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Dominance of Understory Vegetation and Biomass Production of Oil Palm Plantations on Mineral Land

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Abstract

The understory vegetation of oil palm plantations varies across different types of land. The biomass of this vegetation plays a crucial role in maintaining the ecological balance of oil palm plantation ecosystems. This study aims to identify the types of understory vegetation and calculate biomass production on the mineral land of PT. Rigunas Agri Utama's oil palm plantations. The research was conducted in August 2024 using direct observation methods. Observations of understory vegetation were carried out on 45 sample plots utilizing the quadrat method and the Plantnet application, with biomass measurements taken using the destructive sampling method. The results indicated the presence of 27 understory vegetation species with varying compositions. The most dominant species was Mitracarpus hirtus (L.) DC. The highest density, frequency, and dominance values were exhibited, with a species dominance ratio (SDR) of 35%. Understory vegetation primarily comprises broadleaf species and grasses, with a significant proportion being perennial plants that enhance ecosystem stability. The total biomass production of understory vegetation reached 5,943 kg over 12 hectares, resulting in carbon stocks of 2,793 kg C per 12 hectares. The species contributing the most to biomass include Mitracarpus hirtus, Cyperus rotundus, and Eleusine indica. The findings of this study indicate that the total carbon stock of understory vegetation in oil palm plantations is approximately 232.7 kg C per hectare. In comparison, carbon stocks in understory vegetation within agricultural ecosystems, such as oil palm plantations, typically range from 0.18 to 1.00 tons C per hectare (180 to 1,000 kg C per hectare), suggesting a strong potential for carbon storage in the oil palm plantations of PT. Rigunas Agri Utama.

Keywords: Biomass, Carbon Stocks, Oil Palm Plantations, Understory Vegetation

1. Introduction

Understory vegetation, which consists of plants that grow beneath oil palm stands, plays a crucial role in plantation management. The vegetation in oil palm plantations is typically dominated by weeds (Mudhita & Badrun, 2019). This understory vegetation is essential for supporting sustainable oil palm cultivation. Its functions include serving as ground cover for soil and water conservation and providing greenery that enhances nutrient availability. Through photosynthesis, this greenery absorbs carbon dioxide (CO2) from the atmosphere while increasing carbon reserves in the soil. Understory vegetation beneath the oil palm canopy is highly beneficial; it should not merely be regarded as a weed but recognized for its potential to produce biomass that can enhance plantation management by adding organic matter and storing carbon reserves in the soil.

Several factors influence the biomass of lower vegetation, including plant age, vegetation development, and plant composition and structure. Climate factors such as temperature and rainfall also play a significant role in this process.

Understory vegetation refers to a community of plants that occupies the lower strata near the surface of the soil. This vegetation includes herbs, shrubs, and grasses (Kusmana et al., 2022). The composition of greenery beneath oil palm plantations is influenced by several factors, including the characteristics of the plantation soil, competition from other weeds, and the intensity of light that penetrates the area (Mudhita & Badrun, 2019).

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Understory vegetation plays a critical role in supporting oil palm cultivation. This role can be through the function of understory vegetation, as ground cover in soil and water conservation, and through photosynthesis in absorbing CO2, while increasing carbon reserves in biomass (Yahya et al., 2022). Grassy and annual weed species dominate oil palm plantations because weeds reproduce vegetatively with stolons and generatively through seeds. The growth of the weed Axonopus compressus is optimal in dry to slightly humid conditions, but not waterlogged (Gunawan et al., 2025).

The results of research conducted by Abdullah et al. (2023) show a close relationship between soil carbon potential and soil quality index. Many factors, including environmental factors, land use types and human management factors, influence the organic carbon content in the soil.

Based on the description above, this study will identify the types of undergrowth vegetation in mineral land of oil palm plantations and calculate the biomass production by undergrowth vegetation at PT. Rigunas Agri Utama.

2. Material and Methods

The study was conducted in August 2024 at PT. Rigunas Agri Utama, Pranap, Indragiri Hulu, Riau. 0°38′17″S to 0°33′51″S and 101°59′33″E to 102°04′23″E . 5-100 masl. This study conducted direct observations in the field. The data obtained were then analyzed using a descriptive method, describing the results according to the conditions found in the field (Sugiyono, 2018). Observations were carried out in the field using vegetation analysis with the quadrat method, the Plantnet application, and destructive sampling. Method to measure the biomass of lower vegetation. This method is carried out by harvesting all plant parts, including the roots, drying them and weighing the biomass (Sutaryo, 2009). The plot uses a size of 1m x 1 m, and 45 sample plots are determined randomly by determining the location of the plot (drawn).

The data obtained from the results of placing the plots were calculated using the Summed Dominance Ratio (SDR), calculated based on the sum of the relative density (KR), Relative Frequency (FR), and Relative Dominance (DR) values (Kusmana, 2018).

1. Absolute Density (KM) = Number of vegetation types from all sample plots
2. Relative Density (KR) = KM/(Total density of all species) x 100%
3. Absolute Frequency (FM) = Number of sample plots occupied by one species
4. Relative Frequency (FR) = FM/(Sum of frequencies of all types) x 100%
5. Absolute Dominance (DM) = Total dry weight of vegetation types from all sample plots
6. Relative Dominance (DR) = DM/(Total dominance of all species) x 100%
7. Summed Dominance Ratio (SDR) = ((KR+FR+DM))/(3) x 100%

The measurement of lower vegetation biomass, namely herbs or grasses, is found in the observation plot of lower vegetation biomass. All samples of lower vegetation were taken and weighed for their fresh weight. Then the samples were oven-dried at 70 °C for 1 × 24 hours and weighed for their dry weight.

Calculation of carbon reserve production from biomass using the formula C_tb = Botb x% organic C, where C_tb = carbon content of lower plant organic matter (g),

Botb = total biomass of understory plants (g) and % organic C = percentage value of carbon content, amounting to 0.47 (National Standardization Agency, 2019). The understory vegetation biomass is calculated using Excel using the formula above.

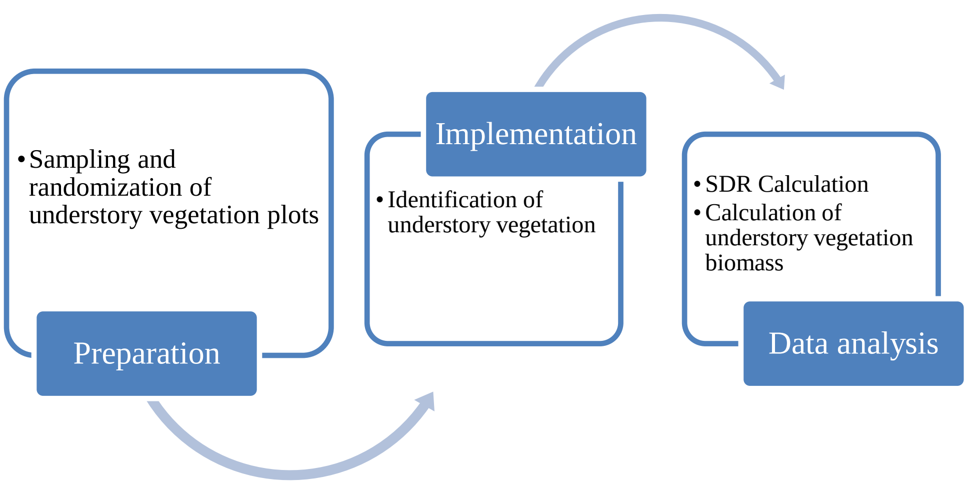

Figure 1. Research flow diagram

3. Results and Discussion

Based on observations of 45 plots, 27 species of understory vegetation were found in the mineral land of PT Rigunas Agri Utama oil palm plantation (Table 1). The most dominant species is Mitracarpus hirtus (L.) DC. The absolute density of this species reached 247, the absolute frequency was 27, and the absolute dominance was 876, with an SDR (Summed Dominance Ratio) value of 35%. The composition of understory vegetation was also analyzed based on the SDR (Summed Dominance Ratio) value, which reflects the relative contribution of each species to the ecosystem. Mitracarpus hirtus has the highest SDR value of 35%, followed by Cyperus rotundus with a value of 11% and Miconia crenata with a value of 7%. Species with high SDR values have a major influence on ecosystem function due to their wide distribution and dominance. Conversely, species with low SDR values, such as Asystasia gangetica (0%), make minimal contributions and tend to be less competitive in the ecosystem.

Based on Table 2 in terms of morphology, the lower vegetation at the research location is dominated by 14 broad-leaved species, including Mitracarpus hirtus and Miconia crenata. Grass species include 9 species, such as Axonopus compressus and Imperata cylindrica. In addition, there are 2 species of ferns, namely Nephrolepis biserrata and Stenochlaena palustris. Ferns such as Cyperus rotundus and Scleria gaertneri are also found in smaller numbers. According to their life cycle, 21 species are annual plants, such as Mitracarpus hirtus and Miconia crenata. These yearly plants have high adaptability and contribute to the stability of the ecosystem in the long term. In contrast, the other 6 species are annual plants, such as Ageratum conyzoides and Scleria gaertneri. Although their life cycle is short, annual plants still play an essential role in adding organic matter through faster decomposition.

Table 1. Composition of understory vegetation

No	Species	Parameter						SDR
		Density		Frequency		Dominance		
		Absolute	Relatively	Absolute	Relatively	Absolute	Relatively	
1	*Ageratum conyzoides* L.	11	2%	2	2%	53	2%	2%
2	*Asystasia gangetica* (L.)	1	0%	1	1%	2	0%	0%
3	*Axonopus compressus* (Sw.)	23	4%	4	4%	107	4%	4%
4	*Axonopus fissifolius* (Raddi)	14	3%	2	2%	112	4%	3%
5	*Cenchrus setosus* Sw.	2	0%	1	1%	16	1%	1%
6	*Centotheca lappacea* (L.)	12	2%	3	3%	50	2%	2%
7	*Centrosema pubescens* Benth.	6	1%	1	1%	50	2%	1%
8	*Chromolaena odorata* (L.)	5	1%	2	2%	99	3%	2%
9	*Croton hirtus* L'Her.	9	2%	1	1%	38	1%	1%
10	*Cyperus rotundus* L.	57	10%	10	11%	343	11%	11%
11	*Elaeis guineensis* Jacq.	1	0%	1	1%	5	0%	0%
12	*Elusine indica* (L.) Gaertn.	19	3%	3	3%	207	7%	5%
13	*Imperata cylindrica* (L.)	25	5%	4	4%	206	7%	5%
14	*Lantana camara* L.	1	0%	1	1%	8	0%	1%
15	*Megathyrus maximus* (Jacq.)	27	5%	5	5%	150	5%	5%
16	*Melastoma malabathricum* L.	3	1%	3	3%	19	1%	1%
17	*Miconia crenata* (Vahl)	31	6%	7	8%	202	7%	7%
18	*Mikania micrantha* Kunth	4	1%	1	1%	17	1%	1%
19	*Mitracarpus hirtus* (L.) DC.	247	45%	27	30%	876	29%	35%
20	*Nephrolepis biserrata* (Sw.)	6	1%	2	2%	135	5%	3%
21	*Neustanthus phaseoloides*	4	1%	1	1%	31	1%	1%
22	*Oplismenus undulatifolius*	2	0%	1	1%	5	0%	1%
23	*Paspalum dilatatum* Poir.	6	1%	1	1%	50	2%	1%
24	*Phyllanthus tenellus* Roxb.	3	1%	1	1%	19	1%	1%
25	*Scleria gaertneri* Raddi	14	3%	2	2%	85	3%	3%
26	*Stachytarpheta jamaicensis*	5	1%	1	1%	35	1%	1%
27	*Stenochlaena palustris*	6	1%	3	3%	74	2%	2%
	Total	544	100%	91	100%	2994	100%	100%

This combination of annual and perennial plants creates a dynamic understory ecosystem that adapts to environmental conditions. Mitracarpus hirtus is the dominant understory vegetation with an SDR value of 35%, because morphologically, Mitracarpus hirtus has broad leaves that allow it to get more sunlight for photosynthesis and has taproots that can grow deeper to absorb nutrients in the soil.

This shows that Mitracarpus hirtus can compete better than other species. At the same time, Cyperus rotundus can dominate under Mitracarpus hirtus because there is no competition between the two vegetations, both in receiving sunlight and absorbing nutrients. Morphologically, Cyperus rotundus has pinnate leaves and fibrous roots.

Table 2. Composition of lower vegetation based on morphology and life cycle

No	Species	Morphology	Life Cycle
1	*Ageratum conyzoides* L.	Broadleaf	One season
2	*Asystasia gangetica* (L)	Broadleaf	One season
3	*Axonopus compressus* (Sw.)	Grass	Annual
4	*Axonopus fissifolius* (Raddi)	Grass	Annual
5	*Cenchrus setosus* Sw.	Grass	Annual
6	*Centotheca lappacea* (L.)	Grass	Annual
7	*Centrosema pubescens* Benth.	Broadleaf	Annual
8	*Chromolaena odorata* (L.)	Broadleaf	Annual
9	*Croton hirtus* L'Her.	Broadleaf	One season
10	*Cyperus rotundus* L.	Tekian	Annual
11	*Elaeis guineensis* Jacq.	Broadleaf	Annual
12	*Elusine indica* (L.) Gaertn.	Grass	One season
13	*Imperata cylindrica* (L.)	Grass	Annual
14	*Lantana camara* L.	Broadleaf	Annual
15	*Megathyrus maximus* (Jacq.)	Grass	Annual
16	*Melastoma malabathricum* L.	Broadleaf	Annual
17	*Miconia crenata* (Vahl)	Broadleaf	Annual
18	*Mikania micrantha* Kunth	Broadleaf	Annual
19	*Mitracarpus hirtus* (L.) DC.	Broadleaf	Annual
20	*Nephrolepis biserrata* (Sw.)	Ferns	Annual
21	*Neustanthus phaseoloides*	Broadleaf	Annual
22	*Oplismenus undulatifolius*	Grass	Annual
23	*Paspalum dilatatum* Poir.	Grass	Annual
24	*Phyllanthus tenellus* Roxb.	Broadleaf	One season
25	*Scleria gaertneri* Raddi	Tekian	One season
26	*Stachytarpheta jamaicensis*	Broadleaf	Annual
27	*Stenochlaena palustris*	Ferns	Annual

Table 3 provides an overview of the basic data used to calculate the biomass production of understory vegetation in oil palm plantations. The information in this table is essential in determining the area and distribution of understory vegetation and its role in biomass production.

Based on the composition of the understory vegetation biomass, this research area is dominated by the Mitracarpus hirtus species, the largest biomass contributor with a total of 876 grams (Table 4).

Table 3. Understory vegetation biomass

Observation	Unit
Basic Unit Per Hectare	136 trees
Disc spokes	2 m
Long market carrying	300 m
Width of the market	1.5 m
Number of market carts per ha	2 lines
Biomass production per m²	67 grams

This dominance illustrates that the species has high density and biomass. In addition to Mitracarpus hirtus, Cyperus rotundus (343 grams) and Elusine indica (207 grams) also showed high biomass contributions. These species tend to be more adaptive to the environmental conditions of mineral land at the research location. In contrast, species such as Asystasia gangetica (2 grams) and Oplismenus undulatifolius (5 grams) have minimal biomass contributions. The total biomass of all species observed was 2,994 grams, reflecting the diversity of plant types in the plantation area.

This study found 27 understory vegetation species with varying levels of dominance, indicating rich ecosystem diversity. Previous studies have shown that vegetation diversity under oil palm stands can maintain soil health and biodiversity. Understory vegetation is dominated by Mitracarpus hirtus, which is the main contributing species, with a biomass of 876 grams. Morphologically, Mitracarpus hirtus has broad leaves that allow it to get more sunlight for photosynthesis and has taproots that can grow deeper to absorb nutrients in the soil. This shows that Mitracarpus hirtus is more adaptable and competitive than other species. The total biomass produced in the research area reached 495 kg per hectare, indicating the ability of various understory vegetation species to absorb carbon dioxide. Anggraini (2021) stated that the ability of understory vegetation to store carbon is highly dependent on species composition and environmental factors.

The results of this study indicate that the total carbon stock of understory vegetation in oil palm plantations reached 232.7 kg C/ha, which provides an overview of the potential carbon storage in understory vegetation in oil palm plantations. Although this figure is lower than the carbon stocks found in several natural ecosystems such as mangrove forests, which is 51.86 tons/ha Sugirahayu & Rusdiana, 2011), carbon stocks in understory vegetation in oil palm plantations still show a contribution to the carbon storage process in plantations. Research (Anggraini & Afriyanti, 2019) supports this finding, showing that understory vegetation effectively absorbs carbon in oil palm plantation environments.

According to the IPCC standard written by Penman et al. (2003), carbon stocks for understory vegetation in oil palm plantations are not explicitly discussed, but based on existing studies, carbon stocks in understory vegetation in agricultural ecosystems such as oil palm plantations tend to range between 0.18 - 1.00 tons C/ha (180 - 1,000 kg C/ha). Compared to this range, the results of this study have met these criteria, although oil palm plantations are not natural ecosystems such as forests or savannas, they still can store carbon. Therefore, good management of understory vegetation in oil palm plantations, such as using ground cover plants or managing other vegetation that supports understory plant growth, can help increase carbon storage in oil palm plantations.

Table 4. Understory vegetation biomass

Types of Vegetation	Vegetation Type Biomass
Ageratum conyzoides L.	53
Asystasia gangetica (L)	2
Axonopus compressus (Sw.)	107
Axonopus fissifolius (Raddi)	112
Cenchrus setosus Sw.	16
Centotheca lappacea (L.)	50
Centrosema pubescens Benth.	50
Chromolaena odorata (L.)	99
Croton hirtus L'Her.	38
Cyperus rotundus L.	343
Elaeis guineensis Jacq.	5
Elusine indica (L.) Gaertn.	207
Imperata cylindrica (L.)	206
Lantana camara L.	8
Megathyrus maximus (Jacq.)	150
Melastoma malabathricum L.	19
Miconia crenata (Vahl)	202
Mikania micrantha Kunth	17
Mitracarpus hirtus (L.) DC.	876
Nephrolepis biserrata (Sw.)	135
Neustanthus phaseoloides	31
Oplismenus undulatifolius	5
Paspalum dilatatum Poir.	50
Phyllanthus tenellus Roxb.	19
Scleria gaertneri Raddi	85
Stachytarpheta jamaicensis	35
Stenochlaena palustris	74
Amount	2994

Table 5. Results of biomass production and carbon reserves calculations

Observation	Results
Area of disc per hectare	1,708.16 m²
Market area per hectare	900 m²
Area of land covered by vegetation per hectare	7,391.84 m²
The total area of land covered by vegetation is 12 hectares	88,704 m²
Biomass production per hectare	495 kg
Total biomass production in 12 hectares	5,943 kg
Total carbon stocks in 12 hectares	2,793 kg
Carbon stocks per hectare	232.75 kg

Previous studies also support these results, although with different variations in numbers. For example, research was conducted by Barus et al. (2022) on an oil palm plantation in PT. Inti Indosawit Subur, Kebun Sei Lala, located in Ukui II Village, Ukui District, Pelalawan Regency, Riau, recorded that the carbon reserves of understory vegetation reached 1,732.60 kg/ha, with Asystasia gangetica being the dominant understory plant in the early TM area and Nephrolepis biserrata being the dominant understory plant in the late TM area. This figure is much higher than the results of this study, but differences could influence this in location and the types of plants growing on the land.

In Mulianto et al.'s (2022) study, the oil palm plantation of PT Borneo Ketapang Indah, located in Central Kalimantan, has been discovered 40.07 kg/ha carbon reserves. At 3 years old, the main understory plant was Scleria samtrensi, while at 10 years old, the dominant understory plant was Cyperus rotundus in the passive soil type. Despite being lower, these results suggest that factors such as plant age, soil type, and land management significantly influence variations in carbon reserves in understory vegetation. Therefore, the findings of this study, which demonstrate 232.7 kg C/ha, can serve as a valuable benchmark for the state of well-managed oil palm plantations. This also presents potential for future research into strategies to enhance carbon storage in the understory vegetation.

4. Conclusion

Drawing from the findings of previous studies and conversations, it can be inferred that:

1. This research discovered 27 species of understory vegetation, each with different levels of dominance. This indicates a diverse ecosystem, with Mitracarpus hirtus being the main contributing species, with a biomass of 876 grams.
2. The carbon reserves in oil palm plantations with dominant understory vegetation of Mitracarpus hirtus range from 0.18 to 1.00 tons of carbon per hectare (180 - 1,000 kg C/ha). The findings of this study indicate 232.7 kg C/ha, which aligns with the current criteria.

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