative relationship with
- altitude (R=-0.240; P=0.14) and (R=-0.238; P=0.14) respectively. The sapling showed positive relation with carbon stock (R=0.558; P=0.00) whereas the LHGs showed no relation at all with the altitude.
- The p-value (0.892) > level of significance (0.05), thus the null hypothesis was retained and it was concluded that there was no significant difference in above ground carbon stock between lower, middle and upper altitudinal zones.

Recommendation

- The altitude plays a key role in determining the types of species found in an area which leads to the differences in the carbon stock. Thus, this kind of study should be given more importance to validate the result.
- It is recommended to apply various management operations to manage the forest effectively as it has enormous potential to sequester more carbon in comparison to un-managed forest.

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Declaration of Interest Statement:

Declaration

The piece of work entitled "**An assessment of Carbon stock variation in Chure area of Arghakhanchi District(A Case study from Different CFs of Sitganga Municipality)"** is our own work, except wherever acknowledged. We have not submitted it or any of its part to any other university for publication. There is no conflict of interest among authors for publication.

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