A | R | J
Amrit Research Journal December 2025, Vol. 6, Issue 1, 112-123
ISSN: 2738-9553
RESEARCH ARTICLE

Estimation of Carbon Stock and Carbon dioxide Equivalent (CO_2-e) Absorption of Needle Leaved Tree and Mixed Broadleaved Trees of Nilbarahi Community Forest of Madhyapurthimi, Bhaktapur

Lalbabu Lal Karn*[1] , *Dipesh Raj Pant*[2] , *Bijay Lal Pradhan*[3], *Vijay Kumar Jha*[4]

[1]*Department of Environmental Science, Amrit Campus, TU*

[2]*Department of Environmental Science, Tri-Chandra Multiple Campus, TU*

[3]*Department of Statistics, Amrit Campus, TU*

[4]*Department of Physics, Amrit Campus, TU*

**E-mail: bijay.jha@ac.tu.edu.np*

(Received: November 6, 2025, Received in revised form: November 30, 2025, Accepted: December 8, 2025, Available online: December 19, 2025)

DOI: https://doi.org/10.3126/arj.v6i1.87538

Highlights

- The Nilbarahi community forest's some part is naturally of mixed broad leaved trees and some part is planted trees of *Pinus roxburghii* (Chirpine)
- The SRS method was used to determine the carbon component of the forest to assess the amount of carbon stock and carbon dioxide equivalent (CO_2-e) absorption of needle leaved tree and the mixed broadleaved tree of the community forest
- The carbon (C) stock and carbon dioxide equivalent (Co_2-e) in the forest ecosystems of Nilbarahi which have been managed and conserved well by the community forest user groups could play an important role in carbon cycle and serve as significant carbon sink to reduce the burning issue of global warming

Abstract

The Nilbarahi Community Forest contains the needle leaved tree species Pinus roxburghii (Chir pine) and mixed broad leaved tree species such as Schima wallichii, Engelhardtia spicata, Eurya acuminate, Litsea monopetala and Alnus nepalensis. This community forest's some part is naturally of mixed broad leaved trees and some part is planted trees of Pinus roxburghii (Chirpine). The SRS method was used to determine the carbon component of the forest to assess the amount of carbon stock and carbon dioxide equivalent (CO_2-e) absorption of needle leaved tree and the mixed broadleaved tree of the community forest. The carbon stock of the forest was measured per hectare basis of the biomass contained by the trees. It is very essential to know the type of trees that can absorb much carbon component from the atmosphere through Photosynthesis and store it in their leaves, branches, stems, barks and in the roots. The much carbon retained by the trees would help to mitigate the climate change. The biomass of the trees was determined by the biomass regression model and then the carbon retained in them was obtained by converting the biomass stock of trees into carbon stock by using the IPCC default carbon fraction of 0.47. After then the CO_2-e absorption was calculated by multiplying one ton of carbon value to 3.67 tons of carbon dioxide equivalent (CO_2-e) which was expressed in metric tons. The total above ground tree biomass was found 188.70 ton/ha at site-3 of mixed broad leaved forest

*Corresponding author

seemed to be the highest biomass followed by the planted forest of Pinus roxburghii (Chir pine) at site-1 which had the biomass of 147.78 ton/ha. The carbon content of above ground tree biomass of the study area was also found to be 88.69 ton/ha followed by 69.45 ton/ha at site-3 and site-1 respectively. The study showed that the needle leaved trees (Pinus roxburghii) had low carbon stock than the natural mixed broadleaved trees in the Nilbarahi Community Forest. The CO_2-e was also found to be highest as 295.21MT in the mixed broad leaved trees than the needle leaved conifer trees of 231.18 MT at site-3 and site-1 respectively. The average carbon stock and average CO_2e was found to 72.41 t/ha and 241.03 MT in the Nilbarahi Community Forest. The biomass, carbon (C) stock and carbon dioxide equivalent (Co_2-e) in the forest ecosystems of Nilbarahi which have been managed and conserved well by the community forest user groups could play an important role in carbon cycle and serve as significant carbon sink to reduce the burning issue of global warming.

Keywords: *biomass, community forest, carbon stock, CO_2-e, climate change, global warming*

Introduction

The forest and tree resources provide a vast array of goods and services to human beings. Community forests (CFs) are generating environmental services such as carbon sequestration, hydrological services, biodiversity services and landscape beauty. Forests play an important role on earth for they are natural storehouses for biomass and carbon. Anthropogenic activities mainly for energy requirements, agriculture, industry, many other demands as well as increase in the human population are the main cause for forest degradation. Forest represents an important carbon store, estimated globally to contain 638 Gt of carbon of which 283 Gt carbon is present in biomass alone (GFR Assessment, 2005). The biomass stock present in forests determines the potential amount of carbon that can be added to the atmosphere, or alternatively sequestered on the land when forests are managed for meeting emission targets (Brown et al., 1999) . In terrestrial ecosystems, forests are the most productive among their biotic components. These productive characteristics of forests make them attractive for mitigation for climate change (Nabuurs et al., 2007).

Biomass and carbon (C) storage in forest ecosystems play dominant roles in global C cycle (Houghton, 2005) and serve as the most significant C sinks to reduce global warming (Schimel et al., 2001). This is largely due to their huge potential for sequestering carbon in vegetation and soil (Heimann & Reichstein, 2008) and interacts with atmospheric processes through the absorption and respiration of CO_2 (Brown & Schroeder, 1999). As an important C pool in the terrestrial ecosystems, forests store more C than any other terrestrial ecosystems (Heimann & Reichstein, 2008) and contain about 80% of all aboveground terrestrial C and 40% of soil C (Waring & Running, 1998).

A ton of carbon in trees is the result of the removal of 3.67 ton of carbon dioxide from the atmosphere (Hunt, 2009). The forest user groups have been contributing for ecological service to local and global level without incentives, it is required to recognize the contribution of community and also necessary to develop mechanism for appropriate incentives for them for conserving forest and tree resources.

The Government of Nepal has introduced a scheme of community forest development project to improve the degraded forest land and to re-establish the forests to increase biodiversity in the forest, fuel wood, fodder and timber as well as to sequester or conserve significant amounts of carbon in the forest land. The community forestry of Nepal is a more success story in terms of expansion on the forest cover area on the one hand and conservation of biodiversity on the other hand (Kanel, 2004). The classical view on bio diversity and human utilization has been found maximum species number in the unused sites (Clements, 1936). The growth of tropical pines in relation to the soil properties in Tamil Nadu showed the soil of sandy loam texture ideal for raising pine species and grow well under low fertility condition and moderately in an acidic soil environment (Bari & Prasad, 1987). The species diversity behaves inversely to the index of dominance that means high species diversity of trees indicates a low concentration of dominance (Odum, 1996). The natural and degraded forests have been classified on the basis of total biomass as poor (< 10 t/ha), fair site (10 – 20 t/ha) and good site (> 20t/ha) (Condori, 1985). In Nepal, Community forests have been recognized as one of the major sources of carbon sink. Carbon sequestration can be defined as the capture of atmospheric carbon dioxide into green plants, which is stored for long time (Watson et al., 2000). The natural storage of carbon dioxide by above ground tree biomass, understory vegetation and below ground parts (roots, and micro-organisms) is one of the effective techniques for mitigating the atmospheric carbon dioxide levels (Jina et al., 2008).

Atmospheric CO_2 is increasing day by day due to industrialization and is causing global warming, making difficult to sustain human life and to mitigate such phenomena is to expand biological sinks of atmospheric carbon in the forests (Climate Change, 2007).

Materials and Methods

Study Area

The study site is located in Madhyapur Thimi Municipality ward no.3. There is a famous temple inside the community forest called Nilbarahi. It has an altitude of 1375m with the longitude of 85^0 20'38'' N and latitude 27^0 40' 65''E. The relief of research site from the base (cultivated land) was found 55m heights. The area of Community Forest is 18.5 hectares from the map of Bhaktapur, Sheet No. 278506 B reprint 2003. The study site environment has fluvio-lacustrine environment (i.e. in old lacustrine environment where later on fluvial environment seemed dominant) and the characteristics of soil texture is found as sandy loam. The river Manohara flows from the North to the South. It is apparent that the Manohara River is the youngest river in the Kathmandu Valley because it always changes its flowing path direction from time to time. This study site has no big boulders and pebbles too which has led one of the major characteristics for selection of this place and the dominant sediment at this location has band of sand and clay alternations representing the various stages of fluvial cycle. Furthermore, the climate of the study area is found to be subtropical as the average annual rainfall of year 1981-2000 of Kathmandu was recorded as 1436.34 mm. The monsoon (rainfall) occurs almost from May to June and reaches peak in July (352.61mm) and secondly in the month of August (325.34mm) and the monsoon then gradually declines from September onwards. The maximum temperature was found to be recorded 29 ^oC in June and the minimum temperature was recorded as 2.4 ^{o}C in the month of January.

Sampling sites and sampling design

The four vegetation sites were chosen in the Nilbarahi Community Forest by stratified random sampling method in four directions for the determination of carbon components such as carbon stock and CO_2-e. The plot size of 30m x 20m was taken at each site for the quantitative analysis of trees of the Nilbarahi Community Forest. The descriptions of these four sites are as follows:

Site-1

This is the site of pine forest or Chir pine forest (*Pinus roxburghii)* in the south face. In this plot-1, the ground vegetation was seemed to be higher and better soil texture as compared with the plot-2.

Site-2

This was also the site of completely pine forest (*Pinus roxburghii*) in the east face and the ground vegetation was found to be sparse and less and the soil texture was sandy in compare to other plots.

Site-3

This was the site of natural forest in the west face. The ground vegetation was seemed more diverse because of lesser human interference and it was in a valley in the steep slope. In this site there was an intermittent stream.

Site-4

This was the site of natural forest in the north face and the ground vegetation was seemed to be the highest in compared to the other three plots wherein the soil was moist and clayey.

Methodology

The height of a tree was measured by the clinometer and the basal area of a tree was measured by the Diameter tape. The data then obtained was used to calculate the foliage biomass, branch biomass, stem biomass, above ground tree biomass, below ground tree biomass and total tree biomass of each plot.

Tree-stem, branch and foliage biomass estimation

The tree species stem, branch and foliage biomass were calculated as prescribed by the MFSC (2014) regression model (MFSC, 2014)). The dead trees were not taken into account for the estimation of branch and foliage biomass.

Regression Model, ln W = a + b x ln (DBH)

Where,

W = Green weight of tree components (biomass) in Kilogram

ln = Natural logarithm to the base 2.71828

DBH = Diameter at breast height in cm

a, and b = Coefficients of the model

Above Ground Tree biomass of each individual tree

Above Ground Tree Biomass (AGTB) = Stem biomass + Branch biomass + Foliage biomass

Below Ground Tree Biomass and Carbon estimation

The process for estimating below-ground tree biomass was calculated from the AGTB using a root-shoot ratio of 1:5 as recommended by Mac Dicken (Mac Dicken, 1997)). In other words, 20% of AGTB gives the biomass contains in the BGTB. Carbon of forest is considered to be a fraction of 47% of biomass, hence 0.47 was the conversion factor which was multiplied with the total tree biomass (Tewari & Karky, 2007). Later, this carbon storage in the trees can be used to find the amount of CO_2 equivalent removal from the atmosphere (Pearson, 2007). A ton of carbon in trees is the result of the removal of 3.67 ton of carbon dioxide from the atmosphere (Hunt, 2009).

Results and Discussion

Table 1. Tree component wise biomass of site-1 of Nilbarahi Community Forest

S.N.	Name of Trees	Dbh (cm)	Height (m)	Density (g/cm3)	Foliage Biomass (Kg)	Branch Biomass (Kg)	Stem Biomass (Kg)	AGTB (Kg)	BGTB (Kg)	TTB (Kg)
1	Pr	27.5	13	0.65	8.96	10.32	165.24	184.51	36.90	221.42
2	Pr	24.9	12	0.65	7.37	7.90	125.82	141.10	28.22	169.31
3	Pr	30.2	14	0.65	10.76	13.28	213.64	237.69	47.54	285.23
4	Pr	24.2	11	0.65	6.97	7.31	116.36	130.64	26.13	156.77
5	Pr	39.3	14	0.65	18.03	27.01	440.06	485.09	97.02	582.11
6	Pr	25.4	12	0.65	7.66	8.33	132.88	148.88	29.78	178.65
7	Pr	31.3	16	0.65	11.54	14.63	235.68	261.85	52.37	314.22
8	Pr	26.3	12	0.65	8.21	9.15	146.20	163.56	32.71	196.27
9	Pr	25.4	12	0.65	7.66	8.33	132.88	148.88	29.78	178.65
10	Pr	42.7	12	0.65	21.21	33.77	552.55	607.53	121.5	729.04
11	Pr	29.4	14	0.65	10.21	12.36	198.47	221.04	44.21	265.25
12	Pr	27.8	10	0.65	9.15	10.63	170.23	190.00	38.00	228.00
13	Pr	35.6	12	0.65	14.85	20.69	335.50	371.05	74.21	445.26
14	Pr	23.2	16	0.65	6.42	6.53	103.64	116.58	23.32	139.90
15	Pr	24.7	14	0.65	7.26	7.73	123.07	138.06	27.61	165.67
16	Pr	25.6	12	0.65	7.78	8.51	135.77	152.06	30.41	182.48
17	Pr	23.1	16	0.65	6.36	6.45	102.41	115.23	23.05	138.28
18	Pr	23.4	16	0.65	6.53	6.68	106.11	119.31	23.86	143.18
19	Pr	37.8	17	0.65	16.70	24.32	395.50	436.52	87.30	523.82
20	Pr	28.9	17	0.65	9.87	11.80	189.35	211.02	42.20	253.23
21	Pr	26.1	16	0.65	8.08	8.97	143.17	160.22	32.04	192.26

22	Pr	29.9	15	0.65	10.55	12.93	207.87	231.36	46.27	277.63
23	Pr	26.8	16	0.65	8.51	9.63	153.95	172.09	34.42	206.51
24	Pr	25.4	14	0.65	7.66	8.33	132.88	148.88	29.78	178.65
25	Pr	37.2	15	0.65	16.19	23.29	378.51	417.99	83.60	501.59
26	Pr	38.1	14	0.65	16.97	24.84	404.17	445.98	89.20	535.17
				Total	**271.48**	**343.75**	**5541.89**	**6157.1**	**1231.**	**7388.5**

Note: Pr = Pinus roxburghii

The site-1 contained altogether 26 trees of Chir pine (Pinus roxburghii). The DBH of the stem of Pinus roxburghii was found between 23.1 cm and 42.7 cm indicated as the adult forest site in the community forest. The total foliage, branch and stem biomass were 271.48 kg, 343.75 kg and 5541.89 kg respectively at site-1 indicated that higher the DBH, higher biomass was found as shown in individual trees (Table 1). The adult tree basal area shows a significant positive relationship with the adult tree carbon stock and the productivity has been proven by many small-scale research and observations in natural ecosystems (Midgley et al., 2010). The above ground tree biomass, below ground tree biomass and total tree biomass at site-1 were 6157.12 Kg, 1213.42 kg and 7388.55 kg respectively. The total tree biomass density of 123.14 t/ha at site-1 indicated the forest condition was good (Condori, 1985).

Table 2. Tree component wise biomass of site-2 of Nilbarahi Community Forest

S.No.	Name of Trees	Dbh (cm)	Height (m)	Density (g/cm3)	Foliage Biomass (Kg)	Branch Biomass (Kg)	Stem Biomass (Kg)	AGTB (Kg)	BGTB (Kg)	TTB (Kg)
	Pr	29.5	15	0.65	10.28	12.35	198.98	221.62	44.32	265.94
	Pr	29.5	18	0.65	10.28	12.35	198.98	221.62	44.32	265.94
	Pr	29.5	18	0.65	10.28	12.35	198.98	221.62	44.32	265.94
	Pr	29.5	15	0.65	10.28	12.35	198.98	221.62	44.32	265.94
	Pr	29.5	15	0.65	10.28	12.35	198.98	221.62	44.32	265.94
	Pr	28.5	16	0.65	9.61	11.26	181.04	201.91	40.38	242.29
	Pr	20.5	15	0.65	5.04	4.64	73.40	83.08	16.62	99.70
	Pr	28.5	14	0.65	9.61	11.26	181.04	201.91	40.38	242.29
	Pr	27.5	15	0.65	8.96	10.23	164.16	183.35	36.67	220.02
	Pr	28.5	15	0.65	9.61	11.26	181.04	201.91	40.38	242.29
	Pr	28.5	15	0.65	9.61	11.26	181.04	201.91	40.38	242.29
	Pr	28.5	16	0.65	9.61	11.26	181.04	201.91	40.38	242.29
	Pr	28.5	15	0.65	9.61	11.26	181.04	201.91	40.38	242.29
	Pr	25.5	14	0.65	7.72	8.35	133.48	149.56	29.91	179.47
	Pr	27.5	11	0.65	8.96	10.23	164.16	183.35	36.67	220.02
	Pr	28.5	14	0.65	9.61	11.26	181.04	201.91	40.38	242.29
	Pr	27.5	15	0.65	8.96	10.23	164.16	183.35	36.67	220.02
	Pr	26.5	14	0.65	8.33	9.26	148.32	165.91	33.18	199.09
	Pr	26.5	14	0.65	8.33	9.26	148.32	165.91	33.18	199.09
	Pr	26.5	16	0.65	8.33	9.26	148.32	165.91	33.18	199.09
	Pr	26.5	15	0.65	8.33	9.26	148.32	165.91	33.18	199.09
	Pr	26.5	12	0.65	8.33	9.26	148.32	165.91	33.18	199.09
	Pr	25.5	15	0.65	7.72	8.35	133.48	149.56	29.91	179.47
	Pr	25.5	14	0.65	7.72	8.35	133.48	149.56	29.91	179.47
	Pr	26.5	15	0.65	8.33	9.26	148.32	165.91	33.18	199.09
	Pr	27.5	15	0.65	8.96	10.23	164.16	183.35	36.67	220.02

Pr	27.5	12	0.65	8.96	10.23	164.16	183.35	36.67	220.02
Pr	28.5	13	0.65	9.61	11.26	181.04	201.91	40.38	242.29
Pr	28.5	15	0.65	9.61	11.26	181.04	201.91	40.38	242.29
Pr	25.5	12	0.65	7.72	8.35	133.48	149.56	29.91	179.47
Pr	24.5	14	0.65	7.14	7.50	119.63	134.26	26.85	161.12
Pr	25.5	15	0.65	7.72	8.35	133.48	149.56	29.91	179.47
Pr	28.5	15	0.65	9.61	11.26	181.04	201.91	40.38	242.29
			Total	**292.99**	**334.94**	**5376.55**	**6004.4**	**1200**	**7205.3**

Note: Pr = Pinus roxburghii

The site-2 contained altogether species richness of 33 number of trees of *Pinus roxburghii*. The diameter at breast height (DBH) of the stem of *Pinus roxburghii* was found to be between 20.5 cm and 29.5 cm indicating the forest containing site-2 is also adult. The total foliage, branch and stem biomass were 292.99 kg, 334.94 kg and 5376.55 kg respectively at site-2. The Table 2 showed that the larger the diameter of trees the larger the biomass it contained which was also confirmed by other researcher stated that the larger diameter trees contribute majority of forest biomass (Brown et al., 1995). The above ground tree biomass, below ground tree biomass and total tree biomass at site-2 were 6004.48 Kg, 1200.9 kg and 7205.38 kg respectively as shown in Table 2. The total tree biomass density of 120.08 t/ha at site-2 indicated the forest condition was good (Condori, 1985). The *Pinus roxburghii* (Chirpine) trees had been planted in the community forest for conservation of soil by the community forest user groups as it being a fast growing tree species and a valuable resources for timber and resin based industries, and firewood (Pant, 2004).

Table 3. Tree component wise biomass of site-3 of Nilbarahi Community Forest

S.No.	Name of trees	Dbh (cm)	Height (m)	Density (g/cm3)	Foliage Biomass (Kg)	Branch Biomass (Kg)	Stem Biomass (Kg)	AGTB (Kg)	BGTB (Kg)	TTB (Kg)
1	ES	26.5	20	0.67	14.95	77.38	65.13	157.46	31.49	188.95
2	ES	26.2	20	0.67	14.69	75.33	63.71	153.73	30.75	184.48
3	ES	30.5	22	0.67	18.62	107.74	85.40	211.77	42.35	254.12
4	ES	15.3	15	0.67	6.34	21.22	22.59	50.15	10.03	60.18
5	ES	11.0	12	0.67	3.79	9.76	11.95	25.50	5.10	30.60
6	ES	31.3	22	0.67	19.39	114.52	89.77	223.68	44.74	268.42
7	ES	27.1	19	0.67	15.48	81.57	68.00	165.05	33.01	198.06
8	ES	23.3	22	0.67	12.23	57.15	50.82	120.19	24.04	144.23
9	ES	18.9	12	0.67	8.82	34.91	33.94	77.67	15.53	93.21
10	ES	18.7	12	0.67	8.67	34.04	33.25	75.97	15.19	91.17
11	ES	16.6	15	0.67	7.20	25.72	26.43	59.35	11.87	71.22
12	ES	17.7	16	0.67	7.96	29.91	29.91	67.78	13.56	81.34
13	ES	35.3	15	0.67	23.40	152.01	113.20	288.61	57.72	346.33
14	ES	20.4	22	0.67	9.94	41.79	39.33	91.05	18.21	109.26
15	ES	14.8	12	0.67	6.02	19.63	21.18	46.83	9.37	56.20
16	ES	22.1	20	0.67	11.26	50.46	45.89	107.61	21.52	129.13
17	ES	11.3	9	0.67	3.95	10.40	12.59	26.94	5.39	32.32
18	ES	13.9	12	0.67	5.46	16.93	18.77	41.16	8.23	49.39
19	ES	24.3	18	0.67	13.06	63.09	55.10	131.26	26.25	157.51
20	ES	12.3	8	0.67	4.51	12.69	14.83	32.03	6.41	38.44
21	ES	21.3	15	0.67	10.63	46.26	42.74	99.63	19.93	119.56
22	ES	14.3	18	0.67	5.70	18.10	19.83	43.63	8.73	52.36

23	ES	11.5	9	0.67	4.06	10.83	13.02	27.92	5.58	33.50
24	ES	17.3	22	0.67	7.68	28.34	28.62	64.65	12.93	77.58
25	ES	19.0	20	0.67	8.89	35.34	34.29	78.53	15.71	94.23
26	ES	14.6	12	0.67	5.89	19.01	20.64	45.54	9.11	54.64
27	ES	14.4	12	0.67	5.77	18.40	20.09	44.26	8.85	53.11
28	SW	26.3	23	0.68	78.07	106.99	411.30	596.35	119.2	715.62
29	SW	14.3	12	0.68	24.23	26.19	88.58	138.99	27.80	166.79
30	SW	13.3	13	0.68	21.08	22.15	73.79	117.02	23.40	140.42
31	SW	20.1	20	0.68	46.59	57.49	208.89	312.97	62.59	375.57
32	SW	14.6	12	0.68	25.22	27.47	93.33	146.02	29.20	175.23
33	SW	14.3	12	0.68	24.23	26.19	88.58	138.99	27.80	166.79
34	SW	10.3	9	0.68	12.91	12.27	38.75	63.92	12.78	76.71
35	SW	17	23	0.68	33.78	39.05	136.96	209.78	41.96	251.74
36	SW	12.3	14	0.68	18.15	18.49	60.59	97.23	19.45	116.67
37	SW	17.6	16	0.68	36.10	42.30	149.47	227.88	45.58	273.45
38	SW	11.9	10	0.68	17.03	17.13	55.75	89.91	17.98	107.89
39	SW	24.2	17	0.68	66.54	88.28	333.49	488.30	97.66	585.97
40	SW	17.6	19	0.68	36.10	42.30	149.47	227.88	45.58	273.45
41	SW	28	18	0.68	88.04	123.64	481.62	693.31	138.6	831.97
42	SW	25.3	18	0.68	72.47	97.82	373.02	543.31	108.6	651.97
43	SW	15	15	0.68	26.56	29.24	99.91	155.71	31.14	186.86
44	SW	19.3	20	0.68	43.09	52.34	188.57	284.01	56.80	340.81
45	SW	27.4	18	0.68	84.46	117.61	456.03	658.10	131.6	789.72
46	SW	13.2	12	0.68	20.78	21.76	72.40	114.94	22.99	137.93
				Total	**1039.81**	**2181.22**	**4641.54**	**7862.5**	**1572.**	**9435.0**

Note: ES = *Engelhadrtia spicata* ; SW = *Schima wallichii*

The site-3 contained altogether 46 number of trees among them 27 number of trees were of *Engelhardtia spicata*, 19 number of trees were of *Schima wallichi* as shown in Table 3. The DBH of the stem of *Engelhardtia spicata* was found to be between 11.0 cm and 35.5 cm and the DBH of the stem of *Schima wallichi* was measured between 10.3 cm and 28.0 cm respectively. The total foliage, branch and stem biomass of *Engelhardtia spicata* were 264.38 kg, 1212.51 kg and 1081.05 kg; and of *Schima wallichii* total foliage, branch and stem biomass was 775.43 kg, 968.71 kg, and 3560.49 kg respectively at site-3 as shown in Table 3. The Table 3 also showed that the larger the diameter of trees the larger the biomass it contained. The above ground tree biomass, below ground tree biomass and total tree biomass at site-3 for the tree species *Engelhardtia spicata* were 2557.94 Kg, 511.59 kg and 3069.53 kg and of *Schima wallichii* was found to be 5304.63 kg, 1060.93 kg, and 6365.56 kg respectively as shown in Table 3. In total, the total foliage, stem and tree biomass at site-3 were found 1036.81 kg, 2181.22 kg, 4641.54 kg respectively within a plot of 500m^2. Also, the total above ground tree biomass, belowground tree biomass and total tree biomass at site -3 were 7862.57 kg, 1572.51 kg and 9435.08 kg respectively which was the site of mixed broad leaved forest. The total tree biomass density of 157.25 t/ha at site-3 also indicated the condition of the forest was good.

Table 4. Tree component wise biomass of site-4 of Nilbarahi Community Forest

S.No.	Name of Trees	Dbh (cm)	Height (m)	Density (g/cm3)	Foliage Biomass (Kg)	Branch Biomass (Kg)	Stem Biomass (Kg)	AGTB (Kg)	BGTB (Kg)	TTB (Kg)
1	AN	18.8	12	0.43	5.26	39.88	45.56	90.70	18.14	108.84
2	AN	19.5	12	0.43	5.56	43.72	49.20	98.47	19.69	118.16
3	AN	19.1	13	0.43	5.39	41.50	47.10	93.99	18.80	112.79

4	AN	17.7	14	0.43	4.81	34.28	40.13	79.23	15.85	95.07
5	AN	18.8	14	0.43	5.26	39.88	45.56	90.70	18.14	108.84
6	AN	11.8	12	0.43	2.63	12.39	17.11	32.14	6.43	38.57
7	AN	11.3	14	0.43	2.47	11.11	15.63	29.21	5.84	35.05
8	AN	11.7	13	0.43	2.60	12.13	16.81	31.54	6.31	37.85
9	AN	12.3	11	0.43	2.80	13.75	18.67	35.23	7.05	42.27
10	AN	12.7	12	0.43	2.94	14.90	19.97	37.81	7.56	45.37
11	AN	17.5	12	0.43	4.73	33.32	39.19	77.24	15.45	92.68
12	AN	18.4	12	0.43	5.10	37.79	43.54	86.43	17.29	103.71
13	AN	17.9	12	0.43	4.89	35.26	41.09	81.25	16.25	97.50
14	EA	12.7	11	0.7	4.14	10.19	16.85	31.18	6.24	37.42
15	EA	11.9	11	0.7	3.77	9.04	14.99	27.79	5.56	33.35
16	EA	12.3	11	0.7	3.95	9.61	15.91	29.47	5.89	35.36
17	EA	12.5	12	0.7	4.05	9.90	16.37	30.32	6.06	36.38
18	EA	12.7	12	0.7	4.14	10.19	16.85	31.18	6.24	37.42
19	EA	10.9	10	0.7	3.31	7.68	12.80	23.80	4.76	28.56
20	EA	11.2	11	0.7	3.45	8.08	13.44	24.97	4.99	29.96
21	EA	12.8	10	0.7	4.19	10.34	17.09	31.62	6.32	37.94
22	EA	12	11	0.7	3.81	9.18	15.22	28.21	5.64	33.85
23.	LM	11.2	12	0.61	4.15	5.77	35.87	45.79	9.16	54.95
24.	LM	11.8	12	0.61	4.49	6.48	40.36	51.33	10.27	61.60
25.	LM	11.5	11	0.61	4.32	6.12	38.08	48.52	9.70	58.22
26.	LM	10.6	12	0.61	3.81	5.11	31.68	40.60	8.12	48.72
27.	LM	11.1	11	0.61	4.09	5.66	35.15	44.90	8.98	53.88
28.	LM	11.5	11	0.61	4.32	6.12	38.08	48.52	9.70	58.22
29.	LM	10.9	12	0.61	3.98	5.44	33.74	43.15	8.63	51.78
30.	LM	10.6	12	0.61	3.81	5.11	31.68	40.60	8.12	48.72
31.	SW	12.3	14	0.68	18.15	18.49	60.59	97.23	19.45	116.67
32.	SW	17.8	12	0.68	36.89	43.42	153.79	234.10	46.82	280.93
33.	SW	16.5	12	0.68	31.90	36.44	127.04	195.37	39.07	234.45
34.	SW	14.4	11	0.68	24.56	26.61	90.14	141.31	28.26	169.58
35.	SW	14.7	11	0.68	25.55	27.91	94.95	148.41	29.68	178.09
36.	SW	21.5	12	0.68	53.02	67.17	247.52	367.71	73.54	441.25
37.	SW	22.0	12	0.68	55.41	70.83	262.28	388.53	77.71	466.23
38.	SW	22.3	12	0.68	56.87	73.08	271.39	401.35	80.27	481.61
39.	SW	14.4	12	0.68	24.56	26.61	90.14	141.31	28.26	169.58
40.	SW	14.7	13	0.68	25.55	27.91	94.95	148.41	29.68	178.09
41.	SW	21.2	13	0.68	51.61	65.02	238.91	355.54	71.11	426.65
42.	SW	14.5	12	0.68	24.89	27.04	91.73	143.66	28.73	172.39
43.	SW	21.6	13	0.68	53.49	67.89	250.43	371.82	74.36	446.18
44.	SW	15.5	12	0.68	28.29	31.54	108.52	168.35	33.67	202.02
45.	SW	14.7	12	0.68	25.55	27.91	94.95	148.41	29.68	178.09
46.	Pr	24.8	15	0.68	23.92	45.69	96.39	166.00	33.20	199.20
47.	Pr	28.9	16	0.68	30.27	55.67	121.44	207.38	41.48	248.85
48.	Pr	26.5	14	0.68	26.49	49.78	106.54	182.80	36.56	219.36

49.	Pr	24.3	14	0.68	23.18	44.51	93.47	161.16	32.23	193.39
				Total	**762.38**	**1333.49**	**3558.9**	**5654.75**	**1130.95**	**6785.70**

Note: LM = Litsea monopetala ; SW = Schima wallichi ; AN= Alnus nepalensis ; EA = Eury acuminate; TTB= Total Tree Biomass; AGTB= Above Ground Tree Biomass; BGTB= Below Ground Tree Biomass; MT=Metric Ton

The site-4 contained altogether 49 number of trees among them 13 number of trees were Alnus nepalensis, 9 number of trees were of Eury acuminate, 8 number of trees were of Litsea monopetala, 15 number of trees were of Schima wallichi and 4 number of trees were of Pinus roxburghii respectively as shown in Table 4. The DBH of the stem of Alnus nepalensis was found to be between 11.3 cm and 19.5 cm together with its total foliage, branch and stem biomass was 54.44 kg, 369.93 kg and 439.57 kg respectively. The total above ground tree biomass contained by this tree species was 1036.72 kg in a sampling plot of site-4. Similarly, the DBH of the stem of Eury acuminate was measured between 10.9 cm and 12.8 cm with the total foliage, branch and stem biomass contained in it was found 34.82 kg, 84.21 kg, and 139.52 kg. The total above ground tree biomass contained in Eury acuminate was 310.26 kg. Likewise, the DBH of the stem of Litsea monopetala was recorded between 10.9 cm and 11.8 cm; and the total foliage, branch and stem biomass of this species was found to be 32.96 kg, 45.82 kg, and 284.64 kg respectively at site-4.

The above ground tree biomass for Litsea monopetala was also found to be 436.10 kg. In the same way, for the tree Schima wallichi, the DBH measurement was found between 12.3 cm and 22.3 cm as depicted in Table 4. As from the view point of species richness, the number of tree species of Alnus nepalensis was found to be dominating to the other trees species available at site-4. The foliage, branch, stem and total tree biomass of Alnus nepalensis was found to be 536.29 kg, 637.88 kg, 2277.35 kg and 4141.82 kg respectively which obviously indicated that among the trees species recorded at site-4, the Alnus nepalensis tree had the largest biomass. The tree Pinus roxburghii was found to be the least in species richness among other trees species as shown in Table 4. However, the DBH of the stem of Pinus roxburghii was found between 24.3 cm and 28.9 cm indicated that its basal area coverage was higher than the other trees species DBH at site-4 as mentioned in Table 4. The Chir pine (Pinus roxburghii) at site-4 was found to be a few, as it had been planted by the community forest user groups for the conservation of soil and also it being a fast growing species and of valuable resources for timber and resin based industries as well as for firewood. However, Chir Pine forests have lower biomass that lies between 150–200 t/ha than other species of the Himalaya trees biomass (Singh, 1992). The total tree biomass density of 113.09 t/ha at site-4 indicated the forest was found to be at good condition (Condori, 1985).

Table 5. Tree component wise carbon stock and CO_2e of Nilbarahi Community Forest

Carbon Components	Site-1	Site-2	Site-3	Site-4
Carbon stock (t/ha)	69.45	67.73	88.69	63.79
MTCO_2e	231.18	225.45	295.21	212.31

The carbon stock in the forest vegetation varies according to geographical location, plant species and age of the stand. Forest plays a vital role in the global carbon cycle, as it sequestrates a large amount of atmospheric carbon stock. Forest **carbon stock** is the amount of **carbon** that has been sequestered from the atmosphere and is now stored within the forest ecosystem, mainly within living biomass and soil, and to a lesser extent also in dead wood and litter. Among the four sites the carbon stock was found higher at site -3 of mixed broad leaved forests with 88.69 t/ha carbon storage and CO_2e of 295.21MT followed by site-1 of needle leaved forests with 69.45 t/ha carbon storage and CO_2e of 231.18 MT as shown in Table 5. Thus, the needle leaved and mixed broad leaved trees of the Nilbarahi forests have potentiality in contributing to the global goal of climate change mitigation and carbon sequestration.

The total carbon stock density and CO_2e as revealed from this study was found to be higher in the mixed broad leaved forest (88.69 t/ha, 295.21 MT) than in the sub-tropical needle leaved *Pinus roxburghii* forest (69.45 t/ha, 231.18 MT). The average carbon stock density and average CO_2e was found to be of 72.41 t/ha and 241.03 MT in the Nilbarahi Community Forest. It can be concluded that the community forest representing of the mixed broad leaved forest had the higher amount of total carbon component per hectare compared to the needle leaved conifer forest of *Pinus roxburghii* (Chir pine). However, both the needle leaved and mixed broad leaved forests of Nilbarahi Community Forests are no doubt important source of carbon sink hence contributing to climate change mitigation. This difference can be primarily attributed to variations in species composition, canopy structure and litter production between the two forest types. Broad-leaved species generally have higher photosynthetic capacity, faster growth rates, and greater leaf area index (LAI), resulting in increased accumulation of above ground biomass and thus higher carbon storage potential (Gautam & Mandal, 2016; Brown, 1977).

Moreover, **mixed forests enhance resource-use efficiency** through *species complementarity*, wherein different tree species occupy distinct ecological niches. This diversity enables more effective **light interception, nutrient absorption, and soil moisture utilization,** ultimately promoting greater overall productivity and biomass accumulation (Liang et al., 2016). Such ecological interactions align with findings from other community forests in Nepal's mid-hills, where **mixed broad-leaved forest stands have consistently exhibited higher carbon storage** compared to pure *Pinus roxburghii* (Chir pine) plantations (Pandey & Bhusal, 2019; Bhandari & Neupane, 2020).

The **average carbon stock density (72.41 t C/ha)** and **average CO_2 equivalent (241.03 t CO_2e/ha)** recorded in the Nilbarahi Community Forest are consistent with findings from other community-managed forests in Nepal's central and western mid-hill regions such as Kaski, Nuwakot, and Dolakha where carbon stocks typically range between **60 and 120 t C/ha,** depending on forest type, management intensity, and disturbance level (Acharya et al., 2019; Sharma et al., 2013). These results indicate that the Nilbarahi Community Forest maintains a **healthy and stable carbon pool,** likely reflecting the effectiveness of local forest management practices and the reduction of anthropogenic pressures through community stewardship.

The **average tree biomass density (128.39 t/ha)** further indicates a **good forest condition,** reflecting successful implementation of the **Community Forestry Programme (CFP)** in Nepal. Since the 1980s, the CFP has empowered local user groups to manage and protect forest resources, leading to **forest recovery, biomass accumulation, and increased carbon sequestration** (Gilmour & Fisher, 1991; Niraula et al., 2013). These community forests not only serve as **carbon sinks,** contributing to **climate change mitigation,** but also enhance **ecosystem services, biodiversity conservation,** and **livelihood resilience** of local communities.

The **higher carbon stock observed in the mixed broad-leaved forest** highlights the crucial role of **forest composition and species diversity** in enhancing climate change mitigation. Promoting the **regeneration and conservation of native broad-leaved species** within community-managed forests can substantially increase the overall ecosystem carbon storage capacity. Furthermore, the carbon sequestration potential of such forests contributes directly to **Nepal's commitments under the REDD+ mechanism** of the **UNFCCC framework,** which focuses on reducing emissions from deforestation and forest degradation while promoting sustainable forest management and conservation (DFRS, 2015).

Conclusions

In summary, the **Nilbarahi Community Forest** shows a **good level of carbon storage**, especially in the **mixed broad-leaved forest**, which stores about **88.69 t C/ha** compared to **69.45 t C/ha** in the *Pinus roxburghii* forest. This study shows that **community-based forest management** helps not only in **restoring degraded forests** but also in **increasing carbon sequestration** and **supporting climate change adaptation**. To maintain and improve these results, it is important to continue **policy support**, conduct **regular forest inventories**, and **promote diverse native tree species.** Such actions will provide long-term benefits to both **local communities** and **global climate goals.**

References

Acharya, K. P., Maraseni, T., & Cockfield, G. (2019). Global warming mitigation and adaptation by community forest users in Nepal. *Applied Geography*, *111*, 102082.

Assessment, Global Forest Resource (2005). Progress towards sustainable forest management. *Forestry Paper*, *147*, Rome.

Bari, P. A. A., & Prasad, K. G. (1987). Growth of tropical pines in Tamil Nadu in relation to soil properties, *Indian Forester*, 53-60.

Bhandari, P., & Neupane, R. (2020). Carbon stock assessment in community managed forests of Kaski District, Nepal. *Banko Janakari*, *30*(1), 45–54.

Brown, I. F., Martinelli, L. A., Thomas, W. W., Moreira, M. Z., Ferreira, C. C., & Victoria, R. A. (1995). Uncertainty in the biomass of Amazonian forests: an example from Rondonia, Brazil. *Forest Ecology and Management*, *75*(1-3), 175-189.

Brown, S. (1997). *Estimating biomass and biomass change of tropical forests: A primer.* FAO Forestry Paper No. *134*, Rome.

Brown, S. L., Schroeder, P., & Kern, J. S. (1999). Spatial distribution of biomass in forests of the eastern USA. *Forest Ecology and Management*, *123*(1), 81-90.

Brown, S. L., & Schroeder, P. E. (1999). Spatial patterns of aboveground production and mortality of woody biomass for eastern US forests. *Ecological Applications*, *9*(3), 968-980.

Change, O. C. (2007). Intergovernmental Panel on Climate Change, 2001. *World Meteorological Organization*, *52*, (1-43), 1.

Clements, F. E. (1936). Nature and structure of the climax. *Journal of ecology*, *24*(1), 252-284.

Condori, L. V. (1985). Community forest management at village level. A case study in Badikhel Panchayat, Lalitpur District, Nepal.

Department of Forest Research and Survey (DFRS). (2015). *State of Nepal's Forests.* Government of Nepal, Ministry of Forests and Soil Conservation.

Gautam, T. P., & Mandal, R. A. (2016). Carbon stock in community managed hill Sal (*Shorea robusta*) forests of Nepal. *Journal of Forest and Livelihood*, *14*(1), 15–24.

Gilmour, D. A., & Fisher, R. J. (1991). *Villagers, forests and foresters: The philosophy, process and practice of community forestry in Nepal.* Sahayogi Press, Kathmandu.

Heimann, M., & Reichstein, M. (2008). Terrestrial ecosystem carbon dynamics and climate feedbacks. *Nature*, *451*(suppl (1)), 289-292.

Houghton, R. A. (2005). Aboveground forest biomass and the global carbon balance. *Global change biology*, *11*(6), 945-958.

Hunt, C. A. (2009). *Carbon sinks and climate change: forests in the fight against global warming*. Edward Elgar Publishing Ltd., U. K., 236 pp.

Jina, B. S., Sah, P., Bhatt, M. D., & Rawat, Y. S. (2008). Estimating carbon sequestration rates and total carbon stockpile in degraded and non-degraded sites of Oak and Pine forest of Kumaun Central Himalaya. *Ecoprint: An International Journal of Ecology*, *15*, 75-81.

Kanel, K. R. (2004, August). Twenty five years of community forestry: contribution to millennium development goals. In *Proceedings of the fourth national workshop on community forestry* (pp. 4-6).

Liang, J., et al. (2016). Positive biodiversity-productivity relationship predominant in global forests. *Science*, *354* (6309), aaf 8957.

Mac Dicken, K. G. (1997). A guide to monitoring carbon storage in forestry and agroforestry projects. Arlington, USA: Winrock International.

MFSC (2014) . Forest Carbon Measurement (Ban Carbon Mapan Margadarshan, 2071 B.S.). Published by the Government of Nepal of Ministry of Forests and Soil Conservation , REDD Forestry and Climate Change Unit, BabarMahal, Kathmandu.

Midgley, G. F., Bond, W. J., Kapos, V., Ravilious, C., Scharlemann, J. P., & Woodward, F. I. (2010). Terrestrial carbon stocks and biodiversity: key knowledge gaps and some policy implications. *Current Opinion in Environmental Sustainability*, *2*(4), 264-270.

Nabuurs, G. J., Masera, O., Andrasko, K., Benitez-Ponce, P., Boer, R., Dutschke, M., ... & Meyer, L. (2007). Climate change 2007: mitigation. Contribution of working group III to the fourth assessment report of the intergovernmental panel on climate change. *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Climate Change*, 159-254.

Niraula, R. R., Gilani, H., Pokharel, B. K., & Qamer, F. M. (2013). Measuring impacts of community forestry program through repeat photography and satellite remote sensing in the Dolakha district of Nepal. *Journal of Environmental Management*, 126, 20–29.

Odum, E. P (1996). Fundamentals of Ecology. Third edition, Natraj publishers. P: 148, 149, 167-168, 179,180, 181, 183.

Pandey, A., & Bhusal, D. R. (2019). Carbon stock and sequestration potential in community forests of mid-hill region of Nepal. *Himalayan Biodiversity*, *7*(1), 34–42.

Pant, D. R. (2004). Biodiversity Assessment in the Nilbarahi Community Forest with Respect to Monkey Ecology (Master's dissertation Tribhuvan University, Central Department of Environmental Science, Nepal).

Pearson, T. R. (2007). *Measurement guidelines for the sequestration of forest carbon* (Vol. 18). US Department of Agriculture, Forest Service, Northern Research Station.

Schimel, D. S., House, J. I., Hibbard, K. A., Bousquet, P., Ciais, P., Peylin, P., ... & Wirth, C. (2001). Recent patterns and mechanisms of carbon exchange by terrestrial ecosystems. *Nature*, *414*(6860), 169-172.

Sharma, E. R., Pukkala, T., & Bashyal, R. (2013). Carbon stock and tree species diversity in different forest types of Nepal. *Forestry: An International Journal of Forest Research*, *86*(5), 539–548.

Singh, J. S. (1992). Forests of Himalaya: Structure, functioning and impact of man. *C Gyanodaya Prakashan*. Gyanodaya Prakashan, p. 84, 89, 142.

Tewari, A., & Karky, B. (2007). Carbon Management Methodology and Results in Reducing Carbon Emission through Community-Managed Forests in the Himalaya, Hill Side Press (P) Ltd. Kathmandu, ISBN 978-92-9115-058-8..

Waring, R. H., & Running, S. W. (1998). Forest ecosystems: analysis at multiple scales, Academic Press. San Diego, California: Academic Press.

Watson, R. T., Noble, I. R., Bolin, B., Ravindranath, N. H., Verardo, D. J., & Dokken, D. J. (2000). Land use, land use change, and forestry. *A Special Report of the IPCC* Cambridge University press, Cambridge, U.K. (pp. ix+-373).