Study of changes in carbon stock in primary and secondary forest in protection forest of Soya Village, Ambon City

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Abstract. This study aimed to determine changes in litter biomass and the effect of changes in litter biomass on carbon stock changes in Permanent Sample Plots of primary and secondary forest in the Protection Forest of Soya Village, Ambon City, for three years of measurement. This study used a sampling method with harvesting/collection and using laboratory analysis, where the working procedure used the SNI: 7724 guidelines. The data taken includes the water content of litter, total wet weight, dry weight of the sample, and wet weight of the sample to calculate the range of biomass or organic matter and carbon content of litter organic matter. The results showed that the average value of water content in both primary and secondary forests decreased. The depletion degree was higher in the first year than the second and third year. The biomass content of litter in primary forests decreased from year to year for three years of measurement. It causes a decrease in the carbon content in the primary forest. In contrast, the biomass content in secondary forests increased from year to year and increased carbon content from year to year for three years of measurement.

1. Introduction
The current climate change is evidenced by the long dry season and relatively short rainy season with high rain intensity. The result is prolonged drought, crop failure, food crisis, lack of clean water, warming sea levels, floods, and landslides [1] and [2].

The cause of this climate change is an increase in the concentration of Greenhouse Gases (GHG), namely Carbon Dioxide (CO2), Methane (CH4), Nitrous Oxide (N2O), Hydro Fluorocarbon (HFC), Perfluoro Carbon (PFC), and Sulfur Hexafluoride (SF6) in the atmosphere. According to [2], the largest source of emissions in the world comes from the energy sector (24% power generation, 14% industry, 14% transportation, 8% construction, and other energy sources 5%) and from the non-energy sector (land change including forestry 18%, agriculture 14% and waste 3%).

Forest biomass plays a critical role in the biogeochemical cycle, especially for the carbon cycle [3]. Photosynthesis causes the binding of CO2 to biomass, while decomposition and combustion cause the release of CO2 into the atmosphere. The natural forest acts as the highest sink (carbon sink or storage) compared to other land-use systems due to the high diversity of trees, dense undergrowth, and litter covering the soil surface. If the forest's function is changed or the forest density decreases, then the stored C will be reduced, and it could be lost entirely [4].

According to [5], forest plants or trees are considered a carbon storage place or deposition. The amount of carbon and tree biomass content varies based on the part of the plant being measured, growth stage, plant level, and environmental conditions. The carbon content and biomass of understorey are influenced by the species of constituent plants [6]. The litter layer or forest floor is all
dead organic material that is above the soil surface. Some of this organic material can still be recognized or is still slightly decomposed [7].

Therefore measuring the amount of carbon in biomass inland can describe the amount of carbon dioxide (CO2) in the atmosphere that plants absorb, and measuring carbon in dead plant parts (necromass) can define the carbon dioxide (CO2) that is not released into the air through combustion.

Mount Sirimau Protection Forest is a forest ecosystem that functions to support life, namely to regulate water management, prevent floods and erosion, maintain global climate stability and maintain soil durability and fertility. Mount Sirimau Protection Forest also has a high diversity of flora and fauna as well as potential tourist attractions. Therefore, research was conducted with the title "Study of Changes in Carbon Stock in Primary and Secondary Forest in Protected Forest of Soya Village, Ambon City." The purpose of this study was to determine the changes in litter biomass and the effect of changes in litter biomass on changes in carbon stocks in primary forest and secondary forest PSP in the Protection Forest of Soya Village, Ambon City, for three years of measurement.

2. Methods

The research was conducted on a Permanent Sample Plot (PSP) built in the Soya Village Protected Forest Management Unit, Sirimau District, Ambon City, and continued in the Silviculture Laboratory Forestry Department, Faculty of Agriculture, Pattimura University. This research was conducted for three years, and data were taken every year.

There were several tools used in this research. GPS to determine the coordinates of sample plots. Digital scale (Ohaus Balance) with 0.5% accuracy. Other tools include meter roll to make a 2 m x 2 m plot, knife and cuttings to cut the litter into small pieces, brown envelope for laying litter, plastic bags for storing wet samples, and oven to dry the sample. The material or object used was litter on PSP floors in Protected Forest of Soya Village, Sirimau District, Ambon City.

2.1. Procedure

Measurement of litter biomass using the steps in [8], where the stages of measuring litter biomass were carried out as follows: a) collect litter in the measurement plot; b) weigh the total litter weight; c) take approximately 300 grams to consider the sample weight; d) oven-dry the litter sample at a temperature range of 70 °C to 85 °C until it reaches a constant weight; e) weigh the dry weight of the litter; f. do an organic carbon analysis in the laboratory to see the carbon content.

2.2. Data Analysis

The analysis used in this method was quantitative analysis by comparing the re-measurement data with the data from the previous measurement results. Calculating the water litter content using the formula:

\[ WC = \left(\frac{WWs - DWs}{WWs}\right) \times 100 \]

Information: WC = Water Content (%), WWs = Sample Wet Weight (gr), DWs = Sample Dry Weight (gr).

The estimate of litter biomass was calculated using the following formula: Calculation of litter organic matter:

\[ Wo = \left(\frac{DWs \times WWt}{WWs}\right) \]

Information: Wo = weight of organic matter, expressed in kilograms (kg); DWs = dry weight of the sample, expressed in kilograms (kg); WWt = total wet weight, expressed in kilograms (kg); WWs = sample wet weight, expressed in (kg).

Carbon accounting of dead organic matter (litter), Calculation of carbon from litter organic matter using the following formula:

\[ Cm = Wo \times \% C \text{ organic} \]

Information: Cm is the carbon content of dead organic matter, expressed in kilograms (tonnes/ acres); Wo is the total biomass/organic matter, represented in kilograms (tonnes/ acres); % C organic is the percentage value of carbon content, amounting to 0.47 or using the percent carbon value obtained from measurement results in the laboratory measurement of litter biomass using the steps in [8], where the stages of measuring litter.
3. Results and discussion

3.1. Water Content of Litter

The amount of water content affects the amount of biomass contained in an object. Water content is an important indicator that must be known, where the greater the value of water content, the smaller the biomass value will be. Based on the research results, it was found that the water content of the litter in the Primary Forest ranged from 43.13 to 46.60% in year I; 63.34-65.50% in year II; and 52.86-64.33% in year III. Meanwhile, the range of water content in Secondary Forest is between 33.50-43.37% in the year I, 60.33-66.67% in year II, and 53.33-66.83% in year III.

The average water content in Primary Forest for the first year reached 45.13%; in year II, it reached 64.63%, and in year III reached 60.40%. Meanwhile, the average water content in secondary forest in the first year was 39.87%; in year II amounted to 63.27%, and in year III amounted to 59.89% (see Table 1 and Figure 1).

Table 1. Interval of the water content of primary and secondary forest in protection forest of soya village

| Location          | Interval Year I (%) | Interval Year II (%) | Interval Year III (%) |
|-------------------|---------------------|----------------------|-----------------------|
| Primary Forest    | 43.13-46.60         | 63.34-65.50          | 52.86-64.33           |
| Secondary Forest  | 33.50-43.37         | 60.33-66.67          | 53.33-66.83           |

Source: Research Data for 3 Years

Figure 1. The average litter water content of primary and secondary forest at protection forest of soya village

From the graph above, it can be seen that the average water content in the two forest types shows that in the year I the water content is low, in the second year it has increased (by 19.50% in Primary Forest and 23.40% in Secondary Forest). Then in the 3rd year, it decreases again (by 4.23% in Primary Forest and 3.38% in Secondary Forest). It happens because of changes in rainfall from year to year. The rain in the first year is 181.5 mm / day; in year II amounting to 420.1 mm/day, whereas in year III, it was 296 mm / day.

The graph shows that the average water content in each measurement year in the primary forest is higher than in the secondary forest. Due to the sampling plots’ condition in the primary forest, it has a higher stand density than the secondary forest density. In the primary forest, treestands dominate over seedling sand poles, but many have died and fell, forming more gaps. According to its characteristics, the primary forest contains large, long-lived trees, alternating with dead tree trunks that are still upright, stumps, and fallen wood. The collapse of these logs can form gaps or gaps in the stands, allowing rainwater to fall onto the floors o that the forest makes the litter water content higher.
While the sampling plots in the secondary forest were many stands at the level of seedlings to poles found in each measurement plot in the secondary forest. It is consistent with the statement put forward by [10] that secondary forest is the forest that grows and develops naturally after damage/change occurs in the first forest. Secondary forest is a phase of forest growth from a bare footprint, due to natural or anthropogenic, to a climax again.

The physical condition of the litter tends to be different each year. Since the litter's potential water has evaporated due to temperature and sunlight's influence, this condition causes the litter's water content to be less.

### 3.2. Biomass Content of Litter

The biomass content in primary forest was 3.6713-13.0720 tonnes/ha with 8.6614 tonnes/ha on average at Year I. The result was 4.0533-7.7475 tonnes/ha with an average of 5.5089 tonnes/ha in next year. For Year III, the range was between 3.9-5.8742 tonnes/ha with an average of 4.802 tonnes/ha at Year III. Meanwhile, secondary forest ranged from 0.7481 to 4.2950 tonnes/ha with an average of 2.2710 tonnes/ha for Year I; 2.7133-4.1058 tonnes/ha with an average of 3.2840 tonnes/ha for Year II; and 2.2950-5.3850 tonnes/ha with an average of 3.808 tonnes/ha for Year III. To more clearly see the biomass content interval in Table 2 and the average biomass content in Figure 2.

#### Table 2. Interval of biomass content of litter of primary and secondary forest in protectin forest of soya village

| Location            | Interval Year I (tonnes/ha) | Interval Year II (tonnes/ha) | Interval Year III (tonnes/ha) |
|---------------------|-----------------------------|------------------------------|------------------------------|
| Primary Forest      | 3.671-13.072                | 4.053-7.748                  | 3.9-5.874                    |
| Secondary Forest    | 0.748-4.295                 | 2.713-4.105                  | 2.295-5.385                  |

Source: Research data for 3 Years

![Figure 2. Average of biomass content of litter of primary and secondary forest at protectin forest of soya village](image)

From the results of biomass calculations, it can be seen that the average biomass content in primary forests has decreased from year to year, while in secondary forests, it is increasing. The value of biomass was higher in the primary forest than in the secondary forest. The result has a similar finding with the previous study [11], where biomass content in secondary forest (6.656) was higher than grove (4.624) and shrubs (1.574). It is due to many plants with a diameter of 10 cm and above in the plot.

Although the secondary forest has a higher vegetation density in water content, it is at the seedling to pole level. In contrast, the primary forest has lower viscosity at a seedling to pole level, but more large trees have a large crown density in the primary forest.
Forests with a high canopy density will get less sunlight so that the decomposition process that occurs will be slower than forests with a lower canopy density [12]. The primary forest has a higher canopy density resulting in a slower decomposition process. The slow decomposition process results in a higher biomass content in the litter compared to the secondary forest.

The factors causing the amount of litter vary because it generally occurs due to litter biomass and the increase in tree age and crown density. Canopy or stand density is a factor that affects the fall of forest litter due to competition for sunlight. The tighter a stand or canopy will produce an enormous amount of litter because the trees that grow in a relatively dense forest quickly release branches and leaves starting from below because there is not enough light for them for the photosynthesis process. In addition to the factor of increasing tree age and the density of the litter canopy, it is also influenced by the dropping of litter both in quantity and quality, influenced by environmental factors (climate, altitude, soil fertility), species of plant, and time (season and age of stands).

Forests with a high vegetation density will get less sunlight so that the decomposition process that will occur will be slower than forests with a lower canopy density [12]. Litter productivity is also influenced by vegetation and rainfall. Rainfall affects vegetation's physiology because the higher the rainfall, the lower the leaves' leaves, twigs, flowers, and fruit. When the rainfall is high, the humidity will increase, so the leaves' evaporation will decrease so that the leaves remain fresh and do not fall easily.

3.3. Carbon Content of Litter
In the calculations carried out, the carbon in primary forest for the year I ranged from 1.7225-6.1438 tonnes/ha with an average of 4.0708 tonnes/ha; for Year II ranged from 1.9051 to 3.6413 tonnes/ha, with an average of 2.4952 tonnes/ha; and for Year III ranged from 1.833-2.761 tonnes/ha with an average of 2.2571 tonnes/ha. Whereas in the secondary forest, the stored carbon content is in the range of 0.3516-2.01833 tonnes/ha with an average of 1.0674 tonnes/ha for Year I; 1.2753-1.9297 tonnes/ha with an average of 1.5435 tonnes/ha for Year II; and 1.0787-2.5310 tonnes/ha with an average of 1.7899 tonnes/ha for Year III. For more details, see Table 3 and Figure 3.

Table 3. Interval of the carbon content of litter at primary and secondary forest in protected forest of soya village

| Location       | Interval Year I (tonnes/ha) | Interval Year II (tonnes/ha) | Interval Year III (tonnes/ha) |
|----------------|----------------------------|-----------------------------|-------------------------------|
| Primary Forest | 1.7225-6.144               | 1.905-3.641                 | 1.833-2.761                   |
| Secondary Forest | 0.351-2.019               | 1.275-1.9297                | 1.0787-2.531                 |

Source: Research data for 3 Years
From the graph above, it can be seen that the average carbon content of litter in primary and secondary forests is different. This difference is influenced by the amount of biomass contained in the litter. Plantations' ability to absorb CO2 from the atmosphere varies according to type, age level, and plant density, so that forests with high plant densities contain more carbon.

Based on these results, it was found that the carbon content stored in litter changes and the biomass in the litter. This change occurs in primary and secondary forests from year to year. Changes in the litter's carbon content are highly dependent on the litter's biomass, so if the biomass content changes, inevitably, the carbon content will also change. At this stage, the primary forest's carbon content is found to be higher than in the secondary forest. It can be compared with the results of research from [11], where carbon in secondary forest (amounted to 3.129) was higher than that in grove (amounting to 2.173) and shrubs (amounting to 0.739). It is due to a large amount of woody vegetation in the plot.

According to [4], the amount of carbon stored between land varies depending on the diversity and density of existing plants, soil types, and management methods. The carbon storage of land becomes greater if soil fertility conditions are perfect. In other words, the amount of carbon stored above the soil (plant biomass) is determined by the amount of carbon stored in the soil (soil organic matter).

When conducting the research, 21 species of trees were found in primary forest and 15 species in secondary forest in the Protection Forest of Soya Village. Vegetation species in the primary forest consist of Bintanggur Hutan (Calophyllum soulatri), Siki (Palaquium javense), NanTi (Metrosideros vera), Redwood (Eugenia cumini), Mangosteen (Garcinia mangostana), Forest mango (Mangifera sp), Loasing, Cempedak Hutan (Artocarphus sp), Sageru wood (Gurania cydrcarpa), Damar (Agathis alba), Iron wood (Intsia bijuga), Ketapang Hutan (Terminalia copelandi), Taheru (Eugenia sp), Pala Hutan (Myristica sp), Tawang, Samar (Homalium foetidum), Kayu Sisir (Cudrania sp), Makila (Litsea angulata), Forest Cloves (Syzygium aromaticum), Gayam (Inocarpus fagiferus), and Bamboo (Bambusa sp).

Some species also found in secondary forests, e.g., Bintanggur Hutan (Calophyllum soulatri), Siki (Palaquium javense), forest jack fruit (Artocarphus sp), forest mango (Mangifera sp), Nani (Metrosideros vera), Ketapang Hutan (Terminalia. sp), Pala Hutan (Myristica sp), Red Wood (Eugenia cumini), Sageru Wood (Gurania cydrcarpa), Taheru (Eugenia sp), Damar (Agathis alba), Guava, Makila (Litsea angulata), Nanari (Cannarium commune), and Kayu Sisir (Cudrania sp).

Several species were only found in plots of primary or secondary forest, namely Mangosteen (Garcinia mangostana), Loasing, Ironwood (Intsia bijuga), Tawang, Samar (Homalium foetidum),
forest cloves (*Syzygium aromaticum*), and Gayam (*Inocarphus fagiferus*). In contrast, the Guava species (*Eugenia* sp) and Nanari (*Cannarium commune*) were only found in secondary forest plots. Litter is organic material in the form of fallen leaves and twigs from woody vegetation. A dense canopy or stand will affect the fall of forest litter due to competition from sunlight. Trees that grow in a slightly dense forest are faster to release branches and leaves from below because there is not enough light for them to photosynthesize [13]. Litter production is a loss of vegetative and reproductive structures caused by aging, stress, or a combination of both [14]. A large amount of litter that affects increasing the amount of biomass and carbon content in primary forests also occurs due to standing age, crown density, and stand density.

4. Conclusion
The water content of litter at the primary and secondary forest in the protected forest of Soya village increased from year I of measurement to year II of measurement but decreased in year III of measurement. The Biomass content of litter in the primary forest from year I to year III decreased, while the biomass content of litter has increased from year to year. However, the content of litter biomass in the primary forest is higher than in the secondary forest. The content of litter carbon in the primary forest from year I to year III decreased, while the carbon content in the secondary forest has increased from year to year. But the Carbon content of litter in the primary forest is higher than in the secondary forest.

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