

Carbon to Nitrogen Ratio in Forage Plants in South Kalimantan's Oil Palm-Cattle Integration Area

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Abstract. The main cause of climate change is confirmed to originate from greenhouse gas emissions from human activities. Human activities such as burning fossil fuels, land use changes, population growth, and the accumulation of greenhouse gases. This research aims to determine the species of plants, organic C/N content, and to compare N₂O emissions in oil palm plantations integrated with cattle farming. The research method used a survey approach in two sampling areas: oil palm plantations integrated with cattle and oil palm plantations without cattle integration. In each location, 5 plots were created, with each plot consisting of 3 subplots as replications from the edge towards the oil palm plantation, resulting in a total of 30 subplots for both locations. Parameters collected included plant species, organic C/N content, and the amount of N₂O emissions. The research results showed that there are 5 plant species growing in both integrated and non-integrated oil palm plantation areas: *Ageratum conyzoides*, *Panicum brevifolium*, *Cenchrus longilamina* Ohwi, *Brachiaria decumbens* dan *Athyrium filix femina*. Integrated and non-integrated land areas significantly affect carbon storage in both leaves and stems. Integrated land has a C/N ratio in leaves of 30.15-40.86%, while in non-integrated areas, it is 27.95-34.15%, and in stems, it ranges from 38.07-55.25% and 32.15-48.46% of total dry biomass. The average N₂O gas emissions in non-integrated land are 4.6 N m²/hour, while in integrated oil palm plantations with cattle, it is 5.6 N m²/hour. The difference in N₂O values between the two locations is within reasonable limits. In conclusion, oil palm plantations can be integrated with cattle for sustainable agriculture

Keywords: accumulation; gas emissions; integration; carbon dioxide

1. Introduction

Currently, the government continues to promote the program of integrating oil palm plantations with cattle farming to increase national meat production. This, of course, will alter the landscape of the area. Oil palm plantations have specific biodiversity in their flora and fauna due to the conversion of forest land into plantations (Sirait et al., 2015). The transformation of new agro-areas into oil palm-cattle agro-areas has both positive impacts on productivity and some

adverse effects that need to be scientifically proven, such as changes in biodiversity and the carbon cycle (Rostini et al., 2020). These changes need to be analyzed to support a sustainable oil palm industry in Indonesia. The primary cause of climate change is undoubtedly the greenhouse gas emissions from human activities. Human activities such as burning fossil fuels, land use changes, population growth, and the accumulation of greenhouse gases contribute to the greenhouse effect.

Research on CO₂ emissions or soil CO₂ flux in mineral soils in Indonesia is still limited. Many people believe that CO₂ emissions are higher from peatlands compared to mineral soils due to the higher carbon content in peatlands. The carbon content in peatland soils is much higher than in mineral soils. The carbon content in peatland soils is also considered a potential source of CO₂ emissions into the atmosphere as it decomposes. However, the results of Subramanian's research (2013) showed that the amount of CO₂ emitted from open peatland areas (no vegetation) with an annual intervention of 11.06 tons CO₂/ha/year is not significantly different from that emitted from mineral soils with low organic matter content. There were no trees or litter, and the emission was 144.90 mg CO₂/m²/hour, equivalent to 12.69 tons CO₂/ha/year.

Grass plants, in the form of C₄ plants, have a high rate of photosynthesis (Gardner et al., 2008). Grass plants absorb CO₂ from the air through photosynthesis, which is then converted into carbohydrates, distributed throughout the plant, and ultimately stored within the plant's body. The process of storing carbon (C) in plants is called sequestration (C sequestration). Therefore, measuring the amount of carbon stored by plants in the soil can indicate the amount of carbon dioxide absorbed by plants from the atmosphere (Hairiah et al., 2011). Carbon stock refers to the accumulation of carbon in the plant's body in the form of biomass.

Grass is considered one of the species capable of storing carbon. As a C₄ plant, grass has a high rate of photosynthesis (Gardner et al., 2008). Carbon fixation occurs in the grass's stems, forming carbohydrates with the help of sunlight. Carbon absorption is the continuous process by which plants (partially) transfer carbon dioxide from the air (partially) through photosynthesis into organic atmospheric components, also known as carbon sequestration (Hairiah et al., 2001). The carbon stock of each grass species can vary significantly depending on the species, plant age, CO₂ concentration in the air, light intensity, and other environmental conditions. To date, the carbon storage potential of Indonesian tropical grasses, especially those growing in shaded areas, has not been widely reported. Research is needed to identify grass species growing under the canopy of oil palm plantations, determine dominant species, measure carbon and nitrogen stocks, and understand the carbon dioxide (CO₂) emissions comparison in oil palm plantations integrated with cattle farming, contributing directly to environmental sustainability.

2. Materials and Methods

Sample collection was carried out at two locations in the Satui District, Tanah Bumbu Regency. The first location was an oil palm plantation integrated with cattle farming, and the second location was an oil palm plantation without cattle integration. Identification and analysis were conducted at the Biotechnology Laboratory of the Cibinong Bogor to determine their taxonomy (Quattrocchi, 2006). Meanwhile, the analysis of carbon (C) and nitrogen (N) was performed at the Faculty of Agriculture, Islamic University of Kalimantan

2.1. Research Design

The research was conducted through a survey approach involving field sampling. At each location, five plots were established, with each plot consisting of three subplots as replicates, transecting from the edge towards the oil palm plantation. This resulted in a total of 30 subplots for both locations. The selected grass species were those that exhibited vigorous growth, with criteria such as a height of approximately 50-100 cm, upright growth, green color, and dominance in the respective areas. Identification was performed by creating a herbarium, and each encountered species was assigned a code. Soil samples from the locations where grass species were collected were also taken for analysis. Subsequently, grass biomass samples were collected at approximately 1000 grams per species and dried for laboratory analysis.

2.2. Observed Variables

The observed variables in this research are as follows:

1. Identification of Grass Species: The collected grass samples were assigned codes, weighed, and preserved as herbarium specimens by spraying them with 70% alcohol and then storing them in paper bags. The plant specimens were taken to the BRIN Biotechnology Laboratory.
2. Carbon Analysis: Carbon content in the leaves and stems of forage plants as well as in the soil was determined using the gravimetric method (AOAC, 1999). Nitrogen analysis in the leaves and stems of forage plants was conducted using the AOAC method (1999).
3. Gas Chamber Box Sampling: A gas chamber box with dimensions of 40 cm in length, 20 cm in width, and 30 cm in height was used to capture gases in the area covered by the box (Minamikawa et al., 2015).
4. Light Intensity Measurement: Light intensity was measured using a Lutron LX-1108 lux meter in each subplot.

2.3. Data Analysis

The data for grass species identification and light intensity are presented descriptively. Subsequently, species that consistently appeared in all sampling locations were selected as dominant species. The average carbon content, nitrogen content, and C/N ratio in the oil palm plantation integrated with cattle farming area and the oil palm plantation without cattle integration were statistically analyzed using the t-test (Steel and Torrie, 1993).

3. RESULTS AND DISCUSSION

3.1. Grass Species Identification

Grass species collected from the field were identified in the Agrostology Laboratory at BRIN Cibinong and compared with existing data in the literature. The identification results are presented in Table 1.

Table 1. Species of Plants in Oil Palm Plantations Integrated and Non-Integrated with Cattle

No	Species Tof Plants	Integrated	Non-integrated
1.	Panicum brevifolium	✓	✓
2.	Brachiaria mutica	✓	-
3.	Ageratum conyzoides	✓	✓
4.	Loersia hexandra	✓	-
5.	Hyptis capitata	✓	-
6.	Melustoma malabathricum	✓	-
7.	Loersia hexandra	✓	-
8.	Cyperus kyllingia	-	✓
9.	Lophatherum gracile	-	✓
10.	Digitaria abyssinica	✓	-
11.	Mikania micrantra	-	✓
12.	Nephrulepis biserrata	-	✓
13.	Brachiaria decumbens	✓	✓
14.	Macaranga gigantea	-	✓
15.	Centotheca longilamina Ohwi	✓	✓

Based on the data Table 1. it can be observed from Table 2 that there are 5 species that consistently appear in both integrated and non-integrated oil palm plantations: Ageratum conyzoides, Panicum brevifolium, Centotheca longilamina Ohwi, Brachiaria decumbens, and Athyrium filix-femina. This is because these plant species can thrive in highland areas with sufficient sunlight. The results of this research align with the findings of Dianita & Abdullah (2012), who stated that topographical factors such as elevation and slope gradient influence pasture quality by determining the environmental temperature and the intensity of sunlight received by plants.

Various species of tropical grass can be found in oil palm plantations in Tanah Bumbu Regency, both those integrated with cattle farming and those without integration, with light intensities ranging from 28.27 fc to 258 fc. The presence of grass under the oil palm canopy is due to the fact that the incoming light is partially blocked by the palm trees, allowing the grass beneath to continue photosynthesizing effectively. Sirait (2006) reported that there are several grass species that are shade-tolerant, enabling them to produce biomass under limited light conditions

3.2. C/N Ratio Content of Plant Species in Oil Palm Plantations

The metabolism of carbon (C) and nitrogen (N), as two essential elements for plants, significantly influences the formation of final yields and the quality of plant production. Plants convert atmospheric CO₂ into organic carbon (carbohydrates) and store it in their biomass, such as in stems, leaves, roots, fruits, and others, through the process of photosynthesis (Sutaryo, 2009). The dynamics of organic carbon (C) content in plant species in oil palm plantations during the study are presented in Table 2.

In general, almost all plant species growing in both areas of oil palm plantations show higher concentrations of organic C and N in the integrated area with cattle. This aligns with soil fertility, where integrated soil contains animal manure, while non-integrated soil may have chemical fertilizers, and light intensity also affects photosynthesis. Light plays a crucial role in plant physiological processes, especially photosynthesis, respiration, and transpiration. Key factors of solar radiation for plants include light intensity, light quality, and duration of exposure. If the received light intensity is low, then the light received per unit leaf area over a certain period is also low per individual (Gardner et al., 2008). Plants require a balance between sources of carbon

dioxide, nutrients, water, and sunlight to maintain their physiological functions, including photosynthesis (Agren, 2008). The organic C produced from photosynthesis can be used for nitrogen assimilation in leaves because nitrogen assimilation requires a carbon scaffold in the form of 2-oxoglutarate, ATP, and reducing agents (Lancien et al., 2000). Another factor is that vegetation in oil palm plantations tends to be denser and more diverse, so the presence of wilted and dead plants increases organic matter during soil decomposition, thereby affecting fertility and nutrient availability.

Table 2. Average Organic Carbon (C) Content, Nitrogen (N) Content, and C/N Ratio of Plant Species in Oil Palm Plantations in Tanah Bumbu

		<i>Ageratum conyzoides</i>	<i>Panicum brevifolium</i>	<i>Centotheca longilamina Ohwi</i>	<i>Brachiaria decumbens</i>	<i>Athyrium filex femina</i>
C organic						
Leaf	Land of integration	54.01 ± 3.22	50.13 ± 1.24	50.34 ± 1.25	49.45 ± 1.13	52.12±1.1
	Non Integrasi	52.15 ± 1.21	48.23 ± 1.24	49.56 ± 1.23	48.65 ± 1.27	49.05 ± 1.24
stem	Land of integration	45.12 ± 1.06	41.63 ± 1.23	46.45 ± 0.67	45.22 ± 1.42	45.31 ± 1.12
	Non Integrasi	35.27 ± 0.34	42.12 ± 1.18	49.26 ± 0.75	50.42 ± 1.53	51.31 ± 1.24
Nitrogen (%)						
Leaf	Land of integration	1.42 ± 0.05	1.24 ± 0.06	1.58 ± 0.15	1.64 ± 0.53	1.28 ± 0.64
	Non integrated land	1.52± 0.1	1.47 ± 0.16	1.64 ± 0.34	1.78 ± 0.23	1.64 ± 0.23
stem	Land of integration	1.04 ± 0.19	0.97± 0.13	1.22 ± 0.33	0.87 ± 0.16	0.82 ± 0.14
	Non integrated land	1.05 ± 0.12	1.31 ± 0.25	1.14 ± 0.25	1.04 ± 0.12	1.26 ± 0.14
Rasio C/N						
Leaf	Land of integration	38.035 ± 0.64a	40.42 ± 1.21a	31.86 ± 0.83a	30.15 ± 2.13a	40.71 ± 1.71a
	Non integrated land	34.15 ± 2.01b	32.80 ± 1.74	31.21 ± 3.61	27.95 ± 5.52	29.90 ± 0.53
stem	Land of integration	43.38 ± 2.57a	42.91 ± 9.46a	38.07 ± 2.03a	51.97 ±8.87a	55.25 ± 8.01a
	Non integrated land	33.59 ± 4.24b	32.15 ± 4.72b	43.26 ±3.02 ^b	48.48 ± 12.75 ^b	40.31 ± 8.85b

The separation of leaf and stem parts aims to examine the distribution of carbon storage in oil palm plants in areas used for integration and non-integration. The analysis results indicate that both integrated and non-integrated land significantly influence carbon storage in both leaf and stem parts. Integrated land has a C/N ratio in the leaves ranging from 30.15% to 40.86%, while in non-integrated areas, it ranges from 27.95% to 34.15%. In the stems, it varies from 38.07% to 55.25% in integrated land and from 32.15% to 48.46% in non-integrated land, based on their total dry biomass. In the leaf part, these plants have achieved the highest carbon storage in

integrated land compared to plants in non-integrated land, and the same applies to the stem part where the plants exhibit higher absorption capabilities compared to the leaves.

The analysis results of organic carbon (C organics) indicate that the plant species *Ageratum conyzoides* can store carbon at a rate of 54.07%. In its leaves, organic carbon is observed to be higher compared to its stems, with a content of 45.12% in integrated land. In non-integrated land, the organic carbon content is 52.15% in the leaves and 35.27% in the stems. This suggests that the integrated area of oil palm plantations with cattle farming can provide higher organic C storage in plants, as the organic fertilizer provided by cattle contributes to higher organic C levels.

Tropical grasses growing in oil palm plantations in Tanah Bumbu Regency have relatively high organic carbon (C organics) content distributed in both leaves and stems (Table 2). In general, the organic carbon content of grasses growing in oil palm plantations integrated with cattle farming is higher than that of grasses in non-integrated plantations. This is due to the higher light intensity in non-integrated oil palm plantations compared to integrated ones. Agren (2008) stated that a balance between sources of CO₂, nutrients, water, and sunlight intensity is required for plants to maintain their physiological functions, including photosynthesis.

The carbon dioxide (CO₂) emission values in both plantation areas, where integrated farming includes continuous organic fertilizer from livestock feces and non-integrated farming involves the use of urea, TSP, and KCl fertilizers, can be influenced by the fertilization practices. This can lead to increased root respiration, resulting in higher CO₂ emissions, as supported by the research of Griswold et al. (2003), which found that nitrogen fertilizer application can lead to increased CO₂ gas production. According to Foong et al. (2019), fertilization and other soil fertility improvement treatments like liming should be carried out carefully, as they can contribute to greenhouse gas emissions.

The carbon dioxide (CO₂) emissions will decrease with the rotation grazing of integrated cattle and oil palm plantation land. The reduction in CO₂ emissions is attributed to a decrease in soil microorganisms. The decrease in both the quantity and activity of microorganisms is likely due to a reduced supply of simple compounds that microorganisms use, resulting in reduced CO₂ emissions (Fitzherbert, 2008). Soil respiration, influenced by various factors, allows for variations in the CO₂ emissions produced. Environmental factors such as soil temperature, air temperature, canopy temperature, and humidity are believed to be the primary factors affecting CO₂ emissions from the soil.

4. Production and Quantity of N₂O Emissions in Integrated and Non-Integrated Land

N₂O is primarily produced in the soil through nitrification processes under aerobic conditions, where ammonia is oxidized, and through denitrification, which occurs under anaerobic conditions, where nitrate is sequentially reduced to nitrite, N₂O, and pure nitrogen molecules (N₂) (Butterbach-Bahl et al., 2013). The loss of nitrogen gases is directly related to soil nitrogen content and soil moisture, which affects soil oxygen availability (Parn et al., 2018). Soils with water content of 0.5-0.6 m³ release the most N₂O. This soil moisture content indicates known conditions where nitrification and denitrification contribute to N₂O emissions (Liu et al., 2002; Luttge, 2013).

Based on research conducted in oil palm plantations in the Satui District, Tanah Bumbu Regency, data on Mean Flux (g N₂O/ha/day) in integrated and non-integrated land were obtained and are presented in the table 3.

Table 3. Average amount of N₂O emissions in oil palm plantations integrated with livestock

weeks	Emisi N ₂ O (g N ₂ O/ha/day)	
	Land of integration	Non integrated land
1	4,19	5,62
2	5,27	6.01
3	4.51	5.76
4	4,72	5.21
5	5.01	5.42
average	4.8	5.6

The average N₂O flux in integrated and non-integrated land in the table above shows varying results each week. The average N₂O gas emissions in non-integrated land are 4.6 N m²/hour, while in integrated oil palm plantations with cattle, it is 5.6 N m²/hour. There is a difference in N₂O values between these two locations due to the presence of cattle feces deposited in the land, leading to higher gas emissions compared to non-integrated oil palm plantations. This is in line with the findings of Ajhar (2010), who stated that the average N₂O production value is influenced by three main factors: environmental factors (climate, organic C content, soil texture, drainage, and soil pH), land management (N fertilizer application and plant types), and factors related to emission measurement (sampling duration and frequency).

N₂O production in non-integrated land is lower compared to the average production in integrated land. This is because the decomposition of cattle manure in integrated land leads to increased N₂O gas emissions. Additionally, land management practices, such as N fertilizer application, in integrated land contribute to higher N₂O emissions. In contrast, non-integrated land lacks cattle manure decomposition, and no fertilization is applied, resulting in lower emissions.

The soil in integrated land has a higher nutrient content, measuring 3.27%, whereas non-integrated land has 2.52%. Despite this, the gas emissions in integrated land are higher than in non-integrated land. The fluctuation in N₂O gas emissions is influenced by several factors, including microenvironmental conditions. Microenvironmental conditions that can affect N₂O flux include air temperature, air humidity, soil temperature, and soil moisture. A positive relationship indicates that when microenvironmental conditions increase, N₂O flux also increases, and vice versa for a negative relationship (Herawati, 2012). Basio (2020) has also suggested similar findings.

5. CONCLUSION

From the research results, it can be concluded that there are five dominant species on integrated land. There are 5 species that are always present both on oil palm plantations integrated with livestock and those that are not integrated, namely *Ageratum conyzoides*, *Panicum brevifolium*, *Centotheca longilamina* Ohwi, *Brachiaria decumbens* and *Athyrium filix femina* on integrated land and non-integration has a significant effect on carbon storage in both leaves and stems. Integrated land has a C/N ratio in leaves of 30.15-40.86%, while in non-integrated areas it is 27.95-34.15%, while in stems it ranges between 38.07-55.25% and 32.15-48.46% of the total dry biomass. The average N₂O gas emissions on non-integrated land averaged 4.6 N m²/hour, while on oil palm plantations integrated with livestock it was 5.6 N m²/hour, there was a difference in N₂O values in the two locations due to feces excreted by livestock onto

the land, thus causing emissions to increase. gas is higher compared to non-integrated oil palm plantations.

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7. CONFLICT OF INTEREST

All researchers stated consciously that they had no conflict of interest in this study.

8. AUTHORS CONTRIBUTION

Tintin Rostini, Achmad Jaelani, Maulana and Danang Biyatmoko contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript.

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