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Research Article

Carbon Sequestration Potential of Coffee Based Agro-Forestry Systems in Nono Sale Forest, Southwest Ethiopia

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Abstract

The study was conducted to demonstrate empirically the carbon stocks of Coffee based agroforestry at Nono Sale District, southwestern Ethiopia. Stratify the study area into three strata based on the Species Abundance, availability of coffee and Density (Mixed Natural Forest coffee strata 51 ha, Albizia strata 34 ha and Syzygiam strata 20 ha) a total 34 nested plots 20 m × 20 m, 2 m × 2 m and 1 m × 1 m were laid in the stratum to measure the biomass of woody plants, herbaceous, and litter biomass respectively. Soil samples was collected from the upper 0-30 cm depth. The Estimation of Carbon was done by using the generic equation AGTB =0.0673 × $(\rho D2H)^{0.976}$ and AGB = 0.147 × $d40^2$ for tree biomass and coffee respectively. The total carbon stored in the CAF in the Strata ranged from 188.54 to 232.43 Mg ha^{-1} with a mean of 203.97 Mg ha^{-1}. The Albizia CAF strata had significantly more carbon than natural mixed forest CAF Strata and Syzygiam CAF strata. 232.43 Mg ha^{-1}, 232.43 Mg ha^{-1} and 188.54 respectably. Soil carbon was found 10.32Mg ha^{-1} in natural mixed forest CAF Strata, 9.8 Mg ha^{-1} the Albizia CAF strata ha^{-1} and 7.27 Syzygiam CAF strata. There was statically significant deferens at 0.1% but there is no significant effect at P< 0.05% between soil carbon stocks in the strata. On average, 75% of the carbon stored in tree biomass (above and below ground) and it is the largest carbon storage of the study area.

Keywords

Carbon Sequestration, Coffee, Agroforestry, Biomass

1. Introduction

Background of the Study

Carbon sequestration is the process through which carbon dioxide from the atmosphere is absorbed by trees, plants and crops through photosynthesis, and stored as carbon in biomass (tree trunks, branches, grasses, foliage, and roots) and soil [6]. Agro-forestry component act as a sink through the process of tree growth and resultant biological carbon sequestration for C by fixing carbon during photosynthesis and storing excess carbon as biomass Carbon sequestration can be increased by increasing the amount of standing biomass and increasing the rotation length of trees and shrubs, and in converting the biomass into durable products [25].

The agroforestry system contributes to climate change mitigation directly through accumulation of C in above and

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belowground biomass, soil and, indirectly through avoiding deforestation via sustainable intensification (land sparing) and provision of alternative sources of products otherwise derived from forests [36]. Agroforestry is therefore particularly suited to reducing emission from deforestation and forest degradation, and accumulating C through sustainable forest management, forest conservation and afforestation and reforestation [5].

The agroforestry system has a high potential for C sequestration owing to availability of trees and shrubs while simultaneously contributing to maintaining food and nutrition security. Besides, the system diversifies household income, provides fiber and energy to local communities, and serves for agro-tourism, aesthetic values, demonstration, and education [14, 23] And these systems improve soil fertility through increasing soil organic matter and biological nitrogen fixation by leguminous trees. Trees help recover nutrients and conserve soil moisture, and hence, may also enhance agricultural productivity. Agroforestry can provide assets and income from carbon and wood energy and enhancement of local climate conditions [17].

Agroforestry systems play a great role in carbon storage. Due to the diversification of trees, agroforestry or forest farming has a higher carbon storage potential than mono-cropping.

Due to high plant species diversity, agroforestry systems have larger chances to sequester C in the long-term than annual cropping systems, adding aboveground C storage capacity through a broader diversity of living forms, including fruit or timber trees, perennial crops and potential fertilizer and fodder trees. Albrecht and Kandji, [1, 13] estimated a potential C sequestration in tropical agro forestry systems of 95 t C ha-1 (varying widely be-tween 12 and 228 t C ha^{-1}).

Ethiopia farmers have experience of cultivating coffee crop under different shade trees. Albizias chimperiana, Albizia gummifera, Millettia ferruginea, Cordia africana and Erythrina abyssinica are the most compatible trees for coffee shade in Ethiopia in addition to shade services, the high productivity of these forests may make them particularly responsive to the growth enhancement from rising atmospheric CO2 concentrations [30]. Several researchers also revealed that coffee-based agroforestry systems have larger chances to sequester C in the long-term [21, 31, 33, 20]. There-fore, this study was conducted to estimate the carbon sequestration potential of coffee-based agroforestry land use systems and its contribution in climate change mitigation in the study area.

2. Description of the Study Area

2.1. Location

The study was conducted in Nono Sale District. Nono Sale District is one of the 13 Districts of Ilubabor Zone of Oromia Region, South-west Ethiopia, and is located at distance of 694 km southwest of Addis Ababa. It is located within the longitudinal range of 7° 45°N 35′ 35 ° 15′ E latitudinal. Nono Sale is bordered on the southwest by the Gambella region, on the north by Bure, on the northeast by Ale, and on the southeast by the southern nations and nationalities and peoples region. Altitude of the District ranges from 1300 to 2552 masl.

2.2. Climate

The long-term average rainfall recorded in the study area [24] was founded to be maximum of 2200 mm and minimum of 1700 mm. Mean minimum and maximum temperatures are 10 ℃ and 27 ℃, respectively [8].

2.3. Land Use and Soil Type

According to Oromia Forest and Wildlife Enterprise Nono Sale district [26], re-demarcation of forest and settlement in 2012 the total area of land the district is 215,550 hectares and out of these 204,772 hectares of land was covered by forest which accounts 94% from the total area. According to FAO/UNESCO soil classification system, the major soils of the woreda are dystric nitisols (red-basaltic soil), dystric gleysols, orthic acrisol and orthic solonchaks are the most prevalent soils in the study area.

2.4. Agro-ecology

The district is divided into three agro ecology zones that is Beda 32% (7 Ganda), Bada Dare 50% (10 Ganda) and Gamooji 18% (4 Ganda). The district is highly potential for production of coffee, honey and livestock, which is mainly undertaken by small holder farmers. The study area is best suited for agro forestry systems and practices.

2.5. Demography and Socio-Economy of the Study Area

According to CSA report of 2007 the total population of the district was estimated at 33,573. The total number of the rural population is 29,039 out of which 14381 are male and 14,658 are female. The total numbers of rural HHs are 4630 (441 female and 4189 male). The total number of urban populations is 4534, out of which 2066 are male and 2468 are female.

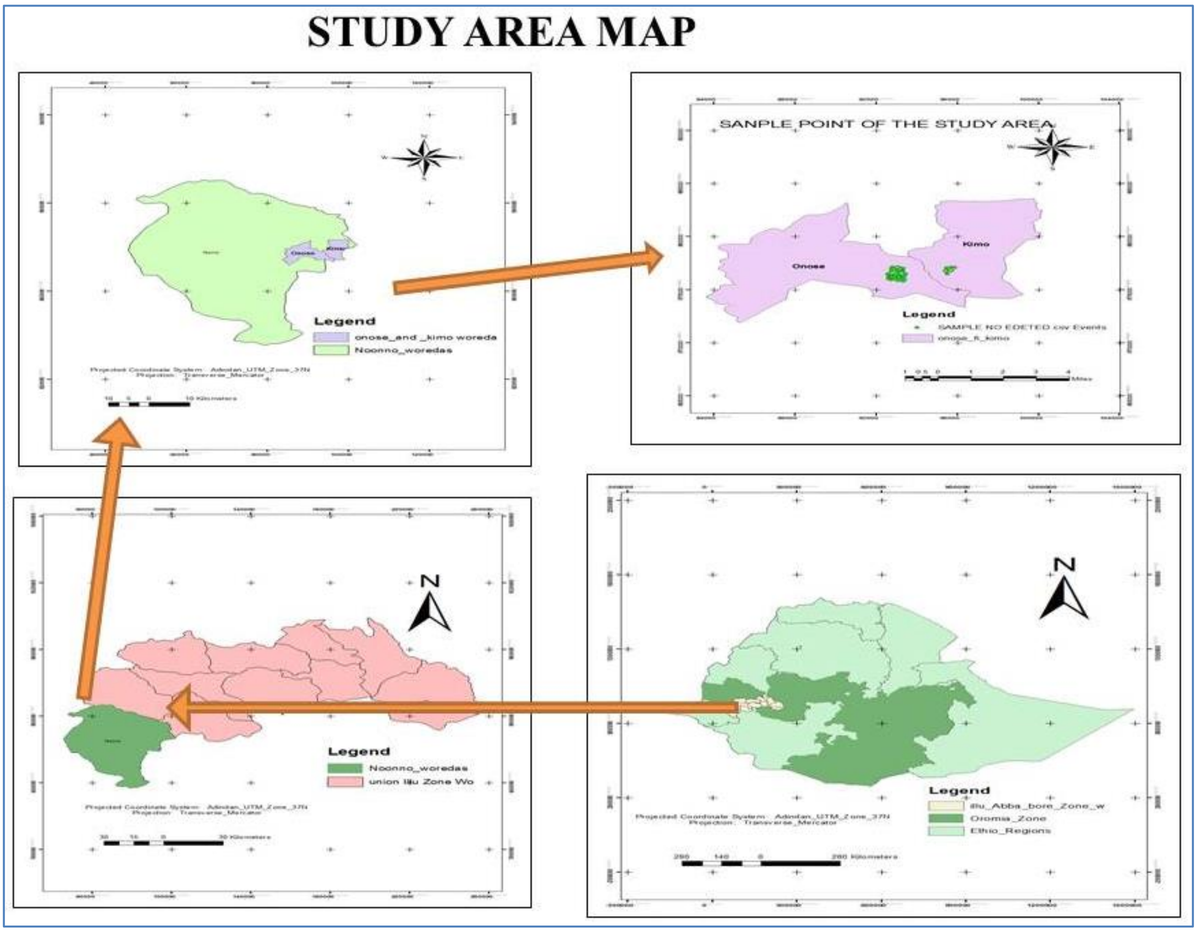

Figure 1. The map of study area.

2.6. Farming Systems

There are several potential rivers which can be used for irrigation. The dominant agricultural production system of district is coffee-based agro-forestry system which occupies about 12000 hectares of land and only 5015 hectares of land is used for crop production comprising 75.33% maize, 10.6% bean, 5.54% field pea, 5.38% teff, and 3.11% barely [24]. Inset is one of the other major perennial crops produced in the district.

According to Nono Sale Livestock and Fishery Office [24], bee production is another dominant practice in the district. Nearly 510 tons honey is produced per year because of potential of forest cover. It is harvested 2-3 times per year. Total beehive of the district is 51,774 from these 888 are modern hive, 1,119 are transitional hive and 49,767 are traditional hive [24]. So, Nono Sale district has economic potential with reliable rainfall for agriculture, coffee and honeybee production. Relatively, the district has adequate physical and market infrastructure. Infrastructures like telecommunication, electric power and schools are on expansion in the district. Rural roads that branched to different Ganda and villages have played significant role of the supply of inputs and output of agricultural production.

3. Methodology

3.1. Sources of Data

The study was conducted by using both qualitative and quantities data based on primary and secondary source that was obtained from different sources like individual household, Government offices and published and unpublished materials accordingly. Nono sale Agricultural office and Oromia Forest and wildlife Enterprise Nono sale district was used for secondary data source about the coffee based agro-forestry land use system. The primary data was collected by direct measurement of height, diameter, weight and laboratory for soil organic carbon.

3.2. Experimental Design and the Study Area

The experimental area has a potential of coffee based agro-forestry and from the total land of the district 215,550 hectare; plantation coffee covered with 13,669 hectare, semi forest coffee 47,000, hectare, 2,015 hectare covered by natural coffee forest; totally coffee occupied 62,684 hectare of land 29% from total land. The area has also a source for indigenous trees which have been used for coffee shade and carbon sequestration. *Albizia gummifera, Milletia ferruginea, Croton macrostachyus, Schefflera abyssinica, Cordia Africana, Diospyros abyssinica, Ekebergia capensis Allophylus abyssinicus* and so on [24]. Out of the vast forest resource in the district my study area was focused on Qofe forest which exists between onose and kimo Ganda (kabale). The experiment was conducted thought direct measuring of different biomass of coffee based agro-forestry, the above ground live biomass, herbaceous, liter and carbon from the soil.

3.3. The Delineation, Map, Stratification, and SAMPLE Technique

The map of the study area was prepared by ArcGIS 10.4 Software. Stratified sampling was used to categorize the coffee based Agro-forestry into relatively homogenous strata The study area was Stratify with indigenous local community which is well know the area; 105 hectare of coffee based agro-forestry identified and delineated (demarcate) by using GARMIN H 72 GPS; than Stratify the study area into three strata based on the Species Abundance, availability of coffee and Density (Mixed Natural forest coffee strata 51 hek, Albizia strata 34 hek and Syzygiam strata 20 hek). Sample plots will be laid in the stratum using purposive sampling technique. In the stratum, biomass for coffee and all trees in the sample plot area was measured. For 105 hectare of study area 34 sample plots was surveyed. 17 sample plots for Mixed Natural forest coffee strata 51 hek 11 for depends on the number of strata to be identified during stratification process Albizia strata 34 hek and 6 for Syzygiam strata 20 hek.

Nested sample plots of 20 m x 20 m, 2 m x 2 m and 1 m x 1 m was laid in the stratum to measure the biomass of woody plants, herbaceous/saplings, and litter biomass, respectively. Soil samples was collected from the upper 0-30 cm depth at four corners and center of the larger plot and mixed to make one composite sample for each nested plot to estimate soil organic carbon in the stratum. All sampling points was geo-referenced using GPS.

3.4. Estimation of Carbon Stocks in Different Carbon Pools

3.4.1. Estimating Above-Ground Living Biomass (AGTB)

In the larger plot, diameter at breast height (DBH) and tree height (H) will be measured for every live tree using caliper and hypsometer, respectively. During estimation of biomass the Wood specific gravity (density) was obtained at species level from the Global Wood Density database [5] and to convert local tree Name at study area to scientific name we used Azene Bekele [2] useful tree and shrubs in Ethiopia. Then, the aboveground biomass of live trees with DBH ≥ 5 cm was estimated by use the revised non-destructive allometric equation described by Chave *et al*., [4] This equation was selected because it was developed for tropical forest stands:

$$AGTB = 0.0673 \times (\rho D2H)^{0.976} \quad (1)$$

Where AGTB is aboveground tree biomass (kg), ρ is wood specific gravity (g cm-3), *D* is tree DBH (cm), and H is tree height.

3.4.2. Estimation of Belowground Biomass (BGB)

According to Geider *et al.*, and Genene *et al*., [11, 12], the below ground biomass estimation is more difficult and time consuming than estimating aboveground biomass. In this research, MacDicken [16] standard method for estimation of belowground biomass which is 20% of aboveground tree biomass i.e., root-to-shoot ratio value of 1:5 will be used. Thus, the equation developed by MacDicken [16] will be used to estimate below-ground biomass as follows:

$$BGB = AGB*0.2 \quad (2)$$

Where, BGB is below ground biomass, AGB is above ground biomass, 0.2 is conversion factor (or 20% of AGB).

3.4.3. Herbaceous / Saplings Biomass

Any live vegetation (Grass and herbaceous) < 5cm DBH was considered as non woody above ground biomass. The sampling frame method (i.e. 2 m × 2 m frame) was deployed to measure these herbaceous/saplings vegetation. The frame will be laid at the four corners and the center of the sample plot; then cut all living herbaceous (saplings) inside the frame at base and record the fresh weight, then estimate biomass as follow:

$$\text{Dry mass} = \frac{\text{dry mass}}{\text{all fresh mass}} \times \text{sample of fresh mass} \quad (3)$$

3.4.4. Litter Biomass

The dry matter of litter and finer plant debris will collect from 1 m x 1 m plot in every four corners and center of the main 400 m^2 plot in the nest. In the 1 m^2 plot, litter was collect and total fresh weight will be record, from which 250 g sample size taken to the laboratory, oven-dried at 85 ℃.

$$\text{Litter biomass} = \frac{\text{dry mass}}{\text{all Litter}} \times \text{sample of Litter} \quad (4)$$

3.4.5. Estimation of Aboveground Biomass for Coffee

The Aboveground coffee (coffee arabica) biomass was estimated used the available Allometric equations Developed by Negash *et al.* [22]. All coffee stamp ≥ 3.8cm diameter at 40 cm in the larger plot was measured. The equation is as follow

$$\text{Coffee } (\textit{Coffee arabica}) \text{ AGB} = 0.147 \times d40^2 \quad (5)$$

Where AGB = aboveground biomass kilogram/plant d40 = diameter at 40cm

3.4.6. Estimation of Belowground Biomass for Coffee

While belowground biomass of *Coffee arabica* was estimated based on root to shoot ratios except enset [15, 22]; the equation is as follow:

$$BGB = 0.28 \times AGB \quad (6)$$

Where BGB =Billow ground Biomass kilogram/plant AGB= aboveground biomass

3.4.7. Soil Organic Carbon

The SOC (Mg ha^{-1}) to specific soil depth was estimates as

$$SOC = OC * \rho b * d * CFU \quad (7)$$

where OC is mg g-1 C concentration, d is soil thickness or depth i.e. 0–30 and 30–60 cm, ρb is bulk density of the soil (g cm-3) and CFU is correction factor for units (= 10-1).

3.5. Estimation Carbon from Biomass

3.5.1. Estimation Carbon from Biomass of Each Pool

The amount of C stored in each pool (kg) was determined by multiplying the biomass of each pool by 0.5 [4] as follows:

$$C\ x = Biomass * 0.5 \quad (8)$$

3.5.2. Estimation Carbon from Biomass

According to Kuyah and Negash [15, 21]; Equation the amount of C in the Coffee arabica multiplying by .049 in AG and BG biomass of coffee; the equation is as follow

$$C\ x = Biomass\ of\ C.\ arabica * 0.49 \quad (9)$$

3.6. Estimation of Equivalent CO_2 Sink

According to Craig *et al*., [7]; 1 Mg of C = 3.67 of Mg of CO_2. So that the total equivalent CO_2 Sink (Mg) in the Agro-forestry was estimated on the total C stock listed below

$$CO_2\ e = 3.67 * CT \quad (10)$$

Where CO_2 e =Carbon dioxide Equivalent CT = total Carbon 3.67 is conversion factor.

3.7. Statistical Data Analysis

The Normality of the data was checked by HDS test software, and the results were subjected to Data analyzed of variance using R version 4.0.3 [27] software as well as XLSTAT Version software [35]. Principal component analysis (PCA) was used relationship between components of biomass. The least significant difference (LSD) of means at $P < 0.05$.

4. Results

4.1. Biomass Accumulation at Different CAF Strata

The accumulation of Biomass in the Coffee Based Agro-Forestry (CAF) land use system usually influenced by kind of Shade tree species, Abundance of the Species, type of CAF management Practice, type of pool, tree size class and density, species composition; the above mentioned factor can affect (determine) the C storage level of the Coffee based Agro-Forestry in the study area.

The study result shows that Albizia CAF strata had accumulated large volume of biomass than Natural Mixed Forest CAF Strata and Syzygiam CAF strata (Table 1. Total biomass accumulation, the sum of biomass stored in all components). Total biomass accumulation, the sum of biomass stored in all components, was highest for the Albizia CAF strata followed Natural Mixed forest CAF and Strata and Syzygiam CAF strata. Larger biomass in Albizia CAF strata might be attributed to DBH, Height and Density of species.

The study result shows that the average biomass stored (Mg ha^{-1}) in different biomass pools Increase in order LB > AGHB> BGCBL> BGLTB > AGLCB> AGLTB for all types of Strata. The biomass accumulated in the study by biomass components ranged from 4.26 Mg ha^{-1} in liter fall to 253.56 Mg ha^{-1} in the aboveground biomass pools.. Canopy cover, abundance, and height of trees might be attributed to the larger proportion of biomass in the aboveground biomass pool.

The accumulation of coffee tree Biomass was high in Albizia CAF strata followed Natural Mixed Forest CAF Strata and Syzygiam CAF strata. Larger biomass in Albizia CAF strata might be attributed to DBH and abundance of coffee. The biomass accumulated of coffee in Aboveground and below ground in the strata was high in Albizia CAF strata 99.04 Mg ha^{-1}, 96.9 Mg ha^{-1} and 38.4 Mg ha^{-1} for Natural Mixed forest CAF Strata and Syzygiam CAF strata respectively.

Table 1. Biomass accumulation in the different CAF Strata and biomass components.

no	Strata	Biomass storage (Mg ha^{-1}) in different components						
		AGLTB	BGLTB	AGLCB	BGCBL	AGHB:	LB	Total
1	Natural Mixed Forest CAF Strata	215.59	43.07	71.8	20.1	7.72	4.75	363.03
2	Albizia CAF strata	284.59	56.91	77.38	21.66	3.61	3.1	447.25
3	Syzygiam CAF strata	260.49	52	30	8.4	7.5	4.93	363.32
*	Mean	253.56	50.66	59.73	16.72	6.28	4.26	391.2
*	Cv	25.87	25.87	16.56	16.56	17.97	14.95	
*	P value	0.02523*	0.02523*	2.192e-09***	2.199e-09***	4.164e-10***	2.534e-07***	

AGLTB = aboveground tree live biomass BGLTB = below ground live tree biomass AGLCB= aboveground live coffee biomass BGLCB= below ground live coffee biomass AGHSB =aboveground grasses, herbaceous and saplings biomass LB = litter biomass CAF = coffee agro-forestry.

Biomass accumulation of CAF from component in the study area from the mean; the largest biomass accumulation was found in AGLTB which accumulate 64.82% and the smallest was found in LB 1.09%.. The accumulation of BGLTB and AGHB was 12.95%, 1.61% respectively. In both aboveground and below ground accumulation Coffee tree was account 19.54% from the mean biomass accumulation of CAF. The quantity of biomass accumulated in the in all pool was significantly different at (p< 0.05) indicating biomass different was occurred in all pool and in all strata.

When we compeer the accumulation of biomass from CAF strata; largest amount of AGLTB was found in Albizia CAF strata; 37%, 34%, 28% found in Syzygiam CAF strata and Albizia CAF strata also they have significantly deference at P < 0.02523. The above result was the same for BGLTB. Because it is the 20 & of AGLTB. Next to AGLTB the largest biomass accumulation was found in coffee tree; the Albizia CAF strata has the largest biomass which account 43%, 40 in Natural Mixed forest CAF Strata and 17 for Syzygiam CAF strata and also the above result was the similar in BGCBL because it was the rot shot ratio of above ground they have highly significantly deference between strata at P < 2.192e-09 ***. biomass in AGHB high; 41% was found in Natural Mixed forest CAF Strata, 40% in Syzygiam CAF strata and 19% was found in Albizia CAF strata. It also have highly significant difference between strata at F < 4.164e-10 ***. The smallest biomass accumulation in the strata was found in LB; from these 39% was found in Syzygiam CAF strata, 37% and 29% was found in Natural Mixed forest CAF Strata and Albizia CAF strata.

They have highly significantly deference between strata at P < 2.534e-07 ***.

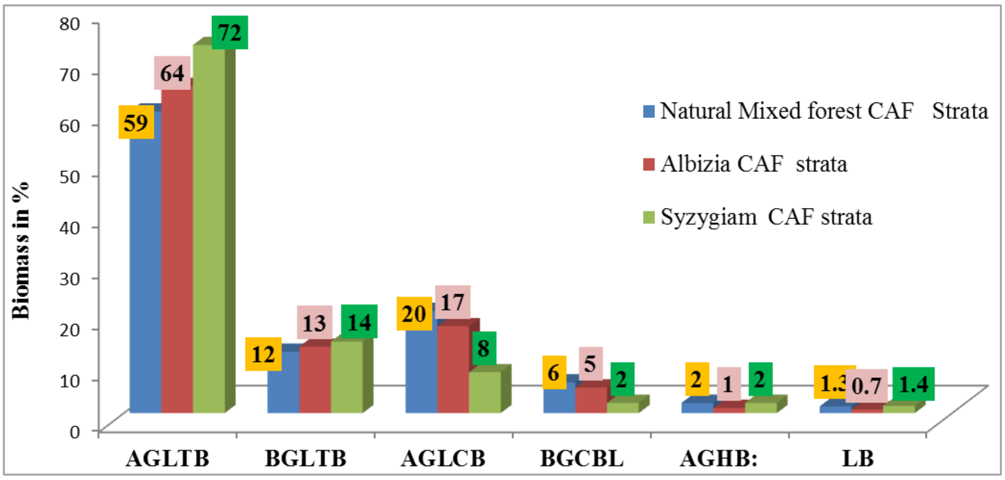

Figure 2. Biomass accumulation in the different CAF Strata and biomass components in%.

4.2. Carbon Storage Capacity of Different Forest Stands and Pools

The total carbon stored in the CAF in the Strata ranged from 188.54 to 232.43 Mg ha^{-1} with a mean of 203.97 Mg ha^{-1}. The study result shows that Albizia CAF strata had accumulated large volume of Carbon storage than Natural Mixed forest CAF Strata and Syzygiam CAF strata (Table 2. Total Carbon Storage a, the sum of Carbon stored in all components).

The mean Carbon storage in the study area by Carbon components ranged from 2.13 Mg ha^{-1} in liter fall to 126.78 Mg ha^{-1} in the aboveground Carbon pools. Trees contained the greatest amount of carbon followed by coffee tree Carbon storage. When all aboveground, belowground, and soil components were included, the Albizia CAF strata had significantly more carbon than Natural Mixed forest CAF Strata and Syzygiam CAF strata. 232.43 Mg ha^{-1}. 232.43 Mg ha^{-1} and 188.54 respectably.

The total C storage capacity of different strata decreased in the following order: AGLTC > AGLCC > BGLTC > SOC > BGLCC > AGHC > LC. Soil carbon was found 10.32Mg ha^{-1} in Natural Mixed forest CAF Strata, 9.8 Mg ha^{-1} the Albizia CAF strata ha^{-1} and 7.27 Syzygiam CAF strata. There was statically significant deferens at 0.1% but there is no significant effect at P< 0.05% between soil carbon stocks in the strata.

Table 2. C storage potential in the different pools by major CAF strata.

No	Strata	Carbon storage (Mg ha^{-1}) in different components							
		AGLTC	BGLTC	AGLCC	BGLCC	AGHC	LC	SOC	Total
1	Natural Mixed forest CAF Strata	107.80	21.54	35.18	9.85	3.86	2.38	10.32	190.92
2	Albizia CAF strata	142.30	28.46	37.92	10.61	1.81	1.55	9.80	232.43
3	Syzygiam CAF strata	130.25	26.00	14.70	4.12	3.75	2.47	7.26	188.54
4	Mean	126.78	25.33	29.27	8.19	3.14	2.13	9.13	203.97
5	Cv	25.87	25.87	16.56	16.56	17.97	14.94	61.45	
6	F value	0.02523*	0.02523*	2.191e-09***	2.191e-09***	4.164e-10***	2.534e-07***	0.3781	

The distribution of carbon storage potential in CAF of the study area; on average, 75% of the carbon stored in tree biomass (above and below ground). It was the largest carbon storage of the study area, 18%in coffee tree (also in above and below ground) the second largest storage of carbon next to tree 4% in the soil with the depth of 0-30 cm 2%i n AGHC, and 1%in liter fall.

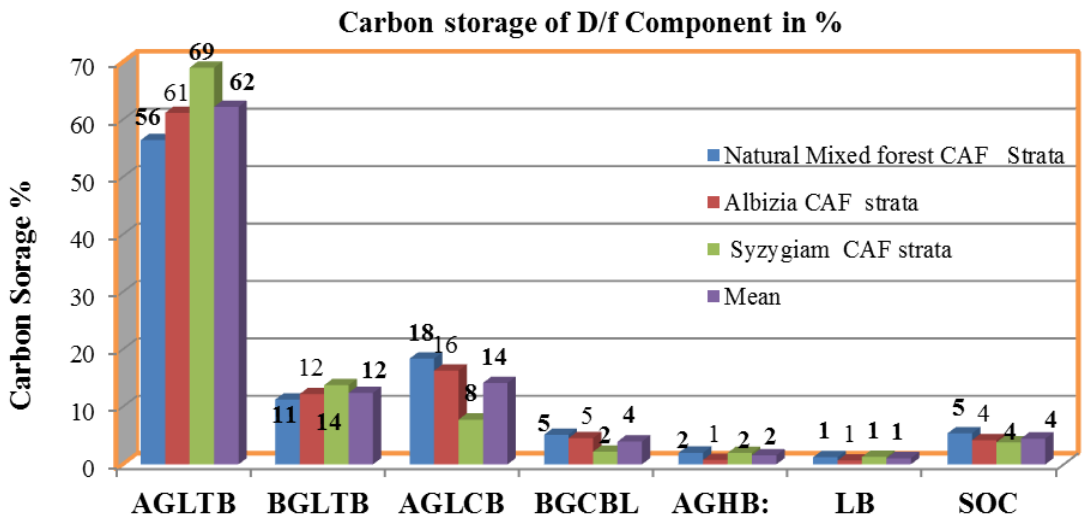

Figure 3. C storage potential in the different pools by major CAF strata in%.

4.3. Climate Change Mitigation and CO_2 Equivalent of Coffee Based Agro-Forestry

In the entire CAF of the study area, a total of 21.41Gg C was stored in the Vegetation (tree and coffee tree) plus soil. 9.74Gg C in Natural mixed forest CAF Strata, 7.90Gg C and 3.77Gg C in Albizia CAF strata and Syzygiam CAF strata, respectively. So, deforestation (land use change) of each hectare of Natural Mixed forest CAF Strata, Albizia CAF strata and Syzygiam CAF strata would cause the loss of about 190.92, 232.43 and 188.54, respectively. Supposed deforestation of the whole Coffee based Agro-forestry of the study area would emit 78.58Gg CO_2 to the atmosphere.

Table 3. *Total C stock and equivalent carbon-dioxide sink across different forest stands.*

No	Type of CAF strata	Total C stock (Gg)	Equivalent CO_2
1	Natural Mixed forest CAF Strata	9.74	35.74
2	Albizia CAF strata	7.90	29.01
3	Syzygiam CAF strata	3.77	13.84

* 1Gg =1000 tons

5. Discussion

The result showed that; the total biomass C stocks of the Coffee based Argo-forestry land use systems of the study area (203.97 Mg C ha^{-1}) are within the range reported for Global agroforestry systems (12−228 Mg C ha^{-1}) [9, 1]; but substantially higher than the range reported for agroforestry systems in sub-Saharan Africa (4.5–19 Mg C ha^{-1}) [32], However, our values were lower than reported for coffee agro-forests in Guatemala from 74.0 to 259.0 Mg C ha^{-1} [18]. It also lower than reported in in Mexico with the range of 167.4–213.8 Mg C ha^{-1} [29].

Similarly, the biomass C stocks (average 203. 97Mg C ha^{-1}) of CAFS in this study was higher than that of Coffee based agroforestry systems practiced at Mana district, southwestern Ethiopia (194.96 Mg C ha^{-1}). Other studies have shown carbon stocks of shade-grown coffee systems to equal 82 Mg C ha^{-1} in Indonesia [34], 82 Mg C ha^{-1} in [10] and Coffee agro-forestry in Gera, Jimma Zone, South-West Ethiopia 58.3 Mg C ha^{-1}] [19].

The difference in biomass C stocks might be due to various factors such as inclusion of coffee plants in carbon accounting, difference in the adopted allometric equation and site factors like Management practice and climate. For instance, in the CAFS studied by Mohammed and Bekele [19], the diameter of coffee shrubs was measured at 15 cm above ground while in our study; the diameter was measured at 40 cm above-ground. In addition, in the case of Coffee based Argo-forestry System studied by Mohammed and Bekele [19] trees and coffee aboveground biomass was determined using Brown *et al* and Segura *et al* [3, 28] allometric equations, respectively. But, for this study, the generic equation developed by Chave *et al* *[4]* for tree biomass and Negash *et al*. [22] for coffee.

6. Conclusion

Generally, recognition of the important role of coffee agro-forests may play in the global carbon cycle, quantifying and understanding the carbon profile of shade-grown coffee systems is critical to the development of climate change mitigation strategies. The study was conduct at kofe Coffee Based Agro-forestry of Nono Sale District, Ilubabor Zone, Ethiopia. 105 hectare of coffee based agro-forestry identified; than Stratify the study area into three strata based on the Species Abundance, availability of coffee and Density (Mixed Natural forest coffee strata 51 ha, Albizia strata 34 ha and Syzygiam strata 20 ha). 34 for sample area was selected after stratify the area.

The Estimation of Carbon was done by using the generic equation developed by Chave *et al* *[4]* for tree biomass and Negash *et al*. [22] for coffee. The study result shows that Albizia CAF strata had accumulated large volume of biomass than Natural Mixed forest CAF Strata and Syzygium CAF strata. The biomass accumulated in the study by biomass components ranged from 4.26 Mg ha^{-1} in liter fall to 253.56 Mg ha^{-1} in the aboveground biomass pools.

The accumulation of coffee tree Biomass was high in Albizia CAF strata followed Natural Mixed forest CAF Strata and Syzygiam CAF strata. The biomass accumulated of coffee in Aboveground and below ground in the strata was high in Albizia CAF strata 99.04 Mg ha^{-1}, 96.9 Mg ha^{-1} and 38.4 Mg ha^{-1} for Natural Mixed forest CAF Strata and Syzygiam CAF strata respectively.

The total carbon stored in the CAF in the Strata ranged from 188.54 to 232.43 Mg ha^{-1} with a mean of 203.97 Mg ha^{-1}.

The mean Carbon storage in the study area by Carbon components ranged from 2.13 Mg ha^{-1} in liter fall to 126.78 Mg ha^{-1} in the aboveground Carbon pools. CAF of the study area, a total of 21.41Gg C was stored in the Vegetation (tree and coffee tree) plus soil. So, deforestation (land use change) of each hectare of Natural Mixed forest CAF Strata, Albizia CAF strata and Syzygiam CAF strata would cause the loss Carbon; of about 190.92, 232.43 and 188.54, respectively.

7. Recommendation

To overcome the problem of climate change two strategies are stated: adaptation and mitigation. The Study area indicated that there was significant sequestration of carbon in different component of biomass (tree, coffee, soil…) and also the coffee based agro forestry was source of honey production and spices. Therefore, to conserve coffee based agro forestry by each concerned bodies such as agricultural sector, environmental sector and Non-Government Organization such as REDD+ should account in his program.

1. Non-Government Organization should be focuses on creating awareness among societies about coffee based agro forestry conservation and finding market for the product which came from CAF (Coffee production, Spices and honey) for its sustainability.
2. Government organization (Agriculture office) should have to work with the community on overall activates done at CAF.
3. Encouraging the local community on their indigenous knowledge of conservation CAF.

Abbreviations

AGB	Above Ground Biomass
AGC	Above Ground Carbon
AGHSB	Aboveground Grasses, Herbaceous and Saplings Biomass
AGLCB	Aboveground Live Coffee Biomass
AGLTB	Aboveground Tree Live Biomass
BGB	Below Ground Biomass
BGC	Below Ground Carbon
BGLCB	Below Ground Live Coffee Biomass
BGLTB	Below ground live tree biomass.
CAF	Coffee Based Agroforestry
CRGE	Ethiopia's Climate-Resilience Green Economy
DBH	Diameter at Breast Height
FAO	Food and Agricultural Organization
FDRE	Federal Republic of Ethiopia
GHG	Green House Gasses
GIS	Geographical Information System
ICO	International Coffee Organization
IPCC	Intergovernmental Panel For Climate Change
LB	litter biomass
m a s l	Meter above sea level
NBP	Net Biome Production
NEP	Net Emission Production
NSAO	Nono Sale Agriculture Office
NSLO	Nono Sale Livestock Office
OFWENSD	Oromia Forest and Wildlife Enterprise Nono Sale District
SOC	Soil Organic Carbon
UNFC	United Nations Framework Convention on Climate Change

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Conflicts of Interest

The authors declare no conflicts of interest.

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