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Carbon Sequestration and Carbon dioixide on Industry Forest Plantation

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Abstract: Global climate change recently caused by disturbance of energy balance between earth and atmosphere. The disturbance is the result of some factors, particularly, the increase of carbon dioxide (CO^2), methane (CH^4), and Nitrous Dioxide (N^2O), which are known as green house gasses. Landuse change from forestry to agricultural land and estate crop leads to species change and its composition. One of alternatives to increase the carbon stock, especially on degaraded lands, is industral forest plantation which aimed to retain natural carbon stock. Sequestration of CO^2 from the atmosphere by vegetation is mainly estimated using carbon stock estimation in plant biomass, necromass, and soil organic matter. This study was conducted in *A. mangium* wild and *E. pellita* industrial forest plantation in Jorong Sub-district, Tanah Laut District. The purpose of this study is to gain information about the quantity of carbon stock on industrial forest plantation which consists of *A. mangium wild* and *E. pellita* Plants, based on their stucture and species composition.

The objectives of the research were to analyze the amount of (1) To estimate the carbon stock of *A. mangium* wild-based industry forest plantation; (2) To estimate the carbon stock of *E. pellita* in industry forest plantation. The result shows that biomass of *A. mangium* figures on 95.167 ton/ha which is more than *E. pellita* on 51.32 ton/ha. The same result is shown on the understory's biomass of *A. mangium* on 0.89 ton/ha which is more than 0.50 ton/ha on *Eucalyptus pellita*. Biomass of necromass of *A. mangium* records on 39.68 ton/ha which is more than the *E. pellita* on 13.18 ton/ha. In summary, carbon stock on organic matter in industrial forest plantation of *A. mangium* figures on 20.23 ton/ha which is more than *E. pellita* on 12.1 ton/ha. REDD project payments are made with a full payment mechanism at the start of the project (full ex-ante credit). The carbon price uses a hypothetical price folks $ 6, US $ 9, and US $ 12 per ton of CO^2 (ha^{-1}). The quantity of CO^2 absorbed by *A. mangium* and *E. pellita* converted to US $ per hectare. *A. mangium* obtained the highest economic value as carbon price per ton CO^2 increase (from US$1,871.604, and 1,403.703 to US$9,35.805). The *E. pellita* Plants (from US$ 925.20, and 693.90 to US$1462.60) and results indicate that with an increase in carbon price, there is a corresponding increase in economic value Industry forest plantation.

Keywords: carbon *stock, Carbon dioxide*

I. Introduction

Industry forest plantations (IFP) are one way to reduce gas emissions by increasing carbon (C) . Global climate change that has occurred lately is due to disruption of the energy balance between the earth and the atmosphere. This balance is affected, among others, by an increase in carbon dioxide or carbon dioxide (CO^2), methane (CH^4) and nitrous oxide (N^2O) gases, which are better known as greenhouse gases (GHG). Currently, GHG concentrations have reached a level that endangers the earth's climate and ecosystem balance (Hairiah and Rahayu, 2007).

This study aims to analyze the amount of (1) carbon stocks in Plants of *A. mangium* at the same age, (2) CO^2 absorbed by Plants of *A. mangium* and *E. pellita*, (3) the economic value of carbon stocks in Plants of *A. mangium* wild and. The importance of this research is to provide information to the government, ie management of the state company (PT. Inhutani II), and related agencies related to carbon stocks, CO^2 absorption and the economic value of carbon stocks in *A. mangium* and *E. pellita* Plants.

II. Research Method

Place and time of study

The research was conducted at PT Inhutani II Pulau Laut South Kalimantan. Geographically, the location is situated at 1140 40’- 1140 55’ South Latitude and 030 58’ - 040 08’ East Longitude. The study was conducted for 3 months, from February to April 2010, including the study preparation, data gathering, and report.

Objects and Equipment

The objects used in this study were:

1. Biomass of plants (trees, and undergrowth or shrubs). Measurement of the biomass for trees was done with a non-destructive method, while measurement for the undergrowth or shrubs was done with a destructive method.
2. Necromass or dead organic matter was divided into two groups: woody necromass and non-woody necromass. Woody necromass was all biomass from dead trees, either standing dead trees, lying dead wood, or those underground with diameter > 10 cm. Non-woody necromass was all biomass from growing plants with diameter from > 2 mm to ≤ 10 cm.
3. Organic matter of soil (the remains of living creatures that have undergone decomposition), that is, all organic matter of soil in the depth of 30 cm, including roots and fine litter with diameter <2 mm.

Equipment used was:

1. GPS for determining the coordinate of the observation plots
2. Plastic rope for marking the observation plots
3. Phi band for measuring tree diameter
4. Soil ring samplers for collecting soil samples
5. Meter tape for measuring the observation plot
6. Woody quadrant with a size of 0.5 m x 0.5 m for marking the spots of colleting biomass and necromass of undergrowth/shrubs
7. Knife/scissors for collecting biomass samples from undergrowth
8. Plastic label for labeling each sample
9. Electric oven for drying biomass samples
10. Scale for weighing object samples
11. Tally sheet for recording observation data in the field
12. Calculator and computer for processing data and preparing reports
13. Stationery for recording Data
14. Laboratory equipment for analyzing carbon contents of samples.

Study Procedures

1. Data gathering

a. Determination of plots and samples

Making plots measuring 20 x 100 m to measure the biomass of acacia Plants aged 13 years, spacing 4 x 2 m and Eucalyptus aged 13 years, distance of 4 x 2 m, woody necromass, as well as taking samples of understorey biomass, coarse litter, fine litter and soil. Sample plots Measurements were carried out using the purposive sampling method with a plot size of 20 x 100 m (area = 2000 m^2), with 2 plots/plot (1 plot in A. mangium Plants and 1 plot in *E. pellita* Plants at PT. Inhutan II Tanah Laut, South Kalimantan.

b. Biomass measurement

1. Calculating tree biomass was carried out by measuring the diameter of the stand > 5 cm.
2. To measure the biomass of understorey plants, sample plots were made which were placed randomly using a 2 x (0.5 x 0.5 m) quadrant of 2 sample plots each in A. mangium 1 (one) sample plot and in *E. pellita* 1 (one) sample plot with the same size as the road cutting all undergrowth (shrubs, grass, herbs) contained in the quadrant.
3. Put the understorey biomass samples per quadrant in a plastic bag, then label it according to the sample point code. For the process of weighing the wet weight, dry weight and oven. The activity was carried out at the Balitran Banjarbaru Laboratory.

c. Necromass measurement

a. Measuring woody necromas was carried out on plots measuring 5 x 40 m by measuring the diameter and length/height of all standing and fallen woody necromass.

b. b. Sampling of coarse and fine litter was used in the same sample plots as sampling of understorey biomass. Coarse litter sampling was carried out after taking samples of understorey biomass, while taking fine litter samples was carried out after taking coarse litter samples.

c. Take all the coarse litter contained in each quadrant, put the coarse litter per quadrant into a plastic bag and label it according to the sample point code. For the process of weighing the wet weight, dry weight and also baking carried out at the Banjarbaru Balitran Laboratory.

d. Take the fine litter (decomposed plant parts and roots) located on the surface of the soil contained in the quadrants, then sift with 2 mm pore holes, and put the fine litter per quadrant into a plastic bag, and label it according to the sample point code.

e. The fine litter that passes through the sieve is classified as a soil sample.

d. Soil organic matter measurement

Measurement of soil organic matter was done as follows: (1) collecting soil samples at the 2 spots in the observation plots, that is 2 samples on plots A. mangium dan 2 sample di Eucalyptus pellita. Soil samples method from the 2 spots collected at different depth (0-15 cm. Soil samples were taken using soil sampler rings with diameter of 5 cm. weighing wet weight of the soil samples, and then dried the soil samples out and weighed them. Final step was to analyze the specific gravity and soil organic carbon that was done in the laboratory.

2. Analysis

a. Biomass calculation

1) **Trees biomass (TB).** Tree biomass was calculated using the allometric equations developed by Elenita L. Racelis *et al.*, (2008) for tropical moist forest:
Where Y = tree biomass (kg)

DBH = diameter at breast height (cm)

$$Y = 0{,}11\,\rho\,D^{2.62}$$

Where:

Y = tree biomass (kg); ρ = average wood density equivalent to 0.9035 g cc^2; DBH = diameter at breast height (cm); 2.62 = constant factor, regression coeffient.

2) Calculation of organic matter of necromass (litter, dead wood, and dead trees)

$$Ow = \frac{D_w \times TW}{W_w}$$

Note:
Ow : Organic matter weight (kg)
Dw : Dry weight of samples (kg)
Tw : Total wet weight (kg)
Ww : Wet weight of samples (kg)

b. Carbon calculation

1) Carbon of biomass was calculated with the formula

Cb = B × % Organic C

Note:

Cb: Carbon content of biomass (kg)
B : Total biomass (kg)
% organic C: Percentage of carbon content using percentage carbon values based on the measurement results from the laboratory.

2) **Carbon calculation of dead organic matter (litter, dead timber, and dead trees) was done using the formula:**

Cs = D × p × % organic C

Note:

Cs : Carbon content of soil (g/cm2)
D : Depth of soil samples (cm)
p : Bulk density of soil (g/cm3)

% organic C: Percentage of carbon content using percentage carbon values based on the measurement results from the laboratory.

4) **Calculation of total carbon stock in the plots**

Cplot = Cboss+ Cbuss + Cbl + Cdt + Cdtr + Cs

Where:

Cplot : Total carbon content at plots (ton/ha)
Cboss : Total carbon content of biomass on the soil surface per ha at plots (ton/ha)
Cbuss : Total carbon content of biomass under soil surface per ha at plots (ton/ha)
Cbl : Carbon content of biomass of litter per ha at plots (ton/ha)
Cdt : Carbon content of dead timber per ha at plots (ton/ha)
Cdtr : Carbon content of dead trees per ha at plots (ton/ha)
Cs : Carbon content of soil per ha at plots (ton/ha).

5) **Calculation of carbon dioxide (CO^2) absorption used the formula**

WCO2 = Rm.CO^2/Ra.C × Wtc

= 44/12 × Wtc

= 3.67 × Wtc.

Where:

WCO2 : Amount of CO^2absorbed (ton)

Wtc : Total carbon content of certain species and age of Plants (ton/ha)

Rm : Relative molecular mass, C=12 and O=16, CO2 = (1 ×12) +(2 × 16) =44

Ra : Relative atomic mass, C=12.

6) **Economic calculation of carbon**

Some assumptions used in the previous studies were used for economic calculation of carbon in the present study. It was estimated that compensation values of forest capacity to absorb carbon was about US$5 up to US$20 per hectare. Another assumption is that the economic value of carbon was calculated using the economic value approach from the REDD project for a life time of 5 years. The REDD project payment was done with a full payment mechanism at the beginning of the project (ex-ante full credit). Carbon price used was hypothetical price4, that is:US$6, US$9, and US$12per ton of carbon dioxide equivalent (CO2-e).

III. Results and Discussion

Carbon in trees

The carbon stock contained in trees is the result of measuring the diameter of the tree which is then calculated for its biomass using an allometric equation to estimate the amount of biomass. So high is the estimated tree biomass by first measuring the diameter of the tree, based on the results of measuring the biomass in A. mangium Plants it is known that the estimated amount of carbon stock in *A. mangium* Plants is 95,167 tons/ha.

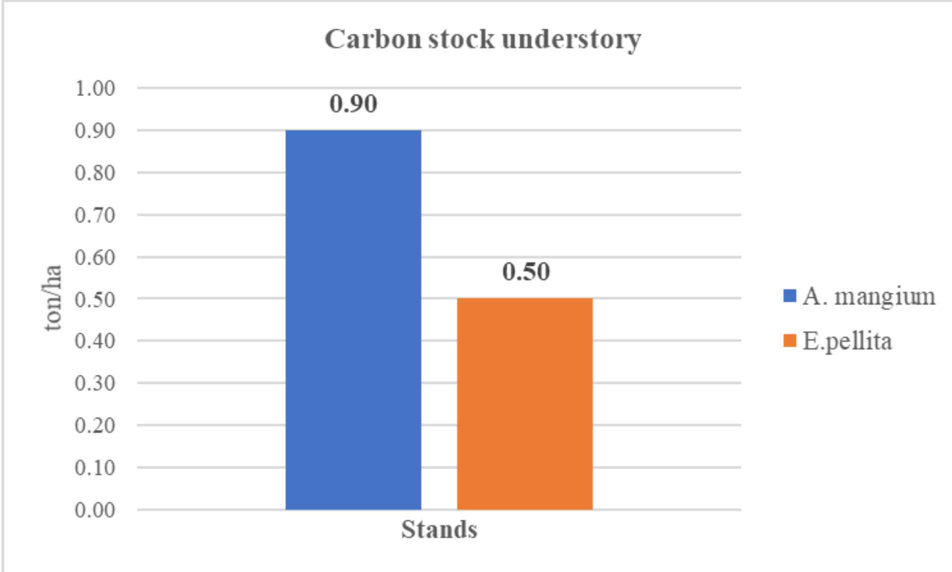
The type of A. mangium is a fast growing species with a wood density of 0.73. This also affects the biomass content of the *A. mangium* plant. smaller specific gravity. *E. pellita* Plants based on the calculated data estimated that the amount of carbon stock stored in tree biomass is 51.32 tons/ha, the specific gravity of the E. pellita plant is 0.60. *E. pellita* is a type of plant that has the same category as *A. mangium*, which is a fast growing plant.

The two Plants subject to carbon stock were planted at the same plant spacing and the same year of planting. In this study, the relationship between plant spacing and planting age on the amount of carbon stock in each stand was ignored.

Based on the above observations, it can be seen that A. mangium Plants store greater carbon stocks in the tree biomass section than the total carbon stocks in the E. pellita stand biomass. The difference in the amount of carbon stock is thought to be due to the physical properties of the *A. mangium* plant itself, such as the higher specific gravity value compared to the *E. pellita* plant. Apart from that, it is suspected that *A. mangium* is better suited for growing places because it is able and can grow well in almost all types of soil, this is different from E. pellita (Mulyadi, 1983).

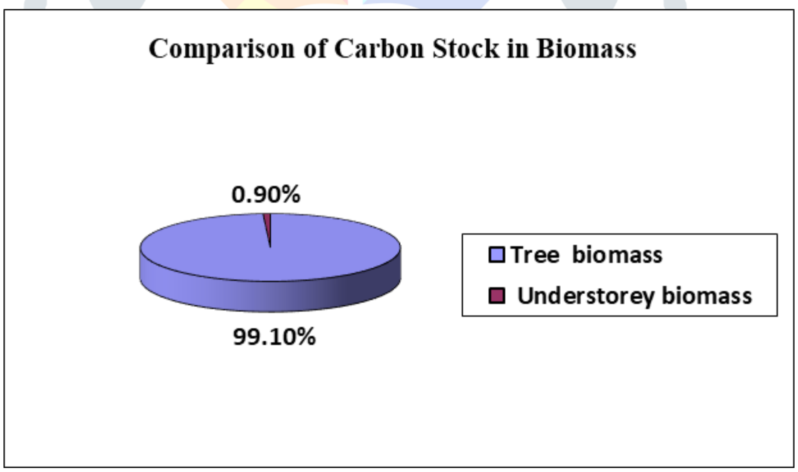
Carbon stocks in understory

The understory in A. mangium and *E. pellita* Plants differed both in type and in the amount of carbon stocks contained therein. Calculation of carbon stocks in understorey plants is carried out by damaging the plants (destructive sampling), namely by slashing (cleaning) them first, then drying the understorey samples (200 gr) and drying them in an oven to determine their dry weight, while the data from measurements of estimated reserves Carbon in understory in *A. mangium* and *E. pellita* Plants is presented in the bar graph below.



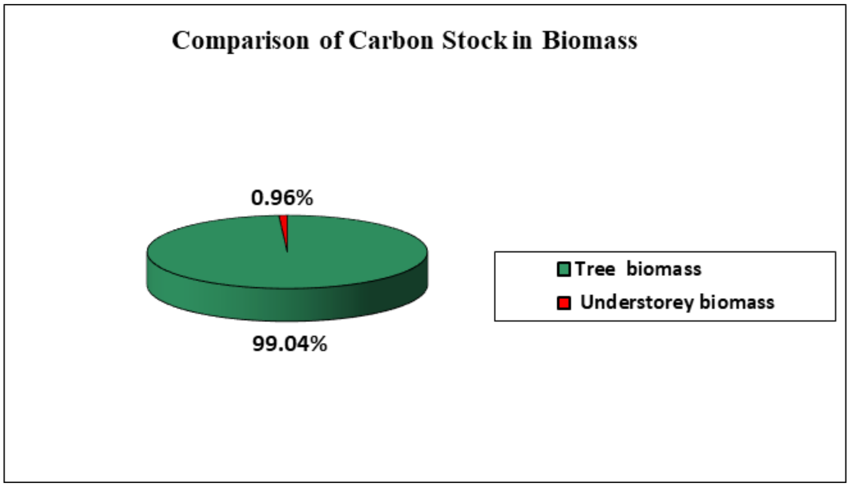
Graph 1. Estimation of carbon stocks in the understory of *A. mangium* and *E. pellita*.

The carbon stock stored in the understory of *A. mangium* is 0.89 ton/ha. The types of understory found in A. mangium Plants include krinyu (Chromolaena odorata) and the type Melastoma malabathricum while in the *E. pellita* stand the carbon stock in the understory is 0.50 tons/ha, while the understory species found in this stand are Alang- reeds (imperata cylindrica) and several types of grasses (graminae). When viewed based on the carbon stocks in the undergrowth of the two Plants, there is not much difference. This is thought to be caused by the same maintenance treatment on both Plants, namely in the form of clearing (slashing) which is generally carried out by the management of PT. Inhutani II twice a year.



Graph 2. Comparison of carbon stock in biomass in *A. Mangium* Plants

Based on a comparison of the amount of carbon stock in the biomass of *A. mangium* Plants (Graph) it is known that the biomass containing the largest carbon is found in tree biomass, in this case trees contain a larger amount of biomass and have a longer life cycle, so that the potential of carbon stocks is tree biomass lasts longer and can be stored compared to carbon stocks in understory.



Graph 3. Comparison of carbon stocks in biomass in *E. Pellita* Plants

Similar conditions also exist in Plants of *E. pellita* where the biomass in trees is larger and dominant than the biomass of the understory. It is very important to maintain the carbon stocks contained in trees and try to increase the amount of carbon absorption, for example by applying fertilizers and using appropriate silvictural techniques, so that tree growth can be maximized (Hairiah et al 2007).

Carbon stock in Necromass

Necromass is a component of carbon stocks found on the surface of the soil. In this study, necromass was differentiated based on woody necromass and litter necromass. Then it was processed in A. mangium necromass Plants in *A. mangium* and *E. pellita* as shown in Table 3 below.

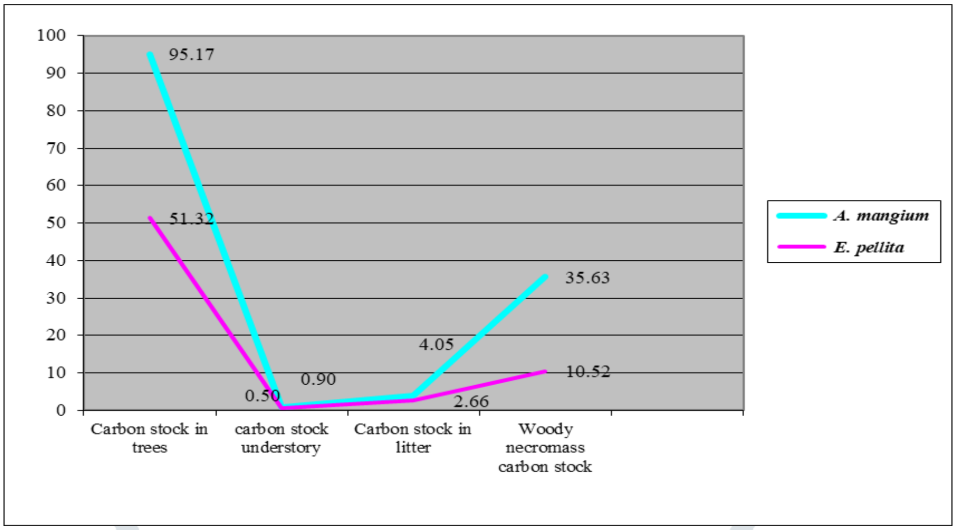
Table 1. Carbon stock in necromass in *A. mangium* and *E. Pellita* Plants

Plants	Necromass	Carbon stock (ton/ha)
A.mangium	Coarse litter	4,05 ton/ha
	Necromass woody	35,63 ton/ha
E. pellita	Coarse litter	2,66 ton/ha
	Necromass woody	10,52 ton/ha

Carbon stocks at the soil surface derived from necromass in *A. mangium* Plants derived from litter and woody necromass with an amount of 39.68 tonnes/ha which is the sum of 4.05 tonnes/ha of litter and 35.63 tonnes/ha of woody necromass . Of the two groups of necromass, woody necromass is larger as a store of carbon reserves compared to litter. Woody necromass comes from logged *A. mangium* trees that are still intact and broken stems and branches, while litter is part of the *A. mangium* plant. the smooth leaves and the understorey as well, however, the leaves of *A. mangium* are still dominated. The leaves of *A. mangium* are difficult to decompose, this can be seen by the large amount of litter that is evenly distributed on the floor of the Plants. In the *E. pellita* stand, carbon stocks derived from necromass consisted of litter with 2.65 tonnes/ha and woody necromass with 10.52 tonnes/ha. The condition is the same as the potential carbon stock in necromass in *A. mangium* Plants where the woody necromass is the largest amount of carbon stock stored in the necromass section compared to carbon stock in litter.

Woody necromass has a larger amount of biomass because it has a higher density compared to finer and lighter litter. From the description above it is also known how the carbon stock in nekromassa *A. mangium* is greater than that in *E. pellita*. Observations found that pieces of branches and twigs on the floor of Plants in this condition contributed to carbon stocks in woody necromass compared to Plants of *E. pellita* which were smaller in number.

Based on the data and description above, it can be seen that the composition of the distribution of carbon stocks above the soil surface in both A. mangium and *E. pellita* Plants is as shown in Fig.



Graph 4. Composition of the distribution of aboveground carbon stocks

The figure above shows the distribution of carbon stocks on the ground surface in Plants of *A. mangium* and *E. pellita* originating from tree carbon stocks, understorey carbon stocks, litter carbon stocks and woody necromass carbon stocks. The graph above shows that in Plants of *A. mangium* trees are the largest carbon stock compared to carbon stocks in understory and carbon stocks in woody litter and necromass. As well, carbon stocks in Plants of *E. pellita*, where trees are the largest carbon stock stores, followed by carbon stocks in woody necromass, litter and carbon stocks in undergrowth. Based on the amount of carbon stocks on the ground surface in *A. mangium* Plants, from all available sources of carbon stocks, the amount is greater than in *E. pellita* Plants.

The level of carbon absorption by terrestrial ecosystems depends on three aspects, namely (1) vegetation (species composition, structure, and age of plants), (2) site conditions (variations of climate, soil, and natural disturbances such as forest fires), (3) management and there is a response of terrestrial ecosystems to increasing concentrations of CO^2 in the atmosphere which previously only served as "fertilization" of CO*2* (Hairiah, 2007). From these three aspects, the most appropriate effort to reduce carbon in the air is through the management of vegetation, especially trees. The binding of CO^2 from the atmosphere by trees and storing it in the form of carbohydrates in biomass is one of the practical steps that can be used to control the amount of CO^2 in the atmosphere. Trees as part of the aboveground carbon stock component make the largest contribution as a carbon 'sink' on land when compared to other vegetation components such as undergrowth, necromass, and litter (Hairiah, 2007).

Carbon Stocks Below Ground

Measurement of carbon below ground level (below ground) is carried out by first taking a soil sample and testing it in the laboratory to determine the weight and specific gravity of the soil sample and the organic C content (% C). In this study, C reserves below the soil surface were calculated only at a depth of 0-15 cm, this condition is due to a depth of up to 15 cm which is assumed to be top soil. The amount of carbon stock below the soil surface in Plants of *A. mangium* and *E. pellita* is presented in Table 4.

Table 2. Belowground carbon stocks

No. Sample	Stock C in Plants *A.mangium* (ton/ha)	Stock C in Plants *E.pellita* (ton/ha)
1	25,15	10,78
2	15,32	13,42
Total	40,47	24,2
Average	20,23	12,1

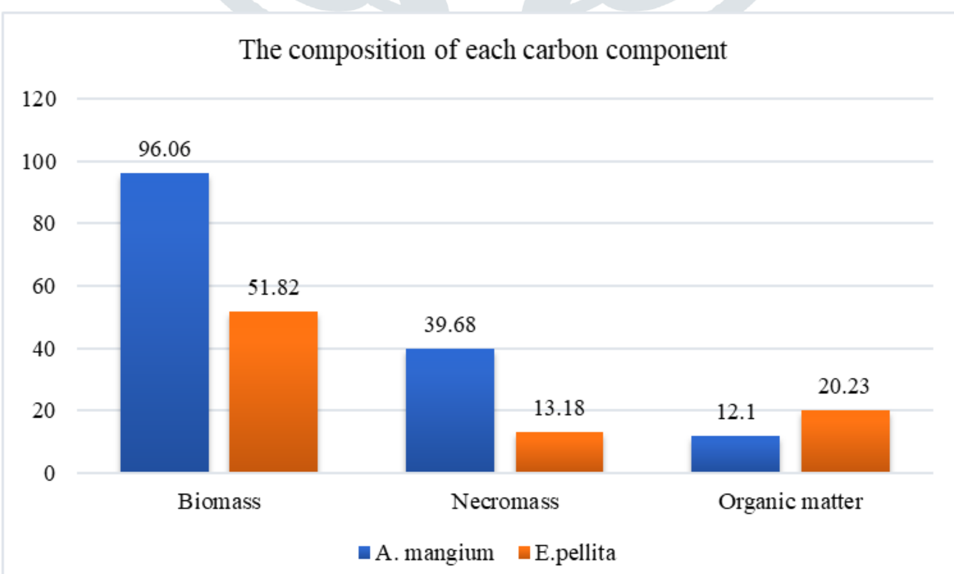
The results showed that the C reserves below the soil surface in *A. mangium* Plants were greater (20.23 tons/ha) than those in *E. pellita* Plants (12.1 tons/ha).

The litter that was erected for *A. mangium* was thicker because this species sheds its leaves quickly, so it is suspected that organic matter from the litter from the leaves of this species is the cause of the high organic C in the soil. This was also proven in the carbon stocks in the litter above, where in *A. mangium* Plants it was greater than in *E. pellita*, namely 4.05 tons/ha, this further confirmed that underground carbon stocks in *A. mangium* Plants were larger. compared to *E. pellita*.

If you look closely at the floor of the stand under *A. mangium*, the conditions are more humid. This can be seen how in this litter layer, you can find lots of white fungus hypa and are in layers of litter, thus the process of decomposition of litter into organic matter under stand *A .mangium* is better than *E. pellita* with the assumption that there are many decomposers on the floor of the Plants besides that the floor conditions of the Plants are more humid, meanwhile different conditions are found in *E.pellita* where the leaves of *E. pellita* shed less so the floor of the Plants is not too thick with litter compared to with *A. mangium*. The condition of the appearance of the more open canopy in *E.pellita* compared to the thicker canopy of *A.mangium* is also thought to be the cause of the amount of light entering the stand floor so that it is assumed that the temperature on the stand floor is higher than in *A.mangium* so that it can limit the activity of decomposing soil decomposers. organic matter.

Total carbon stock

The measurement results described above can illustrate how the carbon stocks in the two Plants, namely *A. mangium* and *E. pellita*, produce data that the carbon stocks in *A. mangium* are larger than those in *E. pellita*, while the comparison of the amount of carbon stocks in the 2 Plants can be presented in picture diagram below:



Picture 5. Composition carbon in *A. mangium* and *E. Pellita* Plants
BOT = Soil Organic Matter

Based on the measurement results, the total value of carbon content for each location is as follows:

Table 6. Total carbon stocks in *A. mangium* forest and *E. Pellita*

Lokasi Plot	**Luas Lokasi**	**Komponen Penyusun C**	**Jumlah C tersimpan (ton/ha)**
A. mangium	2000 m^2	Biomassa: - Pohon *A. mangium* - Tumbuhan bawah	 95,167 0,89
		Nekromassa (serasah)	39,68
		Bahan organik tanah	20,23
Jumlah			**155,967**
E. pellita	2000 m^2	Biomassa: - Pohon *E. pellita* - Tumbuhan bawah	 51,32 0,50
		Nekromassa (serasah)	13,18
		Bahan organik tanah	12,10
Jumlah			**77,10**

Source: Processed primary data, 2010.

Based on Table 6 above, it can be seen that the total carbon stock value for *A. mangium* forest is 155.967 tons/ha while for the total carbon stock value for *E. pellita* is 77.10 tons/ha. For each part, namely *A. mangium* forest, the tree biomass was 95.167 tons/ha, the understorey biomass was 0.89 tons/ha, the necromass was 39.68 tons/ha, soil organic matter was 20.23 tons/ha. Ha. The largest total carbon content is found in *A. mangium* trees, 95.167 tons/ha, while for *E. pellita* forest, tree biomass is 51.32 tons/ha, understory is 0.50 tons/ha, necromass is 13.18 tons/ha, organic matter soil, 12.1 tons/ha.

Carbon stocks in *A. mangium* Plants from all carbon storage components that exist on land, namely: biomass, necromass and soil organic matter based on the measurement results in this study using the same age Plants and the assumption of the same treatment describes how carbon stocks in *A. mangium* Plants. *A. mangium* is larger in total and in terms of components for storing carbon reserves on land. This is an input on how *A. mangium* Plants are able to store carbon stocks that are larger than *E. pellita*.

The results of research on agroforestry silvicultural systems found that carbon stocks in semiarid, humid, and temperate climate types were 9, 21, 50, and 63 tonnes/ha, respectively (Nair, 2004). Whereas on peat land it was found that the carbon stock in the upper biomass was 400 - 900 tons/ha for natural peat swamp forest, 240 - 400 tons/ha for logged-over forest, 210 - 460 tons/ha for burnt areas in 1997 and 15 - 21 tons/ha for burnt forest twice, namely in 1997 and 2002 (Palangka Jaya H, 2005).

Based on the results of the research above, it was found that the carbon stock in industrial plantation forests is greater than in agroforestry. Meanwhile, when compared to peat forests, the carbon stocks in industrial plantation forests of the types *Acacia mengium* and *E. pellita* are lower.

Carbon Dioxide Absorbed

The absorption potential of CO^2 gas in coffee plants is measured using the ratio formula for the relative molecular mass of CO2 gas to the elemental mass of C (Rm CO^2: Ra C) = 44/12 or 3.67, which is used as a continuous value and then multiplied by the total carbon content. It was calculated that CO^2 was absorbed by plants *A. mangium* 572,399 Mg ha-1 and *E. pellita* 282,957 Mg ha-1. The CO^2 gas absorption increased with the corresponding increase in age of *A. mangium* dan *E. pellita* plants.

Calculation of economic value ($)

Value of carbon stocks in coffee plantations is calculated using the value approach of the REDD (Reducing Emissions from Deforestation and Forest Degradation) project within the 5-year project period. REDD project payments are made with a full payment mechanism at the start of the project (full ex-ante credit). The carbon price uses a hypothetical price folks $ 6, US $ 9, and US $ 12 per ton of CO^2 (ha-^{1}).

The quantity of CO^2 absorbed by *A. mangium* and *E. pellita* converted to US $ per hectare. *A. mangium* obtained the highest economic value as carbon price per ton CO^2 increase (from US$1,871.604, and 1,403.703 to US$9,35.805). The *E. pellita* Plants (from US$ 925.20, and 693.90 to US$1462.60) and Results indicate that with an increase in carbon price, there is a corresponding increase in economic value Industry forest plantation.

IV. Conclusion

Based on the results of tree biomass measurements, it is known that the amount of carbon reserves in Acacia mangium is 155,967, followed by Eucaliptus pellita at 95,167 tons/ha. Based on the results of measuring tree biomass in Acacia mangium Plants, it is known that the amount of carbon stock is 155,967 ton/ha, consisting of 95,167 tons/ha of *Eucalyptus pellita* Plants. Value of carbon stocks in coffee plantations is calculated using the value approach of the REDD (Reducing Emissions from Deforestation and Forest Degradation) project within the 5-year project period. REDD project payments are made with a full payment mechanism at the start of the project (full ex-ante credit). The carbon price uses a hypothetical price folks $ 6, US $ 9, and US $ 12 per ton of CO^2 (ha-^{1}).

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