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Estimating of Coffee Plantation Carbon Stock in Jatikerto and Surrounding Areas

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ABSTRACT

The increase in human population causes several negative impacts, one of which is the extreme climatic changes. The main cause of this climatic changes is global warming due to the increase in greenhouse gases (GHG) such as CH_4, CO_2, and NO_2 in the atmosphere where this is caused by the burning of fuel for motor vehicles and factories, as well as a decrease in carbon-absorbing plant vegetation due to the clearing of new land. This research is to estimate how much coffe plantation in ATP Jatikerto contribute on containing carbon stock. The methods used in this study namely non destructive by adhering to SNI-7724 which recommends estimating carbon stocks using an allometric model, the types of plants at the observation site were *Coffea liberica*, *Coffea canephora*, *Gliricidia sp*., *Leuceana sp*., *Musa sp*., and *Theobroma cacao*. There are 4 vegetation structures at the observation site, namely *C. liberica* with *Gliricidia sp*., then *C. canephora* with *Gliricidia sp*., *then C. canephora with Leuceana sp*., *and C. canephora with Musa sp*.

Keywords: Corruption crimes, return of state financial losses

Introduction

The increase in the human population that occurs continuously causes many impacts, one of which is an increase in the content of greenhouse gases (GHG) in the atmosphere in the form of CO_2, NO_2, and CH_4, this is caused by the burning of fuel both from factories and motor vehicles, if it continues to occur, it can cause the greenhouse effect (ERK) so that the temperature of the earth's atmosphere increases or what is called global warming. If this continues, it will cause extreme climate change, where many parties will be harmed. For example from the agricultural sector, global warming can shift the seasons so that it is difficult to predict and will cause crop failure due to floods and droughts. In addition to burning fuel, reduced vegetation increases the amount of CO in the atmosphere which contributes to increased carbon emissions and climate change. Vegetation is able to absorb CO_2 and release O_2 as the end result or commonly referred to as the process of photosynthesis. This process continues, namely the storage of carbon (C) into the body of the plant stem as a result of plant metabolism, this is referred to as carbon sequestration. Therefore, maintaining land cover (vegetation) both inside and outside forest areas is an important effort to mitigate climate change (Irawan & Purwanto, 2020).

Efforts to mitigate climate change can be carried out by maintaining forest areas and plantation areas so that there are still woody plants which are a source of high carbon sinks. Predicting carbon stocks in locations that have the potential as high carbon sinks, it is an effort to mitigate climate change. Estimating carbon stocks in areas that have the potential to absorb a lot of carbon stocks can open up opportunities to increase the number of carbon stocks in plant stands. One area that has the potential for estimating carbon stocks is the Coffee Plantation in Malang Regency. This garden has a land area of 15,086 Ha (BPS, 2018). The extent of the coffee plantation area has great potential for the amount of carbon stock in this land use because coffee planters are plants that are widely planted outside forest areas and have the potential to turn into agricultural land, so it needs to be maintained. Coffee plants are good plants planted in shaded places so that most of the land use for coffee plantations is agroforestry between coffee and various woody plants which are a source of carbon stocks. The problem with coffee plantations related to carbon stocks is the amount of shade and sources of soil carbon stocks that are

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small. This is due to the management of coffee plantations that focus on coffee production and minimal organic matter management so that there are fewer carbon sinks compared to forests. The location that describes this condition is in Agro Techno Park (ATP) Jatikerto. ATP Jatikerto has a coffee plantation with a conventional cultivation system without tillage and without the application of manure. ATP Jatikerto is a young coffee plantation with a coffee plant age of 5-20 years. There is a need for observations regarding carbon stocks in locations that have the potential to increase the opportunity to increase carbon stocks, especially in ATP Jatikerto so that appropriate countermeasures can be made to overcome the problem.

Material and Methods

Research period and site

This research was conducted in a location that has a type of coffee plantation land use. The research location is a coffee plantation owned by Agro Techno Park (ATP) Jatikerto with a garden area of ± 1 ha. The research was conducted from September 2020 to November 2020. The Jatikerto ATP Coffee Plantation is located in the south of Gunung Kawi, Malang Regency, East Java. Geographically the Jatikerto ATP Coffee Plantation is at coordinates 8°7'40.24" - 8°7'47.96"LS and 112°31'27.20" - 112°31'43.09" East Longitude. The observation location has an elevation of 300-325 m above sea level. The climate zone according to Junghuhn is a hot area, the average annual rainfall is ±2059 mm/year, the average annual air temperature is 17ºC - 31ºC, the average relative humidity is 58% - 85%, and the soil type is Alfisol. The coffee garden at the location uses conventional management with organic fertilizer fertilization (fertilization occurs but is not periodic/erratic and does not always get applications every year) so that the soil carbon stock is low (<2%), and there is use of shade trees for coffee trees. The spacing of the coffee trees in the location is ± 2 × 2 m and the shade is ± 4 × 4 m.

Research materials

The materials used in the study were litter samples, understorey samples, and soil samples. To calculate the C-organic value of the soil, the chemicals used were 85% H_2PO_4, $K_2Cr_2O_7$, concentrated H_2SO_4, $FeSO_4$, H_2O, and Diphenylamine.

Research design

This research was conducted using a non-destructive method and using an allometric model that refers to SNI-7724 (2011), then in determining the plot in Jatikerto using a systematic random sampling technique. There are 15 observation plots measuring 10 × 10 m in Jatikerto which are known as main plots. Each main plot consists of 2 sub plots measuring 2 × 2 m and there are two photo points that divide the area of each main plot for canopy estimation. above the coffee tree canopy. Measurements made at the observation site include GBH (girth breast high) on the main plot. Measurement of litter weight and weight of understorey plants, as well as sampling of litter and understorey samples in sub plots. Composite soil samples were taken at 0-30 cm layers and intact soil samples were taken at 0-10 cm, 10-20 cm, and 20-30 cm layers. Soil sampling points are not fixed on the main plot but are carried out in representative areas.

Research Implementation

The implementation of the research is divided into several stages, namely Pre-Survey (1) namely determining observation points and looking for climatic data for observation locations, Data collection (2) namely measuring DBH and taking samples of litter, understorey, and soil, then Data Processing (3) namely calculating the results of the analysis %C-Organic, calculation of carbon stock using allometric model, and analysis of important value index (INP).

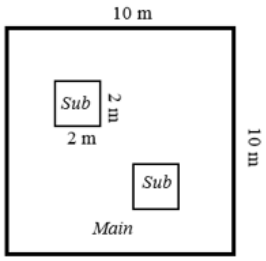

Figure 1. Plot form in research

The calculation formulas used in this study are as follows:

Table 1. Allometric calculations on various types of trees

No.	Tree	Formula	Source
1.	Trees in general	"BK = 0,11 × ρ × $D^{2,62}$ (1)	Ketterings et al. (2001)
2.	Coffee	"BK = 0,281 × $D^{2,06}$ (2)	Arifin (2001)
3.	Banana	"BK = 0,030 × $D^{2,13}$ (3)	Arifin (2001)

Note: BK = dry weight (kg.tree-1) D = DBH (cm) H = total tree height (m) = wood density = 0.7 g.cm-3 (Hairiah & Rahayu, 2007)

The tree species allometric model is commonly used for shade trees other than bananas. For necromas using the same formula but there is a tree integrity coefficient in measuring it, which is as shown in the following Figure 2:

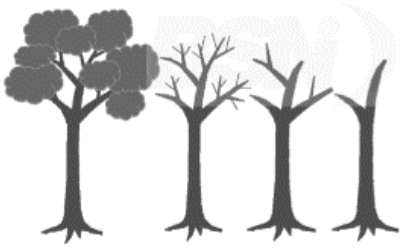

Figure 2. Necromas

Caption:
A. The integrity of the tree with a correction factor of 0.9
B. The integrity of the tree with a correction factor of 0.8
C. The integrity of the tree with a correction factor of 0.7

The dry weight of litter and understorey is calculated by the formula:

$$B = (Bks \times Bbt)/Bbs \quad \text{..... (4)}$$

B= weight of organic matter (kg); Bks= dry weight of sample organic matter (kg); Bbs=wet weight of sample organic matter (kg); Bbt = wet weight of total organic matter/plot (kg).

After obtaining the weight of the organic matter, it is necessary to convert it to get the carbon stock value using %C-organic obtained from the results of laboratory analysis. Soil carbon data for each observation plot is calculated by the formula:

$$Ct = \%\text{Soil organic matter} \times BJ \times \text{Layer depth} \times lplot \text{.....(5)}$$

Ct=soil carbon content in the observation plot (kg/m^2); %C-organic soil = percentage value of soil carbon content (%); BJ= Density of soil (g/cm^3); Layer depth = 10 (cm); lplot = plot area (m^2)

Calculation of carbon stock per hectare uses the formula:

$$Cn = (Cx/1000) \times (10000/lplot) \quad (6)$$

Cn = carbon stock per hectare in each plot (tonnes/ha); Cx = carbon stock in each plot (kg); lplot = area of each main plot (m^2).

The amount of carbon stock from biomass is calculated by the formula:

$$Cb = B \times \%C\text{-organic} \quad (7)$$
$$Cm = B \times FK \times \%C\text{-organic} \quad (8)$$

Cb= carbon content of biomass (kg); Cm= carbon content of dead organic matter (kg); B/Bbo= total biomass (kg); FK=tree integrity factor; %C-organic = percentage value of carbon content, which is 0.47.

INP calculation using the formula:

$$INP = FR + KR + DR \quad (9)$$

Density of a species (K):

$$K = (\sum \text{Individual species}) / (\text{Sampling plot area}) \quad (10)$$

Relative Density of a species (KR):

$$KR = (\text{Density of a species}) / (\text{Density of all species}) \times 100\% \quad (11)$$

Frequency of a species (F):

$$F = (\sum \text{Sample plot found a species}) / (\sum \text{Sample plot}) \quad (12)$$

Relative frequency of a species (FR):

$$FR = (\text{Frequency of a species}) / (\text{Frequency of all species}) \times 100\% \quad (13)$$

Dominance of a species (D):

$$D = (\text{Basal area}) / (\text{Sampling plot area}) \quad (14)$$

Relative dominance of a species (DR):

$$DR = (\text{Dominance of a species}) / (\text{Domination of all species}) \times 100\% \quad (15)$$

The data obtained during the study were tabulated using the Microsoft Excel program. Analysis of the effect of tree species using the significant value index (INP).

Results and Discussion

Carbon Stock Estimation Results

The observations obtained at ATP Jatikerto are carbon stocks and canopy in the research area. As well as things to consider such as the type of shade, basal area, and other equivalent literature. The description of the research area is that the type of coffee plantation in the research area is coffee

agroforestry with several types of shade. Types of trees at the observation site contained main plants such as *Coffea canephora* and *Coffea liberica,* then shade plants such as *Gliricidia* sp., *Leuceana* sp., and *Musa* sp. The number of plants in the 1500 m^2 area of the observation site is 302 trees with the number of each tree, namely C. *canephora* as many as 151 trees, C. *liberica* 58 trees, *Gliricidia* sp. 42 trees, *Leuceana* sp. 13 trees, and Musa sp. 38 trees. The average basal area of the entire tree at the observation site is 0.0059 m2, for each tree species, namely C. liberica 0.0014 m^2, C. *canephora* 0.0009 m^2, *Gliricidia* sp. 0.0283 m^2, *Leuceana* sp. 0.0128 m^2, and *Musa* sp. 0.0104 m^2. Underplants were found to have grass species that dominated the entire observation plot, as well as some weeds and herbaceous plants which usually disappeared after pruning. The necromas found at the observation point were mostly dead trees that had no leaves and brittle stems. For the type of soil in the research location, it is Alfisol soil type (Prasetyo et al., 2014) with an average BOT of 1%.

The total carbon stock in Jatikerto ATP is in the range of 88 tons/ha. Based on the reservoir type, AGB (Above Ground Biomass) carbon stock is 42 tons/ha while BGB (Below Ground Biomass) is 47 tons/ha. From Table 2. it can be seen that the highest amount of carbon storage is found in soil reservoirs, followed by trees, roots, necromass, and lastly is litter. This is in accordance with the opinion of Zerihun et al. (2012) which represents the relative value of soil carbon storage, which is the largest reservoir compared to other reservoirs (40-60%). The results of the estimation of carbon stocks are presented in the form of diagrams and histograms as shown in Figure 3.

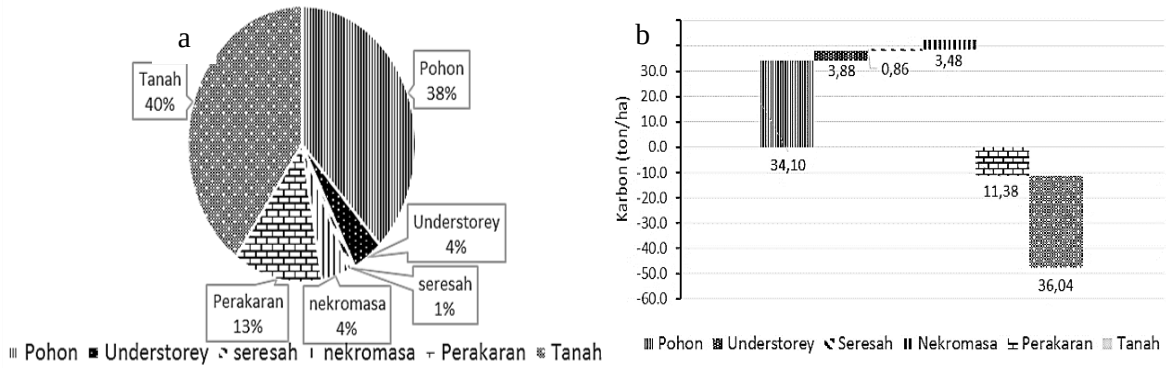

Figure 3. Carbon stock in each reservoir (a) % and (b) tons/ha

Figure 2 shows the amount of carbon storage which is dominated by subsurface carbon, especially soil reservoirs. Despite the low %C-Organic value of the soil (<2%) this result has exceeded the total carbon stock of the coffee tree and its shade. However, when viewed from a unified whole tree, namely tree carbon storage and root carbon storage, the total tree carbon storage (as a whole) will have a carbon value of 45.48 tons/ha which is greater than soil carbon storage (36.04 tons/Ha).

Table 1. Carbon storage in each reservoir

Reservoir	Carbon Storage (tonnes/ha)	Carbon Storage (%)
Tree	34.10	38.00
Understorey	3.88	4.30
litter	0.86	1.00
Root	11.38	3.90
Soil	36.04	12.70
Necromas	3.48	4.10
Total	88.01	100.00

The factors that influence the amount of carbon stock are the age of the coffee plant, the age of the coffee plant in Jatikerto is in the age range of 5-20 years. According to Polosakan et al. (2014), the difference in the amount of aboveground biomass is influenced by the age of the stand and the speed of growth. The speed of plant growth affects the biomass because the speed of plant growth affects the volume of the stem, while the age of the stand affects the volume of the stem and the density of the wood. The faster the growth and the older the age of the stand, the volume and density of the stand wood will increase. Then for the factor of land management at the observation location, there is shade and the application of manure which is routinely not always treated, for the spacing in Jatikerto has a spacing between coffee of 2 × 2 m while shade is 4 × 4 m between trees, according to Hairiah and Rahayu (2007), the amount of carbon between land depends on the diversity and density of plants, soil fertility and management. This shows that the carbon storage of trees in the research location is quite high due to the age of the plant and also influenced by the close spacing between trees and the type of shade trees with relatively large woody trunks.

Table 3. Tree carbon stores

	Tree	DBH (cm)	BA (m^2)	C (kg/tree)	CA (kg/tree)
R.	Coffee	3.44 ±1.45	0.0011	2.34 ±1.85	1.17 ±2.41
R.	Shade	15.15 ±6.64	0.0212	46.71 ± 58.28	15.80 ±19.56

Note: R.:Average, DBH: *Diameter Breast High* (diameter at chest height), BA: Basal Area, C: Carbon, CA: Root Carbon.

Basal area

Basalt area (BA) is one of the important parameters in observing a land use that contains trees. Where it is necessary to estimate the density of the volume of wood from each tree in a certain area. Usually BA is available in ft^2/ha and m^2/ha, in this study using square meters per hectare (m^2/ha) which is a unit commonly used locally at the observation site. Basal area estimation results show a range of 196 $m^{2/}$ ha on coffee trees which are the main crop and 1,273 $m^{2/}$ ha on shade trees. The total basal area of all trees is in the range of 1,470 m^2/ha.

Vegetation structure

The main tree species at the observation point are *Coffea canephora* and *Coffea liberica*, then shade plants such as *Gliricidia sp*., *Leuceana sp*., and *Musa sp*., while the plant is *Theobroma cacao* with 1 tree so it is not included in the table. The amount of carbon stock and standard deviation that varies is caused by the distribution of shade plants that are not the same and not fixed at each observation point. There are four dominant tree species arrangement at each observation point, namely *Liberica* coffee with Gamal at points 1, 4, 5, and 7 then Robusta coffee with Gamal. At points 2, 3, 6 and 8 then Robusta coffee with Lamtoro at point 9, 10, and 11 and robusta coffee with bananas at points 12 to 15. The four arrangements are presented along with a description of the land as shown in Table 4.

Table 4. Description of each observation plot

No	PP	Main Crop (Coffee)		TNPK		TNPNK		TPT		Soil
		JK	JP	JPK	JP	JPNK	JP	Type	Density	BOT (%)
1.	1	Liberica (Lbk)	14	Gamal (Gml)	7	-	-	Grass (Rpt)	Low	1.44
2.	4	lbk	14	Gml	4	-	-	Rpt	Low	0.67
3.	5	lbk	17	Gml	6	-	-	Rpt	Low	0.91
4.	7	lbk	13	Gml	5	-	-	Rpt	Currently	1.17
5.	2	Robusta (Rbt)	15	Gml	5	-	-	Rpt	Low	0.70
6.	3	Rbt	13	Gml	4	-	-	Rpt	Tall	0.99
7.	6	Rbt	17	Gml	6	-	-	Rpt	Tall	0.85

To be continued…

8.	8	Rbt	15	Gml	5	-	-	Rpt	Low	1.17
9.	9	Rbt	15	Lamtoro	4	-	-	Rpt	Currently	0.90
10.	10	Rbt	15	Lamtoro	5	-	-	Rpt	Tall	0.91
11.	11	Rbt	13	Lamtoro	4	-	-	Rpt	Tall	1.36
12.	12	Rbt	17	-	-	Banana	11	Rpt	Low	1.58
13.	13	Rbt	9	-	-	Banana	7	Rpt	Currently	0.91
14.	14	Rbt	11	-	-	Banana	11	Rpt	Tall	0.91
15.	15	Rbt	11	-	-	Banana	9	Rpt	Currently	0.97

Note: PP: Observation Plot; JK: Type of Coffee; JP: Total Population; TNPK: Timber Tree Shade Plants; TNPNK: Non-Wood Tree Shade Plants; TPT: Ground Cover Plants; BOT: Soil Organic Matter

The type of tree that dominates the observation area in terms of distribution is robusta coffee (*C. canephora*). Meanwhile, from the density and area of basal area controlled by gamal (*Gliricidia sp.*). Liberica coffee and robusta coffee have a similar distribution and density when compared to gamal. The lamtoro and bananas have a similar distribution and density when compared to other plants. Shade vegetation generally has a vertical position above the coffee vegetation, or is at the first level of the garden canopy. The shade vegetation dominates in terms of the basal area area compared to coffee vegetation.

Table 5. Dominant plant types in jatikerto coffee plantation in each category

Region Name	Scientific name	KR (%)	FR (%)	DR (%)	INP (%)
Rbt Kopi coffee	*C. canephora*	50.00	45.73	3.41	99.14
Lbk Kopi coffee	*C. liberica*	19.21	17.65	1.62	38,48
	Shade				
Gamal	*Gliricidia sp.*	13.91	12.70	70.35	96.96
Lamtoro	*Leuceana sp.*	4.30	4.23	11.96	20.49
Banana	*Musa sp.*	12.58	19.70	12.65	44.93

Note: KR: Relative Density; FR: Relative Frequency; DR: Relative Dominance; and INP: Important Value Index

Litter and understorey

litter and understorey which showed a relatively uniform range of C (carbon stock), although there was pruning in coffee plants that increased the amount of litter weight randomly, sampling carried out on both replicates could reduce the impact on the variation of the resulting data. The weight of litter and understorey is also a factor that affects the variation in the results of the C range, this indicates the level of uniformity of the C range in each observation plot.

Table 6. Understorey carbon deposits and litter

	C-Organic (%)		Carbon (tonnes/ha)	
	Understorey	litter	Understorey	litter
Average	32.84 ± 7.68	34.63 ± 1.10	4.14 ±0.92	4.01 ±0.65

Soil carbon

The average result of C shows a relatively small standard deviation, this shows the uniformity of the amount of C in each observation plot. The average yield of BO is relatively small to be a planting medium for a production plant where the ideal condition of BO from the growing media is 5% (BPTP Kaltim, 2015). This shows that the management of organic matter at the observation site needs to be improved.

Table 7. Soil carbon stock

	C-Organic (%)	BO (%)	BJ (g/cm ^{3})	C (tonnes/ha)
Average	0, 60	1.03	2.14 ± 0 , 11	12.81 ± 3.76

Note: C-Organic: C-Organic; BO: Organic Ingredients; BJ: Soil Density; C: Carbon.

Canopy

Canopy estimation results show varying values at each observation point. This shows that the pruning is not intended to make the canopy uniform but only to stimulate coffee production by trimming the top of the canopy so that plant nutrition is only focused on coffee fruit production. The coffee canopy over the canopy (ATK) as a whole has a lower percentage of cover than the above ground canopy (APT), this shows that the coffee plant canopy is denser than the shade plant. The percentage value of APT cover reached >90%, indicating that the coffee plant canopy was very dense. The level of shade is also influenced by the high population density of coffee plants compared to shade, this is also because the APT canopy also covers the entire ATK canopy. However, the value of the ATK canopy can be used as an additional description regarding the identity of the canopy at the observation location.

Table 8. Canopy of each category

	Canopy (%)	
	Above Ground	Top Coffee Header
Average	68.9 ± 23.2	39.6 ± 15.2

Comparison of carbon stock estimation results with literature

Coffee agroforestry is a combination of coffee plants as the main crop and shade plants. The amount of C contained in coffee agroforestry in each location varies depending on the age of the plant and the density of the population. The contribution of each tree species at the research site was 3.3 tons/ha for the main coffee plant, while for the shade plant it was 31 tons/ha.

The amount of C at the observation site is in the range of 88 tons/ha, showing a small value when compared to C in forest land use in Java (60 – 300 tons/ha) (Rochmayanto et al., 2014), this is due to the type of plant that Dominating at the observation site is coffee plants. Coffee plants are woody plants but have a small stem diameter when compared to wood plants in general in the forest so that the C yield is smaller than forest land which is dominated by woody plants with large stem diameters. As for some examples of C from the literature to find out the position of the expected C results in this study in Table 9.

Table **9**. Carbon stocks in different types of national fores

Land cover type	Minimum value (tons/ha)	Maximum value (tons/ha)	median (tons/ha)	Average (tons/ha)	N	elementary school	SE	Information
Primary dryland forest	64.21	323,171	178.4	176.10	25	80.79	16,16	Calculated from various sources
Secondary dryland forest	34.99	216.85	87.43	103.59	29	52.79	9.80	Calculated from various sources
Primary peat forest	56.54	200.23	113.33	123.67	8	56.02	19.81	Calculated from various sources
Secondary peat forest	37.51	142.07	92.32	90.26	13	37.14	10,30	Calculated from various sources
Primary mangrove forest	41.8	393.62	162.00	188.30	5	133.18	59.56	Calculated from various sources
Secondary mangrove forest	37.03	142.9	92.14	94.07	10	45.06	14.25	Calculated from various sources
Plantation forest	29.92	237.52	77.22	98.38	76	56.97	6.54	Calculated from various sources

Description: N: Number of data; SD: Standard deviation; SE: Standard error

According to the description of the observation location in this study, it is a coffee plantation on dry land, the location that has similarities in the table above is secondary dry forest land where coffee plants are commonly grown in the area. The amount of carbon stock at the observation site is moderately low.

Conclusion

The total carbon stock in ATP Jatikerto is 88 tons/ha. For each category, AGB is 41 tons/ha and BGB is 47 tons/ha. The types of plants at the observation site were *Coffea liberica*, *Coffea canephora*, with shade plants *Gliricidia sp*., *Leuceana sp.*, *Moses sp*., and *Theobroma cacao*. There are 4 vegetation structures at the observation site, namely *C. liberica* with *Gliricidia sp*., then *C. canephora* with *Gliricidia sp*., then *C. canephora* with *Leuceana sp*., and *C. canephora* with *Musa sp.* The basal area of the entire tree at the observation site is in the range of 1470 m2 / ha, specifically for coffee plants in the range of 196 m2 / ha while shade is in the range of 1273 m2 / ha. The results of the comparison between the research location C and the literature show a moderate C value.

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