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BIOMASS AND CARBON STORAGE POTENTIAL OF TREES IN AGROFORESTRY SYSTEMS PRACTICED IN THREE DISTRICTS OF ARUNACHAL PRADESH (INDIA) LYING ALONG THREE DIFFERENT ALTITUDINAL GRADIENTS

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Abstract
Agroforestry is an effective strategic approach for carbon sequestration and plays a significant role in addressing climate change. Additionally, agroforestry offers various ecological and economic advantages, tackling issues such as forest degradation and soil infertility. This study highlights the carbon storage capabilities of woody species within agroforestry systems across three distinct altitudinal zones. The total biomass was observed to be highest in the tropical zone's agroforestry systems, gradually decreasing with higher altitudes. Species such as Tectona grandis, Terminalia myriocarpa, and various Pinus species were identified as major contributors to carbon storage potential. Promoting agroforestry systems should be emphasized, recognizing them as an important strategy in the fight against global warming and climate change challenges.

Key words: Biomass, Carbon storage, Agroforestry systems, Altitudinal gradients, Arunachal Pradesh

Introduction:

The increase in atmospheric carbon dioxide and methane levels, primarily attributed to industrial activities, highlights the crucial role of forests in acting as natural regulators of climate change (Gibbs et al., 2007). In light of the challenges posed by climate change, agroforestry has emerged as a practical solution, with trees playing a significant role in reducing climate impacts by sequestering carbon from the atmosphere through photosynthesis (Verchot et al., 2007; Islam et al., 2022). The presence of trees on agricultural lands significantly boosts the potential of agroforestry systems to sequester and store carbon (Agevi et al., 2017; Yasin et al., 2019). Agroforestry systems are projected to sequester approximately 6.3 Gt of atmospheric carbon by 2050, achieving a carbon sequestration rate exceeding 600 Mt C per year, which positions them as a valuable means of carbon storage compared to other land-use alternatives (Nair et al., 2009; Deka et al., 2016; Nawaz et al., 2017). This study similarly highlights the role of agroforestry systems in carbon storage, with an emphasis on the woody tree species prevalent within these systems. Farmers in Arunachal have traditionally relied on their established farming practices and have recently begun to incorporate agroforestry systems (Bani et al., 2022), which involve integrating woody species into their agricultural land, creating a sustainable approach that functions well within their tribal communities. This research highlights the capability of traditional agroforestry systems to sequester carbon, contributing directly to efforts in climate change mitigation.

Study area

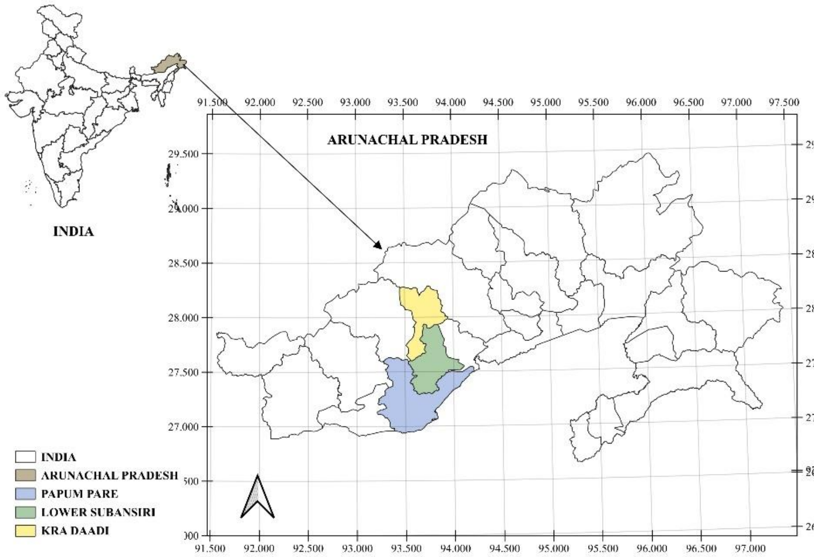

Fig 1. Study area map

The research was conducted in Papum Pare, Lower Subansiri and Kra Daadi districts lying along three different altitudinal gradients (Fig 1.). The altitudes with location coordinates are listed in table 1.

Table 1: The elevation range, location (geographical coordinates) and district/region of the study sites of all the tree elevations.

Elevation I (100-700 m amsl)

Village	Elevation (m)	Location (Coordinates)	District/ Region
Rose	330 m	27°12′38″N 93°50′13″E	Papum Pare
Lekhi	280 m	27°13′36″N 93°50′28″E	Papum Pare
Poma	298 m	27°11′03″N 93°46′46″E	Papum Pare
Yupia	224 m	27°10′20″N 93°46′09″E	Papum Pare
Gumto	144 m	27°08′18″N 93°47′59″E	Papum Pare
Midpu	155 m	27°05′44″N 93°40′40″E	Papum Pare
Khemlee	680 m	27°08′46″N 93°43′08″E	Papum Pare
Chiputa	560 m	27°04′50″N 93°35′18″E	Papum Pare
Tok	180 m	27°13′44″N 93°28′36″E	Papum Pare
Balapu	650 m	27°13′09″N 93°35′30″E	Papum Pare

Elevation II (700-1400 m amsl)

Village	Elevation (m)	Location (Coordinates)	District/ Region
Chullyu	1330 m	27°20′46″N 93°45′53″E	Lower Subansiri
Lumri	1190 m	27°27′36″N 93°44′26″E	Lower Subansiri
Joram	1328 m	27°30′52″N 93°46′32″E	Lower Subansiri
Nimte	770 m	27°14′00″N 93°32′50″E	Papum Pare
Pania	1256 m	27°41′57″N 93°42′22″E	Kra Daadi

Bangte	1252 m	27º42′14″N 93º39′51″E	Kra Daadi
Bangchi	1120 m	27º42′02″N 93º39′33″E	Kra Daadi
Bojo	1300 m	27º42′50″N 93º41′48″E	Kra Daadi
Langdang	1213 m	27º43′19″N 93º42′43″E	Kra Daadi
Jorung	1336 m	27º38′53″N 93º37′31″E	Kra Daadi

Elevation III (1400-2000 m amsl)

Village	Elevation (m)	Location (Coordinates)	District/ Region
Dui	1450 m	27º40′19″N 93º39′05″E	Kra Daadi
Yaglung	1580 m	27º41′37″N 93º40′11″E	Kra Daadi
Amji	1730 m	27º40′42″N 93º41′48″E	Kra Daadi
Tajang	1570 m	27º34′33″N 93º50′42″E	Lower Subansiri
Hari	1580 m	27º32′36″N 93º52′34″E	Lower Subansiri
Siiro	1560 m	27º31′11″N 93º50′16″E	Lower Subansiri
Bokam	1537 m	27º41′23″N 93º41′53″E	Kra Daadi
Paka	1420 m	27º43′52″N 93º44′21″E	Kra Daadi
Tayo	1670 m	27º44′12″N 93º47′05″E	Kra Daadi
Tassar	1615 m	27º38′19″N 93º36′59″E	Kra Daadi

Table 2: Different agro-climatic zones covered in the study

Sl. No.	Agro-climatic zone	Altitudinal range
1.	Temperate zone	1400-2000 m
2.	Sub-tropical	700-1400 m
3.	Tropical zone	100-700 m

Methodology:

For the assessment of biomass, a sample size of at least 1 ha was considered. The Diameter at breast height (DBH) of the tree species with 10 cm or above, falling within the sample size were included. The herbs and shrubs which required destructive method (harvest) in the field, were excluded, as most of the farmers did not permit to harvest the plants from their fields, and most of the vegetable crops being seasonal and their numbers usually varies with time. But the tree species were mostly permanent structures, which contributed to the biomass content of the TAFs.

A non-destructive method of biomass estimation was used where, the biomass equation developed using harvest data from NEI was used to calculate aboveground biomass content (Nath et al., 2019, 2021; Brahma et al., 2021; Sahoo et al., 2021). The **Above Ground Biomass (AGB)est = 0.18 x $D^{2.16}$ x 1.32**, where 'D' is the diameter at breast height, while '1.32' value is the correction factor. A default value of **0.235** was used to estimate the belowground or root biomass (Mokany et al., 2006). The sum of the aboveground and the belowground biomass was considered as the total biomass. The unit considered for biomass was Kg ha $^{-1}$.

By multiplying the biomass of the plant by a default value of **0.5**, the above- and below-ground biomass carbon stock in the vegetation was calculated (IPCC, 1996). By summing the biomass content of the above- and the below-ground layers, the total carbon stock was calculated.

6.2 Results

6.2.1 The Above ground biomass and Belowground biomass

The AGB and the BGB, of woody species, were computed for TAFs of all the three elevations. In the Elevation I, the highest AGB (1337.399 kg ha^{-1}) and BGB (314.048 kg ha^{-1}) was reported in Chiputa followed by Khemlee with AGB (734.765 kg ha^{-1}) and BGB (172.519 kg ha^{-1}), Midpu with AGB (666.48 kg ha^{-1}) and BGB (159.014 kg ha^{-1}). The lowest AGB (205.1 kg ha^{-1}) and BGB (48.104 kg ha^{-1}) was reported in Poma. In the Elevation II, the AGB (820.455 kg ha^{-1}) and BGB (192.807 kg ha^{-1}) was highest in Bangte, followed by Bangchi with AGB (507.420 kg ha^{-1}) and BGB (119.243 kg ha^{-1}), Chullyu with AGB (464.261 kg ha^{-1}) and BGB (109.101 kg ha^{-1}). The lowest AGB (11.658 kg ha^{-1}) and BGB (2.739 kg ha^{-1}) was reported in Nimte.

In Elevation III, the highest AGB (507.342 kg ha^{-1}) and BGB (119.225 kg ha^{-1}) was observed in the TAFs of Bokam followed by Amji with AGB (483.018 kg ha^{-1}) and BGB (113.509 kg ha^{-1}) and Dui with AGB (435.945 kg ha^{-1}) and BGB (102.447 kg ha^{-1}). From the result, it could be seen that the mean AGB values were decreasing in the order E I (518.281 kg ha^{-1}) > E II (310.222 kg ha^{-1}) > E III (290.375 kg ha^{-1}). And the mean BGB values also were observed to be in decreasing order; E I (121.990 kg ha^{-1}) > E II (72.902 kg ha^{-1}) > E III (68.238 kg ha^{-1}).

6.2.2 Total Biomass

The total biomass was calculated by adding the above and below ground biomass (Total Biomass = Above ground + Below ground biomass).

The total biomass in the Elevation I was highest in Chiputa (1651.447 kg ha^{-1}), followed by Khemlee (907.284 kg ha^{-1}), Midpu (825.494 kg ha^{-1}) and others. While, the lowest value was reported in Poma (253.204 kg ha^{-1}). In the elevation II, the highest value of total biomass was reported in Bangte (1013.260 kg ha^{-1}), followed by Bangchi (626.660 kg ha^{-1}), Chullyu (573.360 kg ha^{-1}) and others. The lowest value of the total biomass was reported in Nimte (14.400 kg ha^{-1}). In Elevation III, the highest value of total biomass was observed in Bokam (626.568 kg ha^{-1}), followed by Amji (596.527 kg ha^{-1}), and Dui (538.392 kg ha^{-1}), followed by others. And the lowest was observed in Tayo (35.201 kg ha^{-1}).

The mean total biomass was 640.271 kg ha^{-1} in the Elevation I, 383.125 kg ha^{-1} in the Elevation II and 358.613 kg ha^{-1} in the Elevation III. Hence, the highest amount of tree biomass was reported in TAFs of Elevation I.

Table 3. AGB, BGB and Total biomass content of Trees in TAFs of Elevation I

Elevation I	**AGB (kg ha^{-1})**	**BGB (kg ha^{-1})**	**Total biomass (Kg ha^{-1})**
Balapu	209.074	49.714	258.788
Chiputa	1337.399	314.048	1651.447
Gumto	263.774	61.851	325.625
Khemlee	734.765	172.519	907.284
Lekhi	516.959	121.324	638.283
Midpu	666.480	159.014	825.494
Poma	205.100	48.104	253.204
Rose	345.590	81.007	426.597
Tok	436.600	102.957	539.557
Yupia	467.070	109.364	576.434
Mean	**518.281 (±107.36)**	**121.990 (±25.23)**	**640.271 (±132.59)**

Table 4. ABG, BGB and total biomass content of trees in TAFs of Elevation II

Elevation II	**AGB (kg ha^{-1})**	**BGB (kg ha^{-1})**	**Total biomass (Kg ha^{-1})**
Bangchi	507.420	119.243	626.660
Bangte	820.455	192.807	1013.260
Bojo	266.895	62.720	329.620
Chullyu	464.261	109.101	573.360
Joram	242.317	56.944	299.260
Jorung	189.514	44.535	234.050
Langdang	189.274	44.479	233.750
Lumri	203.125	47.734	250.860
Nimte	11.658	2.739	14.400
Pania	207.301	48.715	256.020
Mean	**310.222 (±72.25)**	**72.902 (±16.97)**	**383.125 (±89.23)**

Table 5. ABG, BGB and total biomass content of trees in TAFs of Elevation III

Elevation III	**AGB (kg ha^{-1})**	**BGB (kg ha^{-1})**	**Total biomass (Kg ha^{-1})**
Amji	483.018	113.509	596.527
Bokam	507.342	119.225	626.568
Dui	435.945	102.447	538.392
Hari	182.326	42.847	225.173
Paka	45.121	10.603	55.724
Siiro	407.887	95.853	503.740
Tajang	172.617	40.565	213.182
Tassar	207.836	48.841	256.677
Tayo	28.503	6.698	35.201
Yaglung	433.160	101.793	534.953
Mean	**290.375 (±57.79)**	**68.238 (±13.58)**	**358.613 (±71.38)**

6.2.3 The Aboveground and the belowground biomass carbon storage of TAFs

The above and the belowground biomass carbon stock was calculated for the TAFs of Elevation I, II and III. The Aboveground biomass carbon storage in the Elevation I was highest in Chiputa (668.690 kg C ha^{-1}), followed by Khemlee (367.380 kg C ha^{-1}), Midpu (333.240 kg C ha^{-1}) and others. The lowest value was reported in Poma (102.550 kg C ha^{-1}). The same case was for the Belowground biomass carbon storage with the highest in Chiputa (157.020 kg C ha^{-1}), followed by Khemlee (86.260 kg C ha^{-1}), Midpu (79.505 kg C ha^{-1}) and others. The lowest belowground biomass carbon storage was reported in Poma (24.050 kg C ha^{-1}).

In the Elevation II, the highest above ground biomass carbon storage was reported in Bangte (410.228 kg C ha^{-1}), Bangchi (253.710 kg C ha^{-1}), Chullyu (232.131 kg C ha^{-1}), and others. The lowest aboveground biomass carbon storage was reported in Nimte (5.828 kg C ha^{-1}). The belowground biomass carbon storage was also reported highest in Bangte (96.404 kg C ha^{-1}), Bangchi (59.622 kg C ha^{-1}), Chullyu (54.551 kg C ha^{-1}), and others. The lowest biomass carbon storage was reported in Nimte (1.370 kg C ha^{-1}).

In the Elevation III, the highest aboveground biomass carbon storage was reported in Bokam (253.671 kg C ha^{-1}), followed by Amji (241.509 kg C ha^{-1}), Dui (217.972 kg C ha^{-1}) and others. The lowest value was reported in Tayo (14.251 kg C ha^{-1}). With the same sequence in case of Belowground biomass carbon storage, the highest value was reported in Bokam (59.613 kg C ha^{-1}), followed by Amji (56.755 kg C ha^{-1}), Dui (51.224 kg C ha^{-1}) and others. And the lowest belowground biomass carbon storage in Elevation III was reported in Tayo (3.349 kg C ha^{-1}).

6.2.4 Total biomass carbon storage of TAFs

The total biomass carbons stock of TAFs in the Elevation I, II and III were computed by adding the above and belowground biomass carbon stocks. In the Elevation I, the total biomass carbon storage of TAFs was reported in Chiputa (825.710 kg C ha^{-1}), followed by Khemlee (453.640 kg C ha^{-1}), Midpu (412.745 kg C ha^{-1}) and others. The lowest value was reported from Poma (126.600 kg C ha^{-1}). The total biomass carbon storage of TAFs in the Elevation II was reported highest in Bangte (506.632 kg C ha^{-1}), Bangchi (313.332 kg C ha^{-1}), Chullyu (286.682 kg C ha^{-1}), and others. The lowest aboveground biomass carbon storage was reported in Nimte (7.119 kg C ha^{-1}). In the Elevation III, the highest value of total biomass carbon storage of TAFs was reported in Bokam (313.284 kg C ha^{-1}), followed by Amji (298.264 kg C ha^{-1}), Dui (269.196 kg C ha^{-1}) and others. The lowest value was reported in Tayo (17.6 kg C ha^{-1}). The mean values of above and belowground and the total biomass carbon stock of TAFs was seen to be decreasing in the order E I >E II > E III.

Table 6. Mean Above ground biomass carbon stock, Below ground biomass carbon stock and Total Biomass carbon stock in TAFs of Elevation I

Elevation I	AGB carbon stock (kg C ha^{-1})	BGB Carbon stock (kg C ha^{-1})	Total biomass Carbon stock (Kg C ha^{-1})
Balapu	105.514	24.857	130.367
Chiputa	668.699	157.024	825.710
Gumto	131.887	30.925	162.816
Khemlee	367.382	86.259	453.640
Lekhi	258.479	60.662	319.142
Midpu	333.240	79.505	412.745
Poma	102.550	24.052	126.600
Rose	172.795	40.503	213.304
Tok	218.300	51.478	269.779
Yupia	233.535	54.682	288.222
Mean	**259.24 (±53.64)**	**60.99 (±12.61)**	**320.23 (±66.26)**

Table 7. Mean Above ground biomass carbon stock, Below ground biomass carbon stock and Total Biomass carbon stock in TAFs of Elevation II

Elevation II	AGB carbon stock (kg C ha^{-1})	BGB carbon stock (kg C ha^{-1})	Total biomass carbon stock (Kg C ha^{-1})
Bangchi	253.710	59.622	313.332
Bangte	410.228	96.404	506.632
Bojo	133.448	31.360	164.808
Chullyu	232.131	54.551	286.682
Joram	121.159	28.472	149.631
Jorung	94.757	22.268	117.025
Langdang	94.543	22.240	116.783
Lumri	101.563	23.867	125.430
Nimte	5.829	1.370	7.199
Pania	103.651	24.358	128.009

Mean	155.10 (±36.12)	36.451 (±8.48)	191.553 (±44.61)

Table 8. Mean Above ground biomass carbon stock, Below ground biomass carbon stock and Total Biomass carbon stock in TAFs of Elevation III

Elevation III	AGB carbon stock (kg C ha^{-1})	BGB carbon stock (kg C ha^{-1})	Total biomass carbon stock (Kg C ha^{-1})
Amji	241.509	56.755	298.264
Bokam	253.671	59.613	313.284
Dui	217.972	51.224	269.196
Hari	91.163	21.423	112.586
Paka	22.560	5.302	27.862
Siiro	203.943	47.927	251.870
Tajang	86.309	20.283	106.592
Tassar	103.918	24.421	128.339
Tayo	14.251	3.349	17.600
Yaglung	216.580	50.896	267.476
Mean	**145.187 (±28.89)**	**34.119 (±16.79)**	**179.306 (±35.69)**

6.2.5 Woody species in TAFs containing the highest amount of biomass

The woody species with the highest amount of biomass were calculated and recorded (Table 9). In the Elevation I, the species with highest amount of biomass in TAFs were *Tectona grandis* (AGB =1248.290 kg ha^{-1}, BGB = 293.340 kg ha^{-1}), followed by *Artocarpus heterophyllus* (AGB = 658.380 kg ha^{-1}; BGB = 154.720 kg ha^{-1}), *Livistona jenkensiana* (AGB = 407.750 kg ha^{-1}; BGB = 95.820 kg ha^{-1}), *Psidium guajava* (AGB = 193.320 kg ha^{-1}; BGB = 45.430 kg ha^{-1}) and *Terminalia myriocarpa* (AGB = 183.780 kg ha^{-1}; BGB = 43.180 kg ha^{-1}).

In the TAFs of the Elevation II, the highest amount of biomass was found in Terminalia *myriocarpa* (AGB = 764.080 kg ha^{-1}; BGB = 177.820 kg ha^{-1}), followed by *Artocarpus heterophyllus* (AGB = 424.581 kg ha^{-1}; BGB = 99.770 kg ha^{-1}), *Phoebe cooperiana* (AGB = 389.39 kg ha^{-1}; BGB = 89.360 kg ha^{-1}), *Pyrus domestica* (222.670 kg ha^{-1}; 52.340 kg ha^{-1}) and *Terminalia bellirica* (115.300 kg ha^{-1}; 27.090 kg ha^{-1}).

In the elevation III, the woody species with highest amount of biomass were Pinus sp. (AGB = 531.650 kg ha^{-1}; BGB = 169.750 kg ha^{-1}), followed by *Artocarpus heterophyllus* (AGB = 425.780 kg ha^{-1}; BGB = 100.050 kg ha^{-1}), *Phoebe cooperiana* (AGB = 357.190 kg ha^{-1}; BGB = 78.410 kg ha^{-1}), *Terminalia myriocarpa* (AGB = 284.160 kg ha^{-1}; BGB = 48.560 kg ha^{-1}) and *Pyrus domestica* (AGB = 164.940 kg ha^{-1}; BGB = 38.760 kg ha^{-1}).

Table 9. Species with the highest amount of biomass in TAFs of Elevation I, II and III

Elevation I		
Species	**AGB (kg ha^{-1})**	**BGB (kg ha^{-1})**
Tectona grandis	1248.290	293.340
Artocarpus heterophyllus	658.380	154.720
Livistona jenkensiana	407.750	95.820
Psidium guajava	193.320	45.430
Terminalia myriocarpa	183.780	43.180
Elevation II		
Species	**AGB (kg ha^{-1})**	**BGB (kg ha^{-1})**
Terminalia myriocarpa	764.080	177.820
Artocarpus heterophyllus	424.581	99.770
Phoebe cooperiana	389.390	89.360
Pyrus domestica	222.670	52.340
Terminalia bellirica	115.300	27.090
Elevation III		
Species	**AGB (kg ha^{-1})**	**BGB (kg ha^{-1})**
Pinus sp.	531.650	169.750
Artocarpus heterophyllus	425.780	100.050
Phoebe cooperiana	357.190	78.410
Terminalia myriocarpa	284.160	48.560
Pyrus domestica	164.940	38.760

6.3 Discussion

This study analyzed the biomass levels of aboveground, belowground, and total biomass. Additionally, the carbon stock was assessed for the TAFs at varying elevations. Average values of biomass and carbon stock/storage were calculated as well. Comparable research was conducted by Singh (2014), who examined the biomass and carbon storage of vegetation across various agroforestry systems in the Giri catchment in Himachal Pradesh, taking into account all plant species within these systems, including trees, shrubs, and herbs. The current study focused exclusively on woody tree species since they represented the largest contribution to biomass content, while shrubs and herbs faced challenges in their harvesting methods. Most farmers were unprepared for harvesting their plants from the TAFs, which largely explained the lack of harvesting for shrub species, and there were very few of them available. In terms of herbs, these are seasonal crops that could lead to unreliable measurements of biomass content in the TAFs, which posed a significant limitation. This aligns with the observations made by Nair and Nair (2014), who noted that annual crops yield higher harvest index values, resulting in a lesser contribution of biomass to overall carbon sequestration in agroforestry systems compared to trees and perennial shrubs. Findings from Roshetko et al. (2002) and Kirby and Potvin (2007) showed that tree-based systems preserved more carbon than grasslands or field crops in similar ecological contexts.

The significance of forests and trees in the carbon cycle is widely acknowledged (Lal and Singh, 2000), and forests are considered to be substantial carbon sinks (Wang et al., 2010). Initiatives are underway to enhance the carbon storage potential of terrestrial plants through various land use practices, with agroforestry emerging as a key strategy (Canadell and Raupach, 2008).

There is a common belief that agroforestry systems possess a greater ability to sequester carbon when compared to single-species crop systems or pasturelands (Nair et al., 2010; Kumar and Nair, 2011). Research conducted in Bukidnon province, Philippines (Labata et al., 2012), provided data on carbon stocks from three different agroforestry systems, indicating that these systems accounted for 23-44% of the total carbon stock found in natural forests.

In the current study, the average biomass carbon stock values were found to decrease in the order of Elevation I > Elevation II > Elevation III, indicating that values diminished with rising altitude. This suggests that the TAFs at Elevation I possess the highest potential for CO_2 mitigation, followed by Elevation II and III. Comparable findings were reported by Minj (2008), who discovered that all forms of biomass, including belowground and total biomass, decreased as altitude increased across various land use systems. The capacity for biomass and carbon storage varies by geographical regions and is also influenced by the growth and characteristics of the tree species present in the system (Rajput et al., 2015; Bhushan et al., 2023). As noted by Sharma et al. (2023), the overall carbon stock in these systems increased from the tropical zone to the wet temperate zone before it declined in the dry temperate zone, reflecting a similar trend in our study with a decreasing pattern from tropical TAFs to subtropical zones and then a slight rise in the temperate zone. The study was inconsistent with the results of Sharma et al. (2023), which indicated that biomass production had a positive correlation with altitude, increasing as altitude increased.

Integrating fruit and timber trees into agricultural systems can increase carbon storage in farming regions while still permitting the growth of food crops (Kursten, 2000). This study also found that traditional agroforestry farms contained a variety of timber and fruit-bearing trees alongside seasonal food crops, which have the potential to enhance carbon storage. Agroforestry systems are believed to possess a superior capacity for carbon sequestration compared to grasslands or field crops. Besides capturing carbon in both biomass and soil, these systems can aid in carbon conservation (by alleviating pressure on forest carbon reserves) and carbon substitution (by decreasing fossil fuel usage through the provision of fuelwood), as detailed in the current study where primarily woody tree species were cultivated for fuelwood and construction uses.

In this study, the highest potential for biomass carbon was observed in woody species such as *Tectona grandis*, *Terminalia myriocarpa*, and various *Pinus* species. Similarly, Nath et al. (2022) identified that woody species like *Mangifera indica* contributed the most biomass carbon at 1.1 Mg ha-1, while *Areca catechu* had the lowest at 0.183 Mg ha-1 in Traditional Agroforestry systems. Nath et al. (2011) also noted that species like *Aphanamixis polystachya* (0.614 Mg ha-1), *Cocos nucifera* (0.296 Mg ha-1), *Aquilaria malaccensis* (3.511 Mg ha-1), *Elaeocarpus* species (1.013 Mg ha-1), *Parkia timoriana* (0.561 and 0.482 Mg ha-1), *Toona ciliata* (0.158 Mg ha-1), and *Delonix regia* (0.317 Mg ha-1) significantly contributed to biomass in their agroforestry study sites. The current investigation found that home garden cultivation was commonly practiced, aligning with the findings of Subba et al. (2018), which suggested that practices that enhance production can indirectly promote greater carbon sequestration.

Conclusion:

According to Newaj et al., (2016), climate change can be mitigated by incorporating trees into agriculture to improve green cover while improving crop coping abilities. The tree-based systems are proven to be a vital component of Indian agriculture with good management practises, and they can be promoted to acquire ecological services. Sanneh (2007), Minj (2008), Gupta & Bandhna (2011), and Khaki & Wani (2013) all explained how tree-based agroforestry systems have a significant biomass production potential. The current study only considered the woody species for the estimation of biomass, as it was done in the case of diversity study as mentioned above. Since, the herbs and other crop species were seasonal and they varied depending on their harvesting time, these were excluded from the biomass estimation procedure. Moreover, the trees were mostly permanent structures, and also contributed to higher amount of biomass content in the agroforestry systems.

Quantifying carbon stocks at the regional/landscape level in Northeast India is crucial for long-term management of multiple land uses that are changing due to anthropogenic factors.

In this study, it was observed that the mean values of Above Ground Biomass (AGB), Below Ground Biomass (BGB), and total biomass decreased with an increase in altitude. The greatest potential for biomass carbon was noted in woody species such as *Tectona grandis*, *Terminalia myriocarpa*, and various *Pinus* species. Agroforestry systems located in tropical regions exhibited the highest carbon storage values when compared to other altitudinal zones. This is likely due to the greater diversity of woody species found in the tropical area. This study highlights the significance of selecting tree or woody species for agroforestry systems based on different elevation zones in a cost-effective way, which serves as an important strategy for addressing global warming challenges, particularly in the Himalayan regions that need such initiatives. These systems could be likened to mixed multi-storey agroforestry frameworks prevalent in various parts of India and globally, known to sequester substantial amounts of carbon. Therefore, promoting and supporting these types of systems could play a vital role in mitigating climate change.

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