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The Relationship Between Soil Conservation Techniques, Topsoil Depth, and Density of Vegetation Growing and Soil Organic C Content in Palm Oil (*Elaeis guineensis* Jacq) Plant Areas at Plantation IV Regional II Pabatu North Sumatra Province, Indonesia

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Abstract
Oil palm (*Elaeis guineensis* Jacq.) is a strategic plantation commodity that plays an important role in the Indonesian economy, contributing significantly to vegetable oil production and foreign exchange earnings. This study aims to identify soil conservation techniques and analyze the relationships among topsoil depth, weed vegetation density, and soil organic carbon content in coconut oil palm plantations at PT Perkebunan Nusantara IV Regional II Pabatu, North Sumatra Province. The research was conducted from April to May 2026 using a descriptive method with a field survey approach. Samples were collected through purposive sampling based on different soil conservation techniques applied in each observation plot. Data were gathered through field observations, measurements of topsoil depth, weed vegetation assessments, and laboratory analysis of soil organic carbon content. Vegetation analysis employed parameters such as density, frequency, Importance Value Index (IVI), and Summed Dominance Ratio (SDR). The study identified five weed species classified as broadleaf, grassy, and nutsedge weeds, with Ageratum conyzoides being the dominant species based on the highest IVI value. Topsoil depth ranged from 23 to 35 cm, averaging 28 cm, while soil organic carbon content varied between 1.08% and 3.07%. The significance of this study lies in its integrated examination of soil conservation aspects, vegetation, and soil chemical properties in coconut oil palm plantations. The findings can serve as a foundation for sustainable land management practices to maintain soil fertility and reduce erosion risks in coconut oil palm plantations.

Keywords: Erosion Soil, Fertility Land, Importance Value Index, Management Sustainable, Summed Dominance Ratio

1. Introduction

Coconut oil palm (*Elaeis guineensis* Jacq.) is one of the strategic commodities crucial to Indonesia's economy. Indonesia has become the world's largest producer of palm oil since 2006, with a crude palm oil (CPO) production of 47.12 million tons in 2019, increasing to 48.29 million tons in 2020, and then decreasing to 46.22 million tons in 2021 (BPS, 2023). The development of the palm oil industry is also reflected in the expansion of plantation areas, which reached around 16 million hectares in 2017, with 53% of the plantations managed by smallholders (Ministry of Agriculture, 2015). These conditions demonstrate that the palm oil sector plays a significant role in supporting national economic growth, providing employment opportunities, and increasing foreign exchange earnings.

The rapid development of coconut oil palm plantations is accompanied by various land management challenges, especially in areas with diverse physical and topographic

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conditions. Land is a critical factor influencing the success of coconut palm cultivation because it directly affects water availability, nutrients, and land stability. Steep slopes increase the risk of erosion, which can lead to the disappearance of the topsoil layer and reduce land quality. Heavy erosion often results in a high-density layer of loose soil, which can cause the loss of fertile topsoil and degrade land quality (Walida, 2020). Plant productivity is also affected by topographical conditions such as slope and land surface shape, which determine the effectiveness of land management (Aziza, 2021).

Erosion-induced land degradation can significantly reduce coconut palm productivity. The loss of the topsoil layer decreases organic matter content, nutrients, and the land's water retention capacity. The depth of the topsoil is an important indicator supporting plant growth, as it is the primary zone for root development and nutrient availability. Deep topsoil provides better conditions for plant growth, while shallow soil limits root development and nutrient absorption (Hidayanto et al., 2026). This underscores the importance of efforts to preserve topsoil thickness to maintain coconut palm productivity.

Land conservation is a key approach to preventing land damage and maintaining long-term productivity. According to Muhammad (2026), implementing land conservation techniques can reduce erosion rates, restore degraded land, and sustain the land's function as a growth medium for plants. Maharani (2026) explains that each land type has unique characteristics, requiring management practices tailored to their physical and chemical properties. Proper conservation techniques are expected to help preserve topsoil depth and improve plantation environmental quality.

Vegetation, especially weeds, also influences land conditions and coconut palm growth. Weeds compete with main crops for light, water, and nutrients, potentially reducing plant productivity (Masyitah, 2025). According to the Directorate General of Plantations (2014), weed species such as Mikania micrantha, Asystasia cromandeliana, and Imperata cylindrica can reduce production by up to 20%. Weed diversity is influenced by environmental factors such as light availability, soil fertility, land cultivation practices, and planting patterns (Wahdana, 2023). Therefore, identifying and managing weeds is an essential part of coconut palm cultivation systems.

Organic carbon (C) content in soil is an indicator of land fertility, originating from the decomposition of plant litter, roots, and microorganisms. Organic C plays a vital role in improving soil physical, chemical, and biological properties, thereby increasing the land's capacity to store water and nutrients. Low organic C content makes soil denser and more prone to erosion. Numerous studies have discussed the influence of topography on coconut palm productivity, weed diversity, and land conditions. However, research integrating conservation techniques, soil depth, weed density, and organic C content in coconut plantations remains limited. This gap highlights the need for further research (Syahputri et al., 2026).

Based on the above, the problem formulation of this study is: How are land conservation techniques applied to coconut plantations at PT Perkebunan Nusantara IV Pabatu? What are the conditions of topsoil depth, weed density, and soil organic C content? Furthermore, what is the relationship between land conservation techniques and these three parameters? The purpose of this study is to identify land conservation techniques applied in coconut plantations and analyze the relationship between conservation practices, soil depth, weed density, and soil organic C content. The results are expected to provide scientific information to support sustainable land management in coconut plantations and serve as a reference for future studies in land conservation and land resource management.

2. Material and Methods

This study was conducted in the coconut oil palm plantation area of PT Perkebunan Nusantara IV Pabatu from April 2026 to May 2026. The research location is situated at coordinates 99°05'–99°12' East Longitude and 03°10'–03°12' South Latitude. The Pabatu plantation is approximately 88 km from Medan City, 7 km from Tebing Tinggi City, and 40 km from Pematang Siantar City.

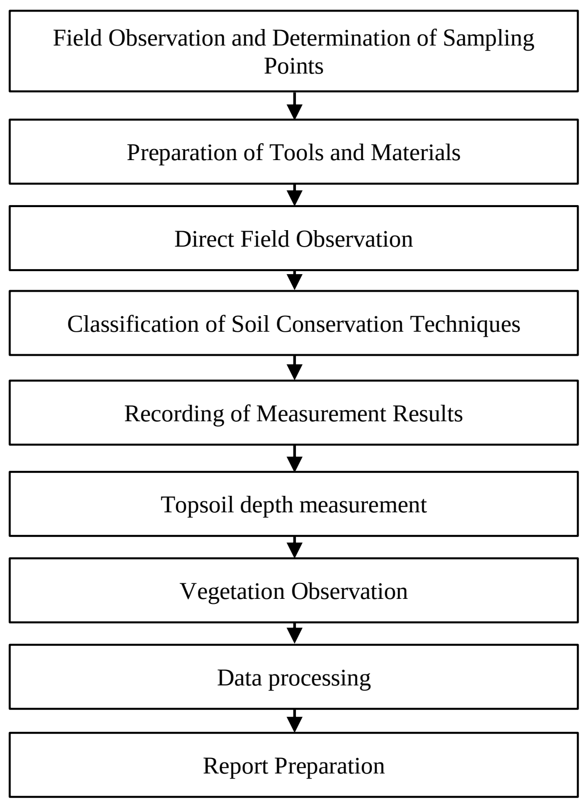

Figure 1. Research flow diagram

The research used a descriptive method with a field survey approach to examine the relationship between land conservation techniques, topsoil depth, weed vegetation density, and soil organic C levels. The study objects were coconut palm oil plantations that implement various land conservation techniques. The observed variables included land conservation techniques, topsoil depth, weed vegetation density, and soil organic C content. Sampling was conducted using purposive sampling based on different land conservation techniques applied at each study location.

Data collection involved field observations, measurement of topsoil depth using a soil drill or a hoe, and observations of weed vegetation in each sample plot. Weed analysis was performed using density, frequency, importance value, and the Summed Dominance Ratio (SDR) to determine weed dominance levels in the plantation areas. Organic C content in the soil was analyzed in the laboratory to assess land fertility levels. The data were analyzed descriptively and presented in tables to describe the relationships between land conservation techniques, topsoil depth, weed vegetation density, and soil organic C levels.

3. Results and Discussion

3.1. Description of Research Location

This study was conducted in the coconut palm oil plantation area of PT Perkebunan Nusantara IV, Plantation Business Unit Pabatu, located in Serdang Bedagai Regency, North Sumatra Province. The research site is situated at coordinates 99°05'–99°12' East Longitude and 03°10'–03°12' South Latitude. The Pabatu plantation is approximately 88 km from Medan City, 7 km from Tebing Tinggi City, and 40 km from Pematang Siantar City. The plantation area borders Tebing Tinggi City to the north and several other plantations in the surrounding southern areas.

The climate in the Pabatu Plantation Business Unit is humid, with annual rainfall of 2000–2500 mm and an average temperature of 29–30°C. The research location is at an elevation of approximately 300 meters above sea level, with undulating topography and intense solar radiation of about 5–7 hours per day. The soil types in the area are predominantly reddish chocolate and regosol, with textures mainly consisting of clayey sandy to sandy clayey soils, and effective land depth exceeding 100 cm.

Data collection was conducted through direct field observation and measurements at each sampling point. The tools used in this study included a soil drill or hoe for land profile observation, a meter for measuring topsoil depth, a Garmin eTrex 10 GPS device to determine coordinate points, a smartphone camera for documenting field conditions, and notebooks for recording data. The collected data were processed using Microsoft Excel 2021 for data tabulation and grouping.

Data analysis consisted of descriptive statistics to describe land conservation techniques, topsoil depth, vegetation density, and soil organic C levels. Additionally, Pearson correlation analysis was performed to examine the relationships between land conservation techniques and variables such as topsoil depth, vegetation density, and soil organic C levels at the study site.

3.2. Observation result Field

Based on the data obtained, there are five weed species consisting of three broadleaf weed species (Ageratum conyzoides, Mikania micrantha, and Peristrophe bivalvis), one grass weed species (Axonopus compressus), and one sedge weed species (Kyllinga nemoralis). Quantitatively, broadleaf weeds dominate with three species, accounting for 60% of the total weed species found, while grass and sedge weeds each comprise one species, or 20%.

Table 1. Types of Weeds at Pabatu Location

No	Type Weeds	Regional Name	Family	Group
1	*Kyllinga nemoralis*	Jukut pendul	*Cyperaceae*	Puzzle
2	*Ageratum conyzoides*	Bandotan	*Asteraceae*	Leaf wide
3	*Axonopus compressus*	Grass mini elephant	*Poaceae*	Grass
4	*Mikania micrantha*	Connect creeper	*Asteraceae*	Leaf wide
5	*Peristrophe bivalve*	Magenta leaves	*Acanthaceae*	Leaf wide

The dominance of broadleaf weeds indicates that environmental conditions at the study location more favor their growth than those of the other groups. This finding aligns with previous studies that report broadleaf weeds generally dominate in coconut palm oil plantation areas. The dominance of broadleaf weeds at 60% in this study suggests a higher proportion than grasses and sedges, each of which reaches only 20%. The presence of two Asteraceae species, Ageratum conyzoides and Mikania micrantha, indicates that this family is the most dominant, accounting for 40% of the total weed species. This percentage reflects the high adaptability and competitive ability of members of the Asteraceae family in the coconut oil palm plantation environment.

The number of weed species found in this study is higher than previous reports, which documented 10–20 weed species in coconut palm oil plantations. However, the pattern of weed composition shows the same tendency, with broadleaf weeds dominating over grasses and sedges. This condition is likely related to factors such as shade levels, soil moisture, and nutrient availability that support the growth of broadleaf weeds such as Ageratum conyzoides and Mikania micrantha. These species are known for their rapid growth rates and high dispersal, often making them dominant in various coconut oil palm plantation ecosystems.

3.3. Thickness in Pabatu

Based on measurement data from 10 observation plots, the topsoil thickness at the study location ranges from 23 to 35 cm, with an average of 28.7 cm. The highest topsoil thickness was found in Plot 5 at 35 cm, while the lowest was in Plot 3 at 23 cm. The 12 cm difference in thickness between plots indicates variation in land conditions, likely influenced by factors such as erosion levels, organic matter accumulation, and land management practices.

Table 2. Topsoil thickness in Pabatu

No	Plot	Thickness (cm)
1	Plot 1	26
2	Plot 2	33
3	Plot 3	23
4	Plot 4	28
5	Plot 5	35
6	Plot 6	28
7	Plot 7	28
8	Plot 8	31
9	Plot 9	27
10	Plot 10	28
Average	-	28 ± 1.01

In general, the average topsoil thickness of 28.7 cm suggests that the soil layer at the study site remains in good condition, providing nutrients, water, and space for the roots of coconut palms (*Elaeis guineensis*).

The research results indicate that the topsoil layer in this study is relatively thicker compared to the research conducted by Walida (2020) on land plantations of coconut oil palm, which reported an average topsoil thickness of 24 cm. The topsoil thickness at the current study site is approximately 4.7 cm greater, or about 19.6% thicker, than in Walida's study. This condition suggests that the land layer at PT Perkebunan Nusantara IV Pabatu remains sufficiently fertile and has experienced relatively low erosion, given its flat terrain.

These findings are also consistent with the study by Setianingsih (2025), which reported that the topsoil thickness of well-managed plantation land generally ranges between 25–35 cm, with an average of 28.7 cm. The topsoil thickness in this study falls within that range, indicating that the land condition at the study site remains good. Additionally, the topsoil layer in Plot 5, which reaches 35 cm, is at the upper limit of this range, suggesting ongoing organic matter accumulation and effective land conservation processes compared to other plots.

Quantitatively, these results indicate better conditions than in areas experiencing moderate land degradation, where topsoil thickness is generally less than 25 cm. With an average thickness of 28.7 cm, the topsoil layer at this location is approximately 14.8% thicker than the 25 cm threshold. This indicates that the land layer at PT Perkebunan Nusantara IV Pabatu is still capable of supporting root growth, nutrient absorption, and optimal productivity of coconut oil palm plants.

3.4. Vegetation Weeds In the Pabatu Garden

Based on observations of vegetation weeds in 10 sample plots, five weed species were identified, totaling 4,202 individuals. The vegetation weed was dominated by Ageratum conyzoides, with the highest number of individuals, totaling 3,434. The density is 343, and the relative density is 82%, indicating strong dominance over other weed species. The frequency value of 1.00 and the relative frequency of 43% indicate that this species is found throughout the observation plots, suggesting a wide distribution. The highest Importance Value Index (IVI) of 125% confirms that Ageratum conyzoides is the most dominant weed in the coconut oil palm (*Elaeis guineensis*) plantation areas at the study site.

Table 3. Vegetation Weeds

Species	Amount	Amount plot found	K	KR	F	FR	INP
Kylinga nominalist	660	8	66.0	16%	0.80	35%	50%
Ageratum conyzoides	3434	10	343	82%	1.00	43%	125%
Axonopus compressus	77	3	7.70	2%	0.30	13%	15%
Mikania micrantha Kunth	12	1	1.20	0.3%	0.10	4%	5%
Peristrophe bivalve	19	1	1.90	0.5%	0.10	4%	5%
Total	4202	10	420	100%	2.30	100%	200%

Based on the observation results in 10 plots, the highest weed density was found in Ageratum conyzoides, with a value of 343, making it the most dominant weed at the research location. Kyllinga nemoralis had a density value of 66.0 and was the second most common species, while Axonopus compressus had a lower density of 7.70. The lowest density values were observed in Peristrophe bivalvis (1.90) and Mikania micrantha (1.20), indicating low individual numbers and limited distribution. The total weed density of 420 suggests that the weed density in the coconut oil palm plantation area is moderate.

Relative density (KR) shows the comparison of the number of individuals of each species relative to the total number of weed individuals. The results show that Ageratum conyzoides has the highest KR value at 82%, making it the most dominant weed community species at the research site. Kyllinga nemoralis has a KR value of 16%, indicating it is sufficiently tall but still well below that of the dominant species. Axonopus compressus has a KR of 2%. In comparison, Peristrophe bivalvis and

Mikania micrantha each have only 0.5% and 0.3%, respectively, indicating their very low contribution to the weed community in the coconut oil palm plantation.

The frequency (F) of weeds indicates the level of species distribution across the observation plots. Ageratum conyzoides has the highest frequency (1.00), indicating it is present throughout all plots and has a very wide distribution. Kyllinga nemoralis has a frequency of 0.80 and is found in most plots, while Axonopus compressus has a frequency of 0.30. The lowest frequency value, 0.10, is found in Mikania micrantha and Peristrophe bivalvis, indicating that these species are only found in a few plots within the coconut oil palm plantation.

Relative frequency (FR) indicates the proportion of each species' distribution compared to the total frequency of all weeds. Ageratum conyzoides has the highest FR (43%), indicating the widest distribution at the research site. Kyllinga nemoralis has an FR of 35%, showing a relatively high level of distribution, while Axonopus compressus has an FR of 13%. The lowest FR values, 4% each, are in Mikania micrantha and Peristrophe bivalvis, indicating their limited distribution within the plantation.

The Importance Value Index (IVI) reflects the dominance of each species in the weed community based on the combined values of relative density and relative frequency. The analysis shows that Ageratum conyzoides has the highest IVI at 125%, making it the most dominant and influential weed at the research location. This IVI value is higher than that reported by Setianingsih (2025), who documented an IVI of 87.50% for Ageratum conyzoides in coconut oil palm plantations, indicating a difference of 37.50%. Kyllinga nemoralis has an IVI of 50%, while Axonopus compressus has an IVI of 15%. These results differ from Sari (2025), who reported Axonopus compressus as a dominant weed with an IVI of 42.30%, which is 27.30% higher than in this study. The lowest IVI values, 5% each, are found in Mikania micrantha and Peristrophe bivalvis, indicating their low relative influence in the weed community. The total IVI of 200% suggests that the overall weed vegetation in the coconut oil palm plantation area is well characterized and balanced.

3.5. Soil Organic C Content

Based on the laboratory analysis results for organic C content in 10 observation plots, the data obtained are presented in the Table 4. Based on the data in Table 4, the organic carbon (C) content of the land at the study site ranges between 1.08% and 3.07%. The lowest value was 1.08% in Plot 1, which falls into the low category, while the highest was 3.07% in Plot 10, which is categorized as high. Most of the plots have organic C content in the moderate to high categories, specifically Plot 4, Plot 5, Plot 7, and Plot 9, with values between 2.03% and 2.94%. Additionally, Plot 6, Plot 8, and Plot 10 have values above 3%. Plots 1, Plot 2, and Plot 3 are classified as low because their organic C content is below 2%.

Table 4. Soil Organic C Content

No	Sample	C- Organic	Criteria
1	Plot 1	1.08	Low
2	Plot 2	1.66	Low
3	Plot 3	1.74	Low
4	Plot 4	2.03	Currently
5	Plot 5	2.69	Currently
6	Plot 6	3.05	Tall
7	Plot 7	2.65	Currently
8	Plot 8	3.03	Tall
9	Plot 9	2.94	Currently
10	Plot 10	3.07	Tall

Information: Observation carried out on each plot with 1 sample and 1 repetition.

Vegetation weed conditions, litter presence, and the decomposition of organic material are likely to influence differences in organic C content. The results show that the organic C content in the soil ranges from 1.08% to 3.07%, with an average of 2.39%. This value is lower than that reported by Aziza (2021), which found organic C content in coconut oil palm plantations ranging from 1.85% to 3.75%. The maximum value in this study (3.07%) is 0.68% lower than that reported by Aziza, while the minimum value (1.08%) is 0.77% lower than the minimum in Aziza's study. This indicates that organic material accumulation at the current study site is still relatively low compared to that at the location studied by Fikri et al. (2023).

High organic material content plays a significant role in improving soil structure, increasing cation exchange capacity, and supporting microbial activity in the soil.

3.6. Connection Between Vegetation Weeds With Topsoil in Pabatu

Research results show a connection between topsoil thickness and the dominance of vegetation weeds at the study site. Topsoil thickness ranges from 23 to 35 cm, with an average of 28 cm, which is classified as sufficiently good to support plant growth. The topsoil layer is rich in organic matter, nutrients, and active microorganisms, which play an important role in supporting the growth of both plants and weeds in the coconut oil palm (*Elaeis guineensis*) plantation.

The results indicate that Ageratum conyzoides is the most dominant species, with an INP value of 125%, followed by Kyllinga nemoralis at 50%, Axonopus compressus at 15%, and Mikania micrantha and Peristrophe bivalvis each at 5%. The INP value of Ageratum conyzoides in this study is higher than that reported by Prayoga et al. (2026), who recorded an INP of 92.40%, indicating a difference of 32.60%. Similarly, Kyllinga nemoralis has an INP of 50%, which is higher than the 34.70% reported by Fahly (2025), a difference of 15.30%. These differences suggest that environmental conditions and topsoil characteristics at the current study site favor the growth of these species more than at previous locations.

The topsoil thickness at the study site ranges from 23 to 35 cm, with an average of 28 cm. The maximum topsoil thickness exceeds 35 cm, which is 7 cm higher than the maximum of 28 cm reported in the study by Ananda (2025) in coconut oil palm plantations. Greater topsoil thickness indicates a higher ability of the land to provide water and nutrients, thereby supporting optimal growth of vegetation and weeds.

Species with low INP values, such as Axonopus compressus, Mikania micrantha, and Peristrophe bivalvis, suggest that other factors—such as interspecific competition, land humidity, light intensity, and microclimate conditions—also influence the composition of weed vegetation.

3.7. Relationship between Soil Organic C-Levels and Vegetation Weeds and Topsoil

The research results in the Garden Pabatu show that the organic carbon (C) content of the land is closely related to the thickness of the topsoil and the vegetation weeds. The organic C content ranges from 1.08% to 3.07%, with values categorized as low to high. Plots with thicker topsoil generally exhibit higher organic C content because the soil layer serves as a site for the accumulation of organic materials from weathering, litter, palm fronds, plant roots, and weed biomass.

Vegetation weed density also affects the organic C content of the land. Weeds produce more biomass, and the decomposition process increases the organic carbon content in the soil. The dominance of Ageratum conyzoides with an INP value of 125% indicates that this species plays an important role in the weed community. This INP value is 32.60% higher compared to the study by Farrasati et al. (2019), which reported an INP of 92.40%. The high dominance of this species contributes to the addition of organic material to the soil through its biomass, which undergoes weathering. This finding aligns with the study by Satriawan et al. (2019), which found that areas with dense vegetation cover tend to have higher organic matter content than those with sparse vegetation.

Topsoil thickness and land conservation techniques significantly influence the land's ability to retain organic material. In this study, the topsoil thickness ranges from 23 to 35 cm, with organic C content between 1.08% and 3.07%. The maximum organic C value of 3.07% is still lower than the 3.75% reported by Wiranda et al. (2025), which has a difference of 0.68%. Although the topsoil conditions at this location are classified as good, the accumulation of organic material is not yet as high as in previous studies. The presence of vegetation cover, natural weeds, and the composition of palm oil leaves and stalks help prevent erosion, thereby supporting the maintenance of organic material in the soil. Generally, better topsoil conditions and dense vegetation cover tend to increase the organic C content in the soil.

4. Conclusion

The research results show that the vegetation at the study site consists of over 5 species, with Ageratum conyzoides as the dominant weed. The topsoil thickness ranges from 23 to 35 cm, with an average of 28 cm, indicating that the land is still in good condition to support the growth of coconut palms (*Elaeis guineensis*). This study demonstrates an important connection between vegetation weeds and topsoil thickness, where certain weeds play a role in helping to stabilize the land and reduce erosion risks in plantation areas.

Based on the research findings, weed control should be carried out selectively, targeting dominant weeds that potentially hinder the growth of other plants while maintaining vegetation cover to protect the land. Implementing land conservation measures—such as organic mulch application, cover cropping, and drainage system repairs—is also necessary to preserve topsoil thickness and sustainably maintain soil fertility.

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