Degradation of carbon stock (C) in calculation analysis of greenhouse gas emissions in cocoa plantations in South Sulawesi

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Abstract. Cocoa as one of the most developed plantation commodities in Indonesia has a strategic position in efforts to increase carbon absorption to reduce the rate of global warming. As a woody plant, cocoa can absorb CO₂ from the air and store it in the form of carbon (C) in its body (biomass). The absorption process of CO₂ also affects the rate of photosynthesis in plants as the main ingredient in the breakdown of carbon in the plant body, especially cocoa. This research was conducted in Gantarangkeke District, Bantaeng Regency, South Sulawesi. Sampling was carried out by purposive sampling method on the basis of consideration of the type, density and cropping system applied. The estimation of biomass used a non-destructive method by measuring the diameter at breast height (DBH 1.3 m) and the height of the cocoa. Carbon storage in cocoa is differentiated by several plant ages, namely 5 years and 10 years. The results showed that the carbon stock in Bantaeng Regency was 27.05 tons / Ha.

1. Introduction

Global warming is an important issue in the early 21st century which is caused by the increase in the concentration of GHG (Greenhouse Gas) in the atmosphere as a result of burning fossil fuels. The increase in the concentration of GHG in the atmosphere is caused by an increase in CO₂ gas emissions. This significant increase in CO₂ must be handled in an integrated manner. The management of forest vegetation that has been carried out by the Indonesian government at this time is still not effective in reducing the amount of CO₂ levels in the atmosphere due to the increasing rate of degradation of forest ecosystems in Indonesia.

In 2016, the total area planted with cocoa in Indonesia reached 1,680,094 ha, which is widespread in several regions such as Sumatra, Java, Nusa Tenggara and Bali, Kalimantan, Sulawesi, Maluku, and Papua [1]. This area illustrates that the potential for cocoa plantations in Indonesia to help reduce GHG emissions is enormous through absorption of CO₂ in the atmosphere.

South Sulawesi is one of the regions in Sulawesi, which is the largest center for smallholder cocoa production in Indonesia. The total area of cocoa plantations in South Sulawesi is 240,073 hectares spread over 22 districts. This figure is almost 50% representing the current production forest in South Sulawesi which is in the area of 494,846 Ha [1]. The landscape of cocoa in South Sulawesi is very varied supported by the suitability of land for cocoa cultivation in South Sulawesi. The landscape effect
determines the amount of carbon stored in a land. The research area is divided into two categories of plantations, namely the monoculture system and the various or multistrata sheds.

In this study, the method used is a non-destructive method with an allometric approach. Allometric is a method that has been developed to estimate carbon stored in plant bodies. The use of allometric formulas in several plants has been used by researchers to determine the carbon stock stored in the plant body, including what was done by Yuliasmara [2] to estimate stored carbon at various ages and cocoa cropping systems. The stored carbon in a land is greater if the soil conditions are fertile. Soil fertility results in fertility of plants so that plant biomass also increases as a result of being influenced by soil organic C.

2. Greenhouse gases
Climate change is a problem facing our planet and has developed rapidly after the industrial revolution. Greenhouse gas emissions have accelerated progress on climate change and made our weather even more intense [3].

Agriculture is the main driver of increasing N₂O emissions, through the use of synthetic fertilizers to increase the supply of nitrogen available to agricultural systems [4]. Emission is the process of releasing GHG into the atmosphere, through the decomposition of organic matter by microbes that produce CO₂ or CH₄ gas, combustion organic materials that produce CO₂ and nitrification and denitrification processes that produce N₂O gas [5].

Emission factors or carbon sequestration for changes in land cover are the differences in the amount of carbon stock due to changes in a particular land cover type to another. Emission factors are obtained using reference data (default) of carbon stocks from all types of land cover [6].

3. Stored carbon
Natural forests are the largest store of carbon compared to other land use systems such as agriculture. Natural forest is a high carbon store due to its high tree diversity and abundant understorey and litter [7].

The ability of forests to absorb and store carbon is not the same in natural forests, plantation forests, brackish forests, swamp forests and community forests, depending on the type of tree, soil type and topography. Carbon stocks in various land cover classes in natural forest range from 7.5 t/ha - 264.7 t/ha. Relatively dry land forests have the ability to store carbon in greater amounts than swamp and mangrove forests, because of their ability to build tall, large-diameter stands as carbon storage [8].

The stored carbon component consists of carbon stored above the soil surface consisting of living plants (stems, branches, leaves, lianas, epiphytes, and understorey plants) and dead plants (fallen trees, standing dead trees, leaves, branches, twigs, flowers and fruits. who fell, as well as the remains of the burning). Meanwhile, carbon stored below the soil surface includes plant roots, both living and dead, soil organisms and soil organic matter. The stored carbon in a land use is influenced by the type of vegetation [9].

4. CO₂ Absorption
Plants have a role in climate change mitigation, which can reduce the amount of emissions and or increase CO₂ absorption and carbon storage (sequestration). As a woody plant, cocoa can absorb CO₂ from the air and store it in the form of carbon (C) in its body (biomass). By measuring the C content in the body of the cocoa plant, it will be known the amount of CO₂ absorbed from the air. The greater the cocoa plant biomass, the higher the amount of CO₂ absorbed, so that the CO₂ content in the air will decrease [10].

One of the efforts made to help reduce CO₂ emissions is to protect the plantation ecosystem. Plants have a role in climate change mitigation, which can reduce the amount of emissions and / or increase CO₂ absorption and carbon sequestration. Long-lived trees that grow in forests and in mixed gardens (agroforestry) are large storage or storage places for carbon compared to annual crops [8].
As a woody plant, cocoa can absorb CO$_2$ from water and store it in the form of carbon (C) in its body (biomass). The absorption process of CO$_2$ also affects the rate of plant photosynthesis as the main ingredient in the decomposition of carbon in the plant body, especially cocoa. Thus measuring the amount of C levels stored in the living plant body (biomass) in the field can describe the amount of CO$_2$ in the atmosphere absorbed by plants. The greater the cocoa plant biomass, the higher the amount of CO$_2$ absorbed so that the CO$_2$ content in the air will decrease [11].

5. Methodology
This research was conducted in Bantaeng Regency. Determination of the location in this study was carried out deliberately (purposive sampling). Samples from the field were then analyzed at the Laboratory of Soil Science, Faculty of Agriculture, Hasanuddin University. Implementation of research starting from preparation, data collection in the field, data processing and analysis and compilation of research results was carried out for 6 (six) months, from September 2020 to January 2021.

Estimation of carbon stocks is carried out by referring to the Practical Guide to Measuring Carbon Stocks from Land Level to Landscapes compiled by Hairiah et al. [10]. The guidelines are part of the Rapid Carbon Stock Appraisal (RaCSA) method, which is specially designed for measuring carbon stocks in mineral soils.

There are three categories of cocoa plantations that become research indicators, namely (K0) Cocoa plantations with an age of 5 years, (K1) Cocoa plantations with an age of 10 years and (K2) Cocoa plantations with an age of 20 years. The data collection began with the creation of sample plots and continued with

6. Results and discussion

6.1. Vegetation of trees
The tree vegetation that was often found in almost 2 research locations which became the research sample was cocoa. In table 1, the results of the calculation of the average carbon stored in a sample plot of 20 m x 20 m are presented per location.

| No | Garden Age | Deuteronomy/Plot | Number of Cocoa Plants | Cocoa Tree Biomass ton/ha | C ton/plot | Total C/ha |
|----|-------------|------------------|------------------------|--------------------------|------------|-----------|
| 1  | 5 Years     | Deuteronomy 1    | 11                     | 2.03                     | 1.02       | 4.73      |
|    |             | Deuteronomy 2    | 12                     | 3.94                     | 1.97       | 7.96      |
|    |             | Deuteronomy 3    | 9                      | 3.48                     | 1.74       |           |
| 2  | 10 Years    | Deuteronomy 1    | 19                     | 15.91                    | 7.96       |           |
|    |             | Deuteronomy 2    | 20                     | 21.32                    | 10.66      | 30.91     |
|    |             | Deuteronomy 3    | 20                     | 24.61                    | 12.30      |           |

Table 1 shows that the largest stored carbon is found in cacao plants that are 10 years old. Cocoa plants that are 10 years old store a lot of carbon with a value of $C = 30.91$ tons / ha while the carbon absorption value of 5 year old cocoa plants can absorb with a value of $C = 4.73$ tons / ha.
6.2. Lower plant vegetation
The vegetation of the lower plants is dominated by kentangan (*Borreria latifolia*), krinyuh (*Chromolaena odorata*), harendong (*Clidemia hirta*), babandotan (*Ageratum conyzoides*), nut grass (*Cyperus rotundus*), jambean (*Selaria plicata*), and mikania (*Mikania micrantha*).

Table 2. Carbon is stored in the vegetation under the Cocoa Plantation in Bantaeng.

| No | Garden Age | Deuteronomy/Plot | W ton/ha | C ton/plot | Total C/ha |
|----|------------|------------------|----------|------------|-----------|
|    |            | Deuteronomy 1    |  1.63    |  0.82      |  2.34     |
| 1  | 5 Years    | Deuteronomy 2    |  1.53    |  0.77      |  2.30     |
|    |            | Deuteronomy 3    |  1.52    |  0.76      |  2.28     |
|    |            | Deuteronomy 1    |  1.09    |  0.55      |  1.64     |
| 2  | 10 Years   | Deuteronomy 2    |  1.37    |  0.69      |  2.06     |
|    |            | Deuteronomy 3    |  1.37    |  0.69      |  2.06     |

Table 2 Shows that the carbon stored in lower vegetation in cocoa plantations that are 5 years old is higher than in lower vegetation in 10 year old cocoa plantations. In lower vegetation in cocoa plantations that are 5 years old, the total value of C = 2.34 ton / ha is obtained, while the carbon absorption value of lower vegetation in cocoa plantations aged 10 years can absorb with a value of C = 1.92 ton/ha.

6.3. Necromass and litter
Stored carbon necromass Carbon stored necromass is in the form of dead trees, both upright and fallen, and the litter of fallen plant parts in the form of leaves and twigs. Biomass and carbon determination was done by taking litter directly from the field, then weighing the wet weight, oven and finally using a factor of 0.46.

Table 3. Stored Carbon Necromass and Litter in Cocoa Plantation in South Sulawesi

| No | Garden Age | Deuteronomy/Plot | W ton/ha | C ton/plot | Total C/ha |
|----|------------|------------------|----------|------------|-----------|
|    |            | Deuteronomy 1    |  1.55    |  0.78      |  2.23     |
| 1  | 5 Years    | Deuteronomy 2    |  1.21    |  0.61      |  1.82     |
|    |            | Deuteronomy 3    |  1.9     |  0.95      |  2.85     |
|    |            | Deuteronomy 1    |  1.21    |  0.61      |  1.82     |
| 2  | 10 Years   | Deuteronomy 2    |  1.11    |  0.56      |  1.67     |
|    |            | Deuteronomy 3    |  1.51    |  0.76      |  2.27     |

Table 3 shows that cocoa plantations that are 5 years old store the most carbon with a value of C = 2.23 tonnes / ha, while the value of carbon absorption in cocoa plantations aged 10 years is C = 1.92 tonnes / ha. The results of carbon measurements in the cocoa plant decreased at the age of 10 years.
6.4. Stored Carbon

The results of stored carbon calculations show that the age of the plant will vary the amount of carbon stored in a cropping area. Details of the amount of carbon stored in cocoa aged 5 years and 10 years are presented in Table 4.

Table 4. Stored carbon necromass and litter in cocoa plantation in South Sulawesi.

| Location                     | Plant Age | Carbon Sequestration | Total C |
|------------------------------|-----------|----------------------|---------|
| Kec. Gantarangkeke Desa      | 5 Years   | 4.73 2.34 2.23 1.77 10.18 | 11.07   |
| Gantarangkeke                |           |                      |         |
| Kec. Gantarangkeke Desa      | 10 Years  | 30.98 1.91 1.92 8.22 12.99 | 43.03   |
| Gantarangkeke                |           |                      |         |
| Average                      |           | 27.05                |         |

Table 4 shows that the 10 year old cocoa plants absorb the most carbon. This illustrates that the cacao plant at 10 years of age absorbs more than the 5 year old cocoa plant. This can also indicate that the older the cocoa plant is, the higher the amount of carbohydrates it can absorb. So the cocoa plant makes a real contribution and also functions as a conservationist for the environment and social conditions, thus ensuring a wider economy and higher food security. Thus, cocoa plantations have the potential to play a dual role, namely as a producer of commodities with economic value and as an environmental conservationist in terms of carbon absorption.

6.5. Carbon Emissions

Carbon emissions from changes in land cover from plantation forests to plantations based on historical land use are the difference between carbon stored in plantations and carbon stored in plantations. The carbon stored in plantation forests in Sulawesi [3] is 92.65 t / ha. Thus the carbon emissions that occur in Bantaeng Regency are:

\[ \Delta CA = 92.65 - 27.05 = 65.6 \text{ t/ha} \]

Based on the calculation, the results of carbon emissions in Bantaeng Regency were 65.6 t / ha.

6.6. CO₂ content

The amount of carbon dioxide sequestered in the sample plot area was calculated by multiplying the amount of carbon stored in the sample plot by the molecular weight ratio of carbon dioxide and elemental carbon, i.e. 44/12 or 3.67 [4]. The amount of CO₂ content in cocoa plants in Bantaeng Regency is 3.67 x 27.05 tonnes C / ha = 99.27 tonnes CO₂ / ha.\[ \Delta CA = 92.65 - 27.05 = 65.6 \text{ t/ha} \]

7. Conclusion

Application of The largest carbon sequestration between the two cocoa plantations is the 10 year old cocoa plant with a total estimated carbon absorption of 43.03 ton/ha. The absorption of carbon emissions by cocoa plants has not been able to beat or balance the absorption of carbon by forest plantations and Based on the calculation, the results of carbon emissions in Bantaeng Regency were 65.6 t / ha.

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