The impact of land covers on carbon stock potential Rantau Research Forest in South Kalimantan

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Abstract. Changes in land cover determine the decrease or increase in carbon storage in a landscape. This study aimed to determine the amount of carbon storage in each type of land cover and determine the effect of land cover type on the carbon storage amount in each carbon pool. This research was conducted in Rantau research forest with three main land coverage, they were: plantation forest, secondary forest, and grassland. The survey was carried out by measuring five carbon pools, namely vegetation, litter, understory, necromass, and soil carbon, carried out on the land cover types of grassland, plantation forests, and secondary forest. The effect of land coverage to carbon storage was determined by using analysis of variance. The results showed that carbon storage was mostly deposited in vegetation carbon and soil carbon. The secondary forest has the largest carbon storage, namely 135.1 Mg/Ha, followed by plantation forest at 107.4 Mg/Ha, and Grassland at 83.3 Mg/ha. Changes in land cover from secondary forest to cogon grass caused the largest carbon storage reduction by 34%. This change decreased in the cover of the plantation forest to grassland by 20.5%. The implication is that an increase in carbon storage can be achieved by planting in grassland so that the cover becomes secondary forest or plants.

1. Introduction
Tropical forests are the world's largest carbon stores compared to other biomes [1,2]. Carbon plays a crucial role as a provider of environmental services by regulating climate change [3]. This carbon is stored in two forms: biomass, vegetation/ground biomass through photosynthesis, and transfer to subsurface carbon, including roots and soil carbon, deadwood, and litter [4]. This condition occurs in some tropical forests around the world [5,6]. In tropical forest ecosystems, carbon storage has decreased/increased following land cover/use conditions.

Land use/cover is the most important factor in maintaining and sustaining an ecosystem's natural functions [6]. The increase in carbon emissions is strongly influenced by land cover changes and as a major factor in carbon emissions after the usage of fossil fuels [1]. This condition is caused by a large amount of carbon storage, which is closely related to the type and structure of vegetation [3], historical land use [3], and use of harvesting/silvicultural techniques [7].

Deforestation and land degradation occur almost worldwide in a wide variety of forest types [5,8]. This condition affects carbon potential changes, changes in ecosystem potential, and climate change [3]. This decreases the function of tropical forests as large carbon stocks and sequestrationers of CO₂ from the atmosphere [9] as well as changes in the soil nutrient cycle [5,10]. Human and natural activities cause deforestation and forest degradation [2].
This study was conducted in Rantau research forest, Tapin District, South Kalimantan. This forest is the only remaining forest with quite complete coverage aside to mining as other landuse/coverage. This forest is seed source for surrounding area and has sufficiently high carbon storage. However, information about carbon storage potential in this location is still very limited. This study aimed to 1) obtain carbon storage in each type of land cover, 2) determine the effect of land cover type on carbon storage in each carbon pool.

2. Materials and Methods

2.1. Materials

This research was conducted in the Rantau Research Forest, located in Tapin Regency, South Kalimantan. The research forest has four coverage, they are: secondary forest, plantation forest, reeds/grassland and mining area. Data collecting was done in 3 main coverage (Figure 1). Materials and tools used included a diameter measuring tape, soil sample ring, oven, and scale.

2.2. Methods

2.2.1. Shape and size of sample plots

The type of land cover was a factor in determining the location of measurements consisting of grassland, plantation forest, and secondary forest. The plot was 400 m² for trees, 100 m² for poles, 25 m² for saplings, and 4 m² for seedlings in the vegetation measurement. The carbon pool of understorey and litter was 4 m² [11]. Necromass (deadwood and course wood debris) used a plot with a size of 200 m². Soil carbon used ring samples to determine bulk density.

2.2.2. Carbon pool measurement

In vegetation carbon, measurements were performed by measuring the diameter and height at all vegetation levels according to the plot size. Litter and understorey were taken and weighed in wet weight and a sample weighing of 300 grams. Necromass were measured in two types, namely wood and dead
trees. Measurements were performed by measuring the diameter, height, and length of the necromass found. Soil carbon was measured to a depth of 30 cm and collected at every 10 cm depth. Sampling was conducted using a ring sample.

2.2.3. Data Processing
The determination of vegetation biomass using the formula \[ B = 0.19(DBH)^{2.37} \] which \( B \) is biomass (kg), DBH: diameter breast height (cm). The understorey biomass, litter, and soil carbon were determined by dry weight. Then, the dry weight was formulated [13]:

\[
\text{BKT} = \frac{\text{BB}}{1 + \left( \frac{\%KA_c}{100} \right)}
\]

which BB is fresh weight (kg); BKT is dry weight (kg); KA_c is sample moisture content (kg). Necromass was determined by the formula for tree volume and tree density to determine the biomass of necromass. Carbon storage was determined based on the carbon content of 47% [14] and a soil carbon content of 2% [15]. Total carbon stores were the sum of all carbon pools [7].

2.3. Data analysis
Univariate analysis (ANOVA and Tukey test Multicomparion) was used to determine the significant difference between each carbon pool and total carbon storage for different land types.

3. Results and Discussion
The main coverage of Rantau research forest are plantation forest, reeds, and secondary forest (Figure 1). These coverage are dominating land coverage for more than 90%.

3.1. Carbon stock potential
The potential for carbon storage varies between land covers. In grassland and plantation forest cover, soil carbon provides the largest carbon storage contribution, while in secondary forests, vegetation is the largest carbon store (Table 1). Diversity analysis shows that the type of land cover has an effect on the amount of carbon storage in the vegetation carbon pool and the total carbon storage with \( P_{\text{value}} < 0.05 \) (Table 1) but the amount of storage in other carbon pools is not influenced by the type of land cover with \( P_{\text{value}} > 0.05 \). This condition is different from the results of research [3] conducted in tropical forests of Malagasy. In these forest types, the largest carbon stores are found in soil carbon for the entire land cover, such as dense stands, sparse/empty stands, degraded forests, and scrub [3]. The amount of soil carbon storage varies greatly with each soil depth [16] and is influenced by the soil horizon [3].

This study indicates that some of the stored carbon is in soil and vegetation carbon (Figure 2). This study's results are supported by [16] carried out on land cover: forests, crops, gardens, and croplands in Nigeria. In the secondary forest land cover type, soil carbon storage has the smallest carbon storage. This is due to the smallest bulk density compared to other land covers. This condition is similar to the results[16], which showed that BD is closely related/influenced by land cover and soil depth [17]. Total carbon storage is strongly influenced by land cover type. This can be explained that the amount of carbon storage is closely related to the amount of carbon stored in vegetation. The carbon storage of the vegetation is related to the density and dimensions of the trees stands [3,7,18]. The increase in these parameters can be adjusted using selective logging with logging intensity adjusted to the conditions of the stands being cut [7,18,19] so that the increase in carbon storage is also related to the length of recovery after logging or the length of time for reforestation [19].
Figure 2. Proportion of carbon pool

Table 1. Carbon stock potential on each carbon pool in difference land cover

| Land cover/parameter       | Carbon stock in each carbon pool (Mg/Ha) | Total  |
|----------------------------|------------------------------------------|--------|
|                            | Deadwood | Litter | Carbon soil | Understory | Vegetation |        |
| Grassland                  | 0.006a   | 3.11a  | 71.51a      | 2.94a      | 5.72a      | 83.291a|
| Secondary forest           | 0.075a   | 1.48a  | 50.61a      | 1.27a      | 98.53b     | 135.10c|
| Forest Plantation          | 0a       | 0.44a  | 72.44a      | 1.48a      | 33.03a     | 107.40b|
| \( F_{\text{calculate}} \) | 2.16     | 1.61   | 2.67        | 1.85       | 111.24     | 13.78  |
| \( p_{\text{value}} \)    | 0.210    | 0.289  | 0.163       | 0.250      | 0.00       | 0.016  |

Remarks: the same letter show that is not significant

3.2. Change in carbon storage

In grassland, the change in carbon storage is smaller than that of plantation and secondary forest (Table 2). This indicates that the grassland area is experiencing land degradation, including converting secondary forests into a plantation forest. According to [6], the reduction in carbon storage occurs in degraded areas by land. The largest decrease is in the type of grassland cover. This is in line with research conducted on forest types, agroforestry, and rubber plants. This study indicates that forest conversion to agroforestry or monoculture causes a decrease in carbon storage, including subsurface and soil carbon [20].

Table 2. The change of carbon stock from one to land cover others

| Land cover       | Carbon stock change (%) |
|------------------|-------------------------|
|                  | Grassland | Secondary forest | Forest Plantation |
| Grassland        | -         | 34.1              | 17.1              |
| Secondary forest | -34.1     | -                 | -20.5             |
| Forest Plantation| -17.1     | 20.5              | -                 |

This condition encourages afforestation/reforestation on grasslands and replacing plantations that have passed their cycle. This will increase the potential for land to squestration and store carbon because reforestation/afforestation efforts will increase the density and canopy cover of degraded areas [21]. However,
the reforestation business requires a relatively long time, and costs are quite expensive so that the condition is close to the natural forest [19].

4. Conclusion
The highest carbon storage potential is secondary forest land coverage and reeds/grassland coverage type is the lowest carbon storage. Land cover affects the amount of carbon storage in the vegetation pool and the total carbon pool. In other carbon pools, carbon storage is not affected by land cover and has the smallest contribution to total carbon storage. Vegetation and soil carbon reserves contribute more than 90% to total carbon. Changes in land cover cause changes in carbon storage. The largest reduction in carbon storage occurred in changes in land cover to grassland.

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