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THE ABILITY OF COFFEE AGROFORESTRY SYSTEM TO STORE CARBON STOCK

Fahriza Luth[1], Hadi Setiyono[2]
[1,2] Department of Forestry, Faculty of Forestry, Winaya Mukti University, Bandung, West Java.
Email : rhiezatech75@gmail.com

A B S T R A C T

Each type of forest ecosystem and the species in it have different abilities to absorb CO_2 and produce biomass. Coffee-based agroforestry is thought to be able to increase the ability of forests to store carbon as a result of increasing species composition and density of plants in these forest areas. This study aims to determine the composition of plants and carbon stocks stored in coffee-based agroforestry forests in LMDH Paniis RPH Rancakalong BKPH East Manglayang KPH Sumedang Perum Perhutani Regional Division West Java and Banten. This study uses survey and experiment methods. Data obtained through observations in the field and laboratory are in the form of tree names, wood density, tree biomass and carbon stocks from biomass. The result shows that the agroforestry forest composition at LMDH Paniis RPH Rancakalong BKPH East Manglayang KPH Sumedang within 17,14 ha consists of Pine (Pinus mercusii), Big-leaf Mahogany (Swietenia macrophylla), Clove (Syzygium aromaticum) dan Coffee (Coffea arabica). The carbon stock is 1.869,73 kg/ha in agroforestry forest, 2.618,32 kg/ha in primary natural forest, and 1.460,91 kg/ha in secondary natural forest. Agroforestry forest has more carbon stock than secondary natural forest does and agroforestry forest has less carbon stock than the primary natural forest.

Key words: Agroforestry, Coffee, Carbon Stock.

1. Introduction

Carbon on earth is reserved in four resources: fossil and rock formation, atmosphere, ocean, and land ecosystem, including forest (Kauppi, 2003). Forest absorbs CO_2 during photosynthesis and stores it as organic material in plant's biomass. The process of storing C in plant is called C-sequestration. Measuring the amount of C in a plant (biomass) in a certain area can describe the amount of CO_2 the atmosphere which is absorbed by the plant. However, the measurement C in a deceased plant (necromass) can imply the amount of CO_2 which is not spread in the air by burning (Hairiah and Subekti, 2007).

Each forest ecosystem within its type has different abilities to absorb CO_2 and to produce biomass. Agroforestry system is predicted to have potential in absorbing carbon from the atmosphere. Acording to Utami et al. (2003), agroforestry is a land management system that has productive and protective purpose. Agroforestry system contributes to increase CO2 and glasshouse effect by increasing the amount of carbon in the soil and reducing the pressure towards forests due to deforestation, where carbon from CO_2 is obtained and stored as biomass. Although the ability of agroforestry in preserving carbon in land is still lower than the ability of forest to do the same, this system can become an alternative to offer more hope to increase the carbon resource at degraded land (Widianto et al., 2003).

At KPH Sumedang Perum Perhutani West Java and Banten Regional Division, agroforestry has been implemented by combining coffee plant under pine trees as primary plant of production at Perhutani at LMDH Paniis RPH Rancakalong BKPH East Manglayang. Agroforestry within coffee base is considered to improve the forest's ability to store carbon as a result of the increase of variety and plant density in the area. To figure this out, it is a necessity to conduct a research named "The Ability of Coffee-Based Agroforestry (Coffea arabica) to Store Carbon".

The purpose of this research is to find out the plant's composition and carbon stock which is stored in coffee-based agrofrestry at LMDH Paniis RPH Rancakalong BKPH East Manglayang KPH Sumedang.

2. Methods

2.1. Research Location

This research is located in area 4 G RPH Rancakalong BKPH East Manglayang KPH Sumedang Perum Perhutani West Java and Banten Regional Division, with the size of the area is 17,14 ha. This location consists of hills with the height of 700-1700 meter above sea level and the rain amount is 1.251 mm/year. The location is chosen as there is agroforestry system at LMDH Paniis with PHBM and LMDH program and it is known as the best LMDH and also sample at KPH Sumedang Perum Perhutani West Java and Banten Regional Division. Test has been taken at Laboratory of Technology of Forest Products, Faculty of Forestry Winaya Mukti University.

2.2. Material and Instruments

The material of this research is the forest and conservation which include pine area. It is is a 25 years old area with the planting distance is 2,5 m x 2,5 m. Besides, there are mahogany trees which are 5 years old and cloves plantations which are 3 years old. The instruments used here are phi band, pruning shears, analytical scale, talleysheet, camera, herbarium equipment, oven, calculator, and stationaries.

2.3. Data Collection

This research used survey and laboratory method. Data is collected by getting the data directly at the location at agroforestry forest area with the size of 17,14 ha, and at the natural forest with the size of 150 ha as comparison. Agroforestry forest at LMDH Paniis is a pine forest with the same age class and planting distance and coffee plant that has the same age and planting distance as well therefore they are combined in one cluster. Natural forest in Pengadegan village with 150 ha of size is divided into two LMU (Land Mapping Unit) based on the soil type, rain density, and height. LMU 1 is a primary natural forest and LMU 2 is a secondary natural forest.

Data in this research consists of primary and secondary data. Primary data is collected through field observation on trees' name, wood specific weight, trees' biomass, and carbon stock from biomass. Secondary data is collected through any supporting literature.

The method to collect data is plot sampling design with each sampling is 2,5% of intensity (Permenhut No. 67/Menhut-II/2006). The plot sampling is square with the size of 40 m x 5 m to measure the carbon reserve with 5 cm to 30 cm of DBH (Diameter Breast Height) (15 cm - 95 cm of tree circumferenxe and plot's size 100 m x 20 m for big trees (DBH > 30 cm) (Hairiah et.al, 2011). The placement of sample plot is performed sistemically using line. The number of plot samples can be seen in Table 1.

Table 1. The Number of Sample Plots in Each Area.

No	Area Type	Area Size (ha)	Sample Plot Size (m)	∑ Sample Plot
1.	Agroforestry forest	17,14	100 m x 20	3
			40 m x 5	22
2.	Primary natural forest	17,12	100 m x 20	3
			40 m x 5	22
3.	Secondary natural forest	132,85	100 m x 20	17
			40 m x 5	166

2.4. Analysis

The carbon stock measurement is applied only for living plants on the soil surface by using some procedures: (1) by measuring plants' age and density; (2) by deciding the trees' biomass; and (3) by deciding the carbon stock.

The name of trees is found directly at the area and it is put in the talleysheet. The purpose is to know the type density (KJ) of the trees on type density list which is available. The wood density is found on db.worldagroforestry.org (Tree Funcional Attributes and Ecological Database Wood Dencity). If the trees are not on the list, in order to know the density, the heating method using oven is used at the temperature of 100^0C for 48 hours to know the dry weight. After that, to know the density, there is a measurement by using a formula as quoted from Hairiah (2007) :

$$KJ\ (g/cm^3) = \frac{\mathbf{BK\ (g)}}{\boldsymbol{V\ (cm^3)}}$$

Description : KJ = Wood Density (g/cm^3)
BK = Dry Weight (g)
V = Volume (cm^3)

To know the volume, the formula below is used :

$$Volume\ (cm^3) = \pi\ R^2\ T$$

Description : π = 3,14
R = Wood Radius = ½ x Diameter (cm)
T = Wood Length (cm)

The measurement of biomass is done by predicting the trees' volume without any destruction. The volume is predicted from the diameter which is calculated by DBH or 1,3 meter above the land. Trees' height is measured to improve the estimation of trees' volume.

When measuring the diameter, not all trees are perfectly straight. Therefore, DBH is decided by measuring the straight position of all kinds of limbs that are buttress, wavy, low-branched, or those which grow on the steep area when they grow normally on the field.

The biomass calculation is using the formula by Hairiah (2007) :

$$B_p = V_p\ x\ Kj_p = ...gr$$

Description :
B_p = Trees biomass
V_p = Trees volume
KJ_p = Trees density

After the amount of biomass is obtained, the carbon stock can be calculated by using this formula below :

$$C_b = B\ x\ \%C_{Organik}$$

Description :
C_b = Carbon stock of biomass (kg).
B = Total biomass (kg)
% $C_{Organik}$ = Percentage of carbon stock 47%.

3. Result and Explanation

3.1. Plant's Composition

3.1.1. Agroforestry Forest

Agroforestry forest at LMDH Paniis RPH Rancakalong BKPH East Manglayang KPH Sumedang is a productive forest which turned out to be a protected forests. The tree types in area 4 G are in the Table 2.

Table 2. Tree Types in Agroforestry Forest Area 4 G.

No	Trees Name	
	Local	Latin
1.	Clove	*Syzygium aromaticum*
2.	Coffee	*Coffea arabica*
3.	Big-leaf Mahogany	*Swietenia macrophylla*
4.	Pine	*Pinus mercusii*

Table 2 shows that the trees composition at agroforestry forest consists of 4 species. They are Pine tree, Clove plant, Coffee plant, and Big-leaf Mahogany. Among the species, coffee is the most populating plant because it has small distance, which is 2,5 m x 2,5 m.

3.1.2. Primary Natural Forest

The primary natural forest in Pangadegan village has various vegetation with high density, therefore there is a little sunlight to reach the lower surface. As a result, it is difficult to

grow shrub plants or young trees. Due to the condition, the trees here are categorized as big trees. The types of trees in primary natural forest are as described in Table 3.

Table 3. Types of Tree at Primary Natural Forest.

No	Trees Name	
	Local	Latin
1.	Baros	*Manglietia glauca*
2.	Beunying	*Ficus Fistulosa*
3.	Huru	*Litsea angulata Bl.*
4.	Kareumbi	*Homalanthus populneus*
5.	Kihujan	*Samanea saman*
6.	Kihuut	*Simplocus sp.*
7.	Kinangsi	*Villebrunea rubescens*
8.	Puspa	*Schima wallichii*
9.	Rasamala	*Altingia excelsa*
10.	Saninten	*Castanopsis argentea*
11.	Waru Lot	*Thespesia populnes*

Table 3 shows that there are 11 species in the primary natural forest, which are Baros, Beunying, Huru, Kareumbi, Kihujan, Kihuut, Kinangsi, Puspa, Rasamala, Saninten and Waru lot.

3.1.3. Secondary Natural Forest

The secondary natural forest in Pangadegan village as agroforesrty forest so it has less density and small diameter because there are frequent human activities in the forest such as hunting so there are damages like pathway in the area. Besides, people often take wood from the forest for household. The types of trees in secondary natural forest are described in Table 4.

Table 4. Types of Trees in Secondary Natural Forest.

No	Trees Name	
	Local	Latin
1.	Hantap	*Sterculia coccinea*
2.	Kibanen	*Criyteronia paniculata*
3.	Kibawang	*Dysoxylum alliaceum*
4.	Kibesi	*Lindera sp.*
5.	Kihuut	*Simplocus sp.*
6.	Kinangsi	*Villebrunea rubescens*
7.	Kitamiang	*Celtis timorensis Span.*
8.	Kitangogo	
9.	Kisireum	*Eugenia cymosa*
10.	Puspa	*Scima walici*
11.	Rasamala	*Altingia excelsa*
12.	Saninten	*Castanopsis argentea*

Table 4 shows that the trees composition consists of 12 species, which are Hantap, Kibanten, Kibawang, Kibesi, Kihuut, Kinangsi, Kitamiang, Kitangogo, Kisireum, Puspa, Rasamala and Saninten.

3.2. The Carbon Stock Measurement

3.2.1. Density Type

Based on the observation, there are 4 species of tree in agroforestry area, while there are 18 tree species in primary and secondary natural forest. The density type is described in Table 5 and Table 6. The value is from Wood Density ICRAF-Database for 20 types of tree. While there is a different result for other 2 types tree as it is tested at Laboratory of Technology of Forest Products, Faculty of Forestry Winaya Mukti University as it is seen in Table 7.

Table 5. The List of Wood Density at Agroforestry Forest.

No	Trees Name		Density Type	
	Local	Latin	WD. g/cm^3*	Lab. g/cm^3**
1.	Cengkeh	*Syzygium aromaticum*	0,70	
2.	Kopi	*Coffea arabica*	0,62	
3.	Mahoni DL	*Swietenia macrophylla*	0,50	
4.	Pinus	*Pinus mercusii*	0,70	

Source: Secondary Data.

Table 6. The List of Wood Density in Primary and Secondary Natural Forest.

No	Trees Name		Density Type	
	Local	Latin	WD g/cm^3*	Lab. g/cm^3**
1.	Baros	*Manglietia glauca*	0,41	
2.	Beunying	*Ficus Fistulosa*	0,59	
3.	Hantap	*Sterculia coccinea*	0,23	
4.	Huru	*Litsea angulata Bl.*	0,45	
5.	Kareumbi	*Homalanthus populneus*	0,36	
6.	Kibanen	*Criyteronia paniculata*	-	
7.	Kibawang	*Dysoxylum alliaceum*	0,65	
8.	Kibesi	*Lindera sp.*	0,65	
9.	Kihujan	*Samanea saman*	0,61	
10.	Kihuut	*Simplocus sp.*	0,57	
11.	Kinangsi	*Villebrunea rubescens*	0,62	
12.	Kitamiang	*Celtis timorensis Sp..*	0,72	
13.	Kitangogo		-	
14.	Kisireum	*Eugenia cymosa*	0,72	
15.	Puspa	*Scima walici*	0,75	
16.	Rasamala	*Altingia excelsa*	0,81	
17.	Saninten	*Castanopsis argentea*	0,73	
18.	Waru Lot	*Thespesia populnea*	0,585	

Source: Secondary data.
Description :
**WD (g/cm^3) = Wood Density ICRAF-Database. **Lab. (g/cm^3) = Result from Laboratory of Technology of Forest Products, Faculty of Forestry Winaya Mukti University*

Table 7. The Result of Measuring The Trees' Density at Laboratory of Technology of Forest Products, Faculty of Forestry Winaya Mukti University.

No	Trees Name		Example		K (cm)	T (cm)	V (cm^3)	KJ (g/cm^3)
	Local	Latin	BB	BK				
1.	Kibanen	*Criyteronia paniculata*	50,06	24,72	10	7	47,77	0.52
2.	Kitangogo		94,69	43,66	14	6	109,24	0,40

Source: Primary Data (proceeded).

Description : BB = Gross Weight (g), BK = Dry Weight (g), K = Circumference (cm), T = Height (cm), V = Volume (cm^3), KJ = Wood Density (g/cm^3)

Table 7 shows that Kibanen's density measured in the laboratory has 50,06 g of gross weight and 24,72 g dry weight with density type as much as 0.52 g/cm^3, Kitangogo has gross weight 94,69 g and dry weight 43,66 g with 0,40 g/cm^3 of density.

3.2.2. The Amount of Carbon Stock

1. Agroforestry Forest

Agroforestry forest in Pangadegan village has 17,14 ha of size and it consists of Pine, Big-leaf Mahogany, Cloves and Coffee. The measurement of carbon stock and the result can be seen in Table 8

Table 8. The Amount of Carbon Stock in Agroforestry Forest

Plot Size (m)	∑ Carbon Stock (Kg)	
	Ha	Area
40 x 5	197,15	3.379,20
100 x 20	1.672,58	28.668,00
Total	1.869,73	32.047,20

Table 8 above shows that the carbon stock in agroforestry forest with 17,14 ha of its size is 32.047,20 kg or 1.869,73 kg/ha.

2. Primary Natural Forest

Primary natural forest in Pangadegan village has 17,12 ha of the size and it consists of Baros, Kihuut, Kihujan, Puspa, Rasamala, Saninten, Beunying, Huru, Kareumbi, Kinangsi, Puspa and Waru lot. The result of measuring the carbon stock in primary natural forest can be seen in Table 9.

Table 9. The Amount of Carbon Stock in Primary Natural Forest.

Plot size (m)	∑ Carbon Stock (Kg)	
	Ha	Area
40 x 5	92,01	1.575,20
100 x 20	2.526,31	43.250,20
Total	2.618,32	44.825,60

Table 9 above shows that the carbon stock in primary natural forest with size of 17,12 ha is 44.825,60 kg or 2.618,32 kg/ha.

3. Secondary Natural Forest

Secondary natural forest in Pangadegan village has 132,85 ha and it consists of Kibanen, Kibawang, Kibesi, Kihuut, Kinangsi, Kitamiang, Puspa, Rasamala, Hantap, Kisireum, Kitangogo and Saninten trees. The amount of carbon stock in the area is as seen below in Table 10.

Table 10. The Amount of Carbon Stock in Secondary Natural Forest.

Plot Size (m)	∑ Carbon Stock (Kg)	
	Ha	Area
40 x 5	359,86	47.808,00
100 x 20	1.101,05	146.274,80
Total	1.460,91	194.082,80

Table 10 above shows that the carbon stock in secondary natural forest with size of 132,85 ha is 194.082,80 kg or 1.460,91 kg/ha.

Based on the information in Table 8, Table 9 and Table 10 it is seen that secondary natural forest has less carbon stock than agroforestry forest and primary natural forest. It is due to the small density of vegetation in secondary natural forest and its plants have smaller diameter compared to agroforestry forest and primary natural forest eventhough agroforestry forest has fewer trees variations. This circumstance is related to Hairiah et al (2011) that the carbon stock in each area is different, it depends on the variety and trees density, soil type, and the cultivation method. As Kusmana (2009) stated, climate and rain density are factors that affect the increase of carbon biomass in a tree.

4. Conclusion and Suggestion

4.1. Conclusion

1. The composition of agroforestry forest at LMDH Paniis RPH Rancakalong BKPH East Manglayang KPH Sumedang with area of 17,14 ha consists of Pine tree (Pinus mercusii), Big-leaf Mahogany (Swietenia macrophylla), Clove (Syzygium aromaticum) and Coffee (Coffea arabica).
2. Agrofrestry forest has carbon stock of 1.869,73 kg/ha, primary natural forest has carbon stock of 2.618,32 kg/ha and secondary natural forest has carbon stock of 1.460,91 kg/ha. Agroforestry forest has less carbon stock than secondary natural forest although it is less than the carbon stock in primary natural forest. It is due to few vegetations and trees with small diameter compared to those in primary natural forest and agroforestry forest.

4.2. Suggestion

It is advised to conduct a further observation related to carbon stock in agroforestry system with different plant composition in order to find out the carbon stock.

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