



RESEARCH ARTICLE

Open Access

Soil cover vegetation analysis on soil physical properties at PT Cibaliung Tunggal Plantation Cibaliung I Rokan Hilir reGENCY Riau province



Muhammad Nurkholis Batu Bara¹, Ingrid Ovie Yosephine^{1,*}

Abstract

Ground cover vegetation plays a crucial role in maintaining soil quality and preventing degradation by altering soil physical properties. This study aimed to analyze differences in soil physical properties, particularly bulk density, porosity, and water content, in areas covered with different types of ground cover vegetation at PT Cibaliung Tunggal Plantation, Kebun Cibaliung I, Riau. The method used was a field survey with purposive sampling of soil at two depths, namely 0-10 cm and 10-20 cm. The observation sites included three vegetation conditions: fern (*Nephrolepis biserrata*), crocodile-nest grass (*Ottochloa nodosa*), and bare land. Laboratory analysis indicated that vegetation significantly improved soil physical properties. The lowest bulk density values were found in areas with *Ottochloa nodosa* vegetation (0.35-0.78 g/cm³), whereas the highest values were found in areas without vegetation (1.35-1.45 g/cm³). All locations exhibited “very good” porosity criteria (>20%), with the highest values in *Ottochloa nodosa* areas reaching 88-95%. In terms of water retention, vegetated areas demonstrated greater capacity than bare areas; the highest water content was recorded in *O. nodosa* areas (81-202%), whereas bare areas exhibited water content ranging from 18-21%. This study concluded that using ground cover vegetation can significantly reduce soil density and increase porosity and water storage capacity, thereby supporting sustainable land productivity, especially during the oil palm replanting period. These findings highlight *Ottochloa nodosa*'s superior performance in optimizing soil moisture and structure, suggesting that plantation managers should prioritize its conservation to enhance long-term soil sustainability.

Keywords: Bulk Density, *Nephrolepis biserrata*, *Ottochloa nodosa*, Soil Porosity, Water Retention

1. Introduction

Oil palm (*Elaeis guineensis*) is a monoecious plant in which male and female flowers are borne on the same individual plant. Oil palm cultivation has a significant impact on the Indonesian economy. Indonesia is currently the world's largest producer and exporter of palm oil, and palm oil accounts for approximately 17.3 billion US dollars of the plantation subsector's export value. According to Indonesian Plantation Statistics, Volume I (2023–2025), the total area of oil palm plantations in 2023 reached 16,833,985 ha, consisting of smallholder plantations (PR) covering 6,736,516 ha, state-owned plantations (PBN) covering 577,937 ha, private plantations (PBS) covering 8,614,259 ha, and other land categories (LAD) covering 905,273 ha. In 2024, the plantation area slightly increased

to 16,833,986 ha, with PR accounting for 6,783,102 ha, PBN for 580,505 ha, PBS for 8,641,459 ha, and LAD for 828,920 ha. In 2025, the total plantation area remained relatively stable at 16,833,985 ha, consisting of PR covering 6,900,589 ha, PBN covering 600,131 ha, PBS covering 9,160,430 ha, and LAD covering 172,835 ha (Ditjebun jilid 1, 2025). The extensive area of oil palm plantations requires optimal land management, in which understanding soil characteristics is a crucial factor.

Related to this, the physical properties of soil are one component of the 3 types of soil properties: physical, chemical, and biological. The physical properties of soil are very important in supporting plant productivity and maintaining ecosystem balance. Poor soil conditions, such as structural degradation, loss of texture, and reduced soil

*Correspondence: ingrid_ovie@itsi.ac.id

1) Institut Teknologi Sawit Indonesia - Jl. Willièm Iskandar, Kenangan Baru, Kec. Percut Sei Tuan, Kabupaten Deli Serdang, Sumatera Utara 20371, Indonesia

fertility, can affect the productivity of oil palm plantations. In the face of this problem, a treatment approach that considers the role of plants in various types of ground cover vegetation is needed. Ground cover vegetation, such as *Ottlochloa nodosa* (grasses) and *Nephrolepis Biserrata* (Ferns), has the potential to improve soil physical properties. Through strong roots, ground cover plants can improve soil structure, minimize erosion, and increase soil water retention (Melinda, 2020).

Ground cover plants make many positive contributions to the cultivation of oil palm plantations. The presence of these ground cover plants can protect the soil surface from erosion caused by direct splashing from raindrops and wind, and can also maintain soil structure stability. In addition, other benefits of ground cover plants include improving soil quality both physically and chemically, improving aeration, enriching the organic matter content of the remaining leaves that die and fall to the ground, and increasing the soil's capacity to store water and nutrients. On the other hand, ground cover plants can reduce the risk of root diseases attacking the main plant. Thus, all of these benefits can support sustainability and productivity in oil palm plantations (Yardha, 2018).

In the area of oil palm plantations, especially at PT Cibaliung Tunggal Plantation, Cibaliung I has diverse topographic conditions and high rainfall, making the land vulnerable to soil degradation, including erosion and reduced soil physical fertility. Therefore, an in-depth analysis of the types of ground cover vegetation most effective in maintaining soil physical properties is needed to sustain long-term land productivity and support sustainable management of oil palm plantations.

Ottlochloa nodosa as ground cover in oil palm plantations has a positive influence on soil physical properties. In general, this ground cover plant helps to reduce the water deficit, protecting the soil surface from direct raindrops and sunlight. According to Suryana *et al.* (2020), selected plants from vegetation analysis results suitable for ground cover are *Ottlochloa nodosa* and *Nephrolepis biserrata*. The criteria for plants that can be used as ground cover are easy to propagate, non-competitive, fast-growing, producing many leaves, and tolerant of shade.

Ground cover plants such as *Nephrolepis biserrata* benefit from absorbing rainfall, helping maintain soil water content, especially during the dry season. There is a close relationship between the impact of *Nephrolepis biserrata* on the water balance of oil palm plantations, resulting in a 36.71% decrease in groundwater deficit during the dry month or dry season (Ariyanti *et al.*, 2016).

The presence of vegetation under the oil palm canopy is no longer viewed solely as a nuisance weed to be eradicated. Subsoil or ground cover vegetation plays a crucial ecological role in maintaining the balance of the plantation ecosystem, especially as a surface cover that

contributes to soil and water conservation (Pangestu *et al.*, 2025). This shows that the proper management of land cover vegetation, both grasses and ferns, is of high urgency because the biomass produced can modify the soil microenvironment and minimize structural damage to the soil surface from leaching and erosion.

Replanting or replanting oil palm plants is one of the right strategies to maintain and ensure the sustainability of the oil palm plantation industry in the future. However, the replanting process cannot be separated from challenges and problems, especially those related to the reuse of land previously planted with oil palm. Reuse of used land can cause many problems, such as decreased productivity due to soil structure degradation and changes in soil physical, chemical, and biological properties resulting from previous oil palm cultivation activities. The productivity of oil palm plants on a given land is highly dependent on nutrient conditions and soil fertility. Previous research by Lukman Hakim *et al.* (2024), oil palm plantations owned by PT: Salim Ivomas Pratama Tbk, the parent company of PT. Cibaliung Tunggal Plantation Cibaliung Plantation focuses on how the role and thickness of litter from each type of ground cover vegetation can stabilize and maintain the soil's physical structure. Meanwhile, in my research, there is a specific urgency to provide reference data on soil physical properties for the first-generation 1989 & 1990 crop blocks. The Data is intended as a basis for the company's management in making decisions before replanting for the second-generation planting. Therefore, to ensure the success of replanting activities and support optimal production outcomes, a thorough evaluation of soil fertility in the area to be planted with oil palm is again needed (Qishty *et al.*, 2023).

This study aims to analyze the differences in the physical properties of soil bulk density, porosity, and soil moisture content in areas with Fern vegetation (*Nephrolepis biserrata*), crocodile nests (*Ottlochloa nodosa*), and without vegetation in PT Cibaliung Tunggal Plantation Cibaliung I with different depths of 0-10 cm and 10-20 cm.

2. Material and Methods

This research was conducted at PT Cibaliung Tunggal Plantation Cibaliung I, Pasir Putih village, Balai Jaya District, Rokan Hilir regency. Riau Province. Astronomically, the plantation area is located at 01°44'30" LU - 01°47'15" LU and 100°32'40" - 100°36'10" BT, with an altitude ranging from 25-65 meters above sea level (MASL). The study lasted \pm 3 weeks.

2.1. Tools and materials

Tools used are notebooks, knives, pencils/markers, documentation tools, soil sample rings, digital scales, ovens, calipers, pycnometer flasks, funnels, mortars and pestles, and filters and droppers. The materials used are plastic and mineral soil samples taken from land overgrown

with vegetation of *Ottchloa nodosa* and *Nephrolepis biserrata*, and from land without vegetation in the plantation of PT Cibaliung Tunggal Plantation Cibaliung I, planting years 1989 and 1990.

This study was conducted from February 27 to March 17 using a 2-stage survey method. The first phase conducted a preliminary survey from February 27 to March 04, and the second phase of the main survey was conducted from March 05-10. At the first stage of the preliminary survey, determine the location of the study and the secondary data. The second stage of the main survey is to determine the soil sampling blocks and points. The soil samples can then be analyzed at the Soil Biology and Chemistry Laboratory of the Faculty of Agriculture at USU on March 11-17. Purposive sampling of soil (deliberately) at a point that has been overgrown by ground cover vegetation such as *Ottchloa nodosa*, *Nephrolepis biserrata*, and without vegetation. Soil samples collected in the field will then be analyzed in the Laboratory of Soil Biology and Chemistry at the Faculty of Agriculture of USU, with data analysis and thesis preparation. Observation parameters include the weight of contents (*bulk density*), porosity, and water content. Implementation of the study includes several stages, namely:

2.1.1. Preparation & Determining The Research Area

Research preparation is the first step before conducting the research. Preparations were made to maintain legality (research permit) and to determine the land used in the sampling process: mineral land in oil palm plantations, overgrown with ground cover vegetation (*Ottchloa nodosa* and *Nephrolepis biserrata*), and without vegetation.

2.1.2. Soil Sampling & Laboratory Analysis

Soil sampling was carried out using a sample ring measuring 10 cm in length and 7.3 cm in diameter. Soil sampling by Purposive Sampling (intentionally) at the point where vegetation has been grown, *Ottchloa nodosa*, *Nephrolepis biserrata*, and no vegetation. Then clean the soil surface of vegetation, then dig a circle around the soil sample point to a depth of 0-20 cm. Soil sampling is done 2 times, namely at depths of 0-10 cm and 10-20 cm. Ring soil samples are placed on the surface of the soil and pressed to a depth of 0-10 cm depth I and 10-20 cm depth II, then the ring soil samples are taken by digging using a hoe, and after the sample ring is raised, it is given a label in order (Agus, 2017). The determination of sample points was carried out at 3 locations with different soil cover vegetation categories: areas with Fern vegetation (*Nephrolepis biserrata*), areas with vegetation (*Ottchloa nodosa* crocodile nests), and areas without vegetation. At each vegetation location, samples were collected at 2 depth levels (0-10 cm and 10-20 cm), resulting in 3 sample points and 6 depth data points. Soil samples collected in the field

are then analyzed in the Soil Biology and Chemistry Laboratory of the Faculty of Agriculture at USU for data analysis and thesis preparation. Observation parameters analyzed include the weight of the contents (*bulk density*), porosity, and water content.

2.2. Observation Parameters

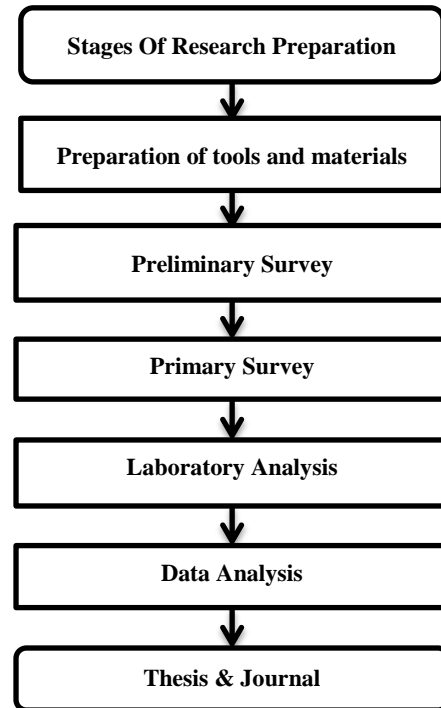


Figure 1. Research flow diagram

Laboratory analysis was performed on intact soil samples collected in the field using sample rings. The soil sample, along with the Rings, is weighed before ovulating. Then, the sample is heated in an oven at 105° C for 24 hours. After that, the soil sample, together with the rings, is weighed again. The tools used in this measurement include a stainless steel sample ring (diameter 7.3 cm, height 10 cm), a drying oven (Memmert Type UN55) with a temperature accuracy of up to 105°C, and a digital analytical balance (Ohaus Pioneer PX224, USA with an accuracy of 0.0001 grams. Next, the soil bulk density was calculated. According Atmanto dalam (Melly Deslina, et al., 2022) namely:

1. How *Bulk density weights work*
 - a. Record the value of each dry weight of oven soil
 - b. Then, input the value of the ring volume as 418.3 cm³

$$\text{Volume weight} = \frac{BKO}{VRS} \text{ (g/cm}^3\text{)}$$

Where:

BKO = Oven Dry Weight of Soil (g/cm³)

VRS = sample Ring Volume

$$\text{Volume Ring Sample} = \pi \times r^2 \times t$$

Description:

t = sample ring height (cm)

Phi (with a value of 3.14)

r = radius (cm)

2. How pore space Volume, Total pore space, and particle Density work
 - a. Soil samples are ground to a fine powder
 - b. Put the soil in a pycnometer flask, measuring at 50 ml each
 - c. The soil that has been measured is poured into a cup and weighed. The cup is rated on the scales to be 0.
 - d. After weighing, the soil is returned to a pycnometer flask and given an initial volume of water of up to 100 ml.
 - e. Record the final volume after filling 100 ml of water and stirring the soil.

Pore Space Volume

$$\text{VRP (cc)} = (\text{Vol. land} + \text{Vol. water}) - \text{Vol. groundwater}$$

$$\text{Total pore space (\%)} = \frac{\text{pore space Volume} \times 100\%}{\text{soil Volume}}$$

$$\text{Partikel Density (g/cc)} = \frac{\text{Soil weight}}{\text{Soil volume} - \text{Vol.Pore Space}}$$

3. Porosity calculation. According to Utoyo in (Melly Deslina et al., 2022), namely:

$$\text{Porositas} = \left(1 - \frac{BD}{PD}\right) \times 100 \%$$

Where:

BI = Bobot isi / Bulk Densitiy (g)

PD = particle density (g)

4. Water Content

- a. Record the value on the wet weight of the soil before the oven (BA)
- b. Record the value on the dry weight of the oven soil (BKO)

According (Abdurachman, Ummah, 2019), application of water content as follows:

$$\text{Gravimetric water content} = \frac{BA - BKO}{BKO} \times 100\%$$

Where:

BA = Wet Weight of soil before oven (g)

BKO = dry weight of soil after oven (g)

3. Results and Discussion

The analysis of soil physical properties, particularly bulk density, was conducted to evaluate the effects of various types of ground cover vegetation on soil density in the plantation area. The content weight value is an important indicator that reflects the pore space and the soil's ability to pass water and air, and is directly influenced

by the perakara system of each vegetation and by the accumulation of organic matter at different depths. *Nephrolepis biserrata*, *Otochloa nodosa*, and areas without vegetation on two different soil depth profiles can be presented in detail in Table 1 below.

Table 1. Laboratory Analysis Results Bulk density (*Bulk density*) (g/cm³)

Depth	Vegetation		
	<i>N.biserrata</i>	<i>O. nodosa</i>	T. Vegetation
0 – 10 cm	1,20 g/cm ³	0,78 g/cm ³	1,35 g/cm ³
10 – 20 cm	1,52 g/cm ³	0,35 g/cm ³	1,45 g/cm ³

Description: is a marker of the results of the bulk density value of various vegetation on the physical properties of soil with different depths. (source: analysis and calculation)

Table 1 shows that both vegetation types and those without vegetation have values of 0.35–1.52 g/cm³. The table data from the analysis above also show a striking difference between land with land cover vegetation and open land without land cover vegetation dipermukaanmya. On land without vegetation, the value of content weight/bulk density tends to be higher, ranging from 1.35 g/cm³ to 1.45 g/cm³, compared with land with ground cover vegetation. These findings indicate that land devoid of ground-cover vegetation is associated with increased soil density.

The presence of vegetation *Otochloa nodosa* has a significant influence on the physical properties of the soil, especially the terhadap value of the soil content weight. The land with vegetation from the recorded data showed the lowest content weight, especially in the soil layer at 10-20 cm, with a value of 0.35 g/cm³. This condition is thought to be closely related to the accumulation of litter derived from *Otochloa nodosa* leaves that have undergone decomposition, thereby increasing soil organic matter content. This increase in organic material, as stated by Arifin (2010), plays an important role in improving soil structure, making it crumblier or looser, and directly reducing soil bulk density.

The vegetation of *Nephrolepis biserrata* influences soil physical properties, particularly bulk density. In the 0-10 cm soil layer, the measured density of the contents in areas dominated by Fern vegetation is 1.20 g/cm³. A well-developed root system increases the soil's water infiltration capacity. In addition, the lower content weight value in vegetated land compared to open land can be explained by the presence of Root activity and the addition of organic matter, which together enlarge the soil pore space.

On land that is not covered by ground cover vegetation, the value of the weight of the contents of the above tael data was recorded at 1.45 g/cm³ at a depth of 10-20 cm. conditions on soils such as this increase the susceptibility to direct impact of rain grains, which have the potential to damage the aggregate structure of the soil and trigger compaction in the soil surface layer. According to Neneng et al. (2014), soils with high content weights generally have

low porosity, limiting their capacity to infiltrate and transmit water.

Analysis of soil physical properties, especially porosity, was conducted to understand the extent to which ground cover vegetation affects pore space and water infiltration. Soil porosity plays a crucial role in maintaining aeration balance and the availability of water needed for optimal oil palm growth. By comparing the effects of various vegetation types, such as *Nephrolepis biserrata* and *Otochloa nodosa*, with conditions without vegetation on two soil profiles at different depths, the effectiveness of each treatment in improving the soil's physical structure can be observed in the field. In detail, the laboratory test data on the percentage of soil porosity can be seen in Table 2 below

Table 2. Results of laboratory analysis of soil porosity (%)

Depth	Vegetation		
	<i>N.biserrata</i>	<i>O. nodosa</i>	T. Vegetation
0-10cm	76 %	88 %	71 %
10 – 20cm	65 %	95 %	67 %

Description: is a marker of the results of soil porosity values of various vegetation on the physical properties of soil with different depths. (source: analysis and calculation)

Table 2 shows that different types of vegetation and no vegetation have values of 65-95%. This shows porosity is classified as very good. Conforming to the soil porosity table noted by USDA (Rizal et al., 2022): > 20% is very good. From the treatment of different types of vegetation and without vegetation, it can be seen that the porosity at 10–20 cm is lower than that at 0–10 cm. Despite this, there were deviations in the pattern of data for vegetation, *Otochloa nodosa* (crocodile nest grass). At a depth of 10-20 cm, porosity increases significantly to 95%, the highest observed value. This condition is thought to be closely related to the characteristics of the environment at the sampling site, which is located on the edge of the road, directly bordering the watershed, and is classified as swampy land.

At the time of soil sampling at these depths, the soil is saturated with water and even stagnant. This phenomenon indicates that most of the soil pore space is filled with water, especially in slow-draining pores (micropores). Methodologically, such circumstances contribute to the high total porosity value obtained through laboratory analysis. Based on the observations in Table 2 above, soil porosity at 10-20 cm depth ranges from 65% to 95%, indicating that most of the pore space is filled with the liquid phase (water). The high water saturation percentage is in line with the research results (Imanudin et al., 2023) published in the journal Agriculture on the physical characteristics of soils in the Tidal marshlands of the Salek Delta. They explained that natural tidal marsh soils have a very large total pore space, ranging from 60% to more than 85%, which results in high groundwater retention. The location of the sampling site in this study, on the edge of

the road and directly adjacent to the river flow (marshland), is the main factor driving the high water saturation rate, which is quantitatively close to the maximum limit of swamp water tamping capacity.

Porosity of various vegetation types and the best vegetation is found in *Otochloa nodosa*, with values of 88-95% at two depths. With this "excellent" porosity result, the company plans to carry out *replanting* (rejuvenation), during which the loose soil will greatly support the root growth of second-generation oil palm seedlings.

Analysis of the physical properties of the soil. Specifically, the availability of water is examined to understand how the type of *tutupan Jahan* affects the soil's moisture-holding capacity. Water content was measured at two depths to examine the distribution of water in the areas of the vegetation roots, *Nephrolepis biserrata* and *Otochloa nodosa*, and to compare it with areas without vegetation. The laboratory analysis results for water content are shown in Table 3 below.

Table 3. Results of laboratory analysis of water content (%)

Depth	Vegetation		
	<i>N.biserrata</i>	<i>O. nodosa</i>	T. Vegetation
0 – 10cm	26%	81%	21%
10 – 20cm	21 %	202 %	18 %

Description: is a marker of the results of the value of soil moisture content of various vegetation on the physical properties of soil with different depths.

Table 3 shows that different types of vegetation and no vegetation have a value of 18-202%. Variations in these values reflect differences in the soil's water-absorption capacity, influenced by vegetation, soil depth, and environmental conditions at the sampling site.

On land overgrown with vegetation *Nephrolepis biserrata*, soil moisture content at a depth of 0-10 cm by 26%, then decreased to 21% at a depth of 10-20 cm. this decrease indicates that the upper layer has a better water retention ability than the lower layer. Hal tersebut di duga berkaitan dengan akumulasi bahan organik di permukaan tanah yang berasal dari serasah daun, sehingga meningkatkan kapasitas tanah dalam menahan air (Halimun et al., 2025).

Vegetation of *Otochloa nodosa* had a relatively high water content compared to other vegetation, reaching 81% at 0-10 cm depth. However, at a depth of 10-20 cm, there was a very significant increase to 202%. This value is considered very high, indicating that the soil is saturated with water. This condition is thought to be closely related to the characteristics of the environment at the sampling site, which is located on the edge of the road, directly bordering the watershed, and is classified as swampy land. This is in line with research. Hal ini sejalan dengan penelitian (Suryana et al., 2020) yang menunjukkan bahwa vegetasi *Otochloa nodosa* memiliki adaptabilitas yang baik terhadap kelembaban makro tinggi dan mampu berfungsi sebagai barrier terhadap aliran permukaan, sehingga tanah

bawahnya memiliki kemampuan yang sangat tinggi untuk menyimpan air.

Meanwhile, on land without vegetation, soil moisture content was lowest among the treatments, at 21% in the 0-10 cm layer and 18% in the 10-20 cm layer. The low moisture content in open land is caused by the absence of ground-cover vegetation on the soil surface, which helps resist evaporation and increase water infiltration. Soils without vegetation tend to lose water more quickly due to direct evaporation and the lack of organic matter, which helps absorb water. According to Hanafiah, Anwar et al. (2014), the absence of vegetation cover leads to the destruction of soil aggregates by rainwater blows, which triggers an increase in bulk density. Quantitatively, open soil that undergoes direct evaporation without litter protection generally maintains soil moisture content at a critical level, typically 17% - 19%.

Analysis of the relationship of Bulk Density, porosity, and soil moisture content based on the results of the study in Table 1, Table 2, and Table 3, there is an interrelated relationship between the value of Bulk density (BD), porosity, and soil moisture content in various types of

ground cover vegetation. These three parameters are the main indicators of soil physical quality, particularly in terms of water availability and plant root development. (Henrianto, A., Okalia, D., 2019).

4. Conclusion

This study confirms that the application of ground cover vegetation, especially *Ottochloa nodosa*, provides significant theoretical and practical advantages in restoring and improving soil physical properties compared to open land. The canopy structure and root system of this vegetation proved effective in improving the soil microenvironment by significantly reducing bulk density, optimizing porosity to achieve excellent criteria, and sustainably enhancing soil water retention capacity.

As a strategic recommendation for practitioners and plantation managers, the use and management of ground cover vegetation, such as *Ottochloa nodosa*, are highly recommended as nature-based solutions to minimize soil compaction risk, prevent erosion, and maintain long-term hydrological stability.

References

- Abdurachman, A., & Ummah, M. S. (2019). *Sifat fisik tanah dan metode analisisnya*. Balai Penelitian dan Pengembangan Pertanian, Departemen Pertanian.
- Agus. (2017). Sifat fisik tanah dan metode analisisnya di berbagai lahan, 6, 1-6.
- Arifin, M. (2010). Kajian sifat fisik tanah dan berbagai penggunaan lahan dalam hubungannya dengan pendugaan erosi tanah. *Jurnal Pertanian MAPETA*, 12(2), 72-144.
- Ariyanti, M., Yahya, S., Murti Laksono, K., Suwanto, S., & Siregar, H. H. (2016). Pengaruh tanaman penutup tanah *Nephrolepis biserrata* dan teras gulud terhadap aliran permukaan dan pertumbuhan kelapa sawit (*Elaeis guineensis* Jacq.). *Kultivasi*, 15(2). <https://doi.org/10.24198/kultivasi.v15i2.11889>
- Direktorat Jenderal Perkebunan. (2025). *Statistik perkebunan Indonesia 2023-2025* (Jilid 1). Kementerian Pertanian Republik Indonesia.
- Halimun, M., Salsabila, J., Winata, B., Rusdiana, O., & Catur, W. (2025). Laju dekomposisi serasah daun pada kelas kerapatan I dan II di zona rehabilitasi Taman Nasional Gunung Halimun Salak, 22, 29-43.
- Hanafiah, K. A., Winarso, S., Monde, A., & Anwar, K. (2014). *Dasar-dasar ilmu tanah*.
- Henrianto, A., Okalia, D., & Mulyani, M. (2019). Uji beberapa sifat tanah bekas tambang emas tanpa izin (PETI) di tiga kecamatan di daratan sepanjang Sungai Kuantan. *Jurnal Agroteknologi*, 1(2), 19-31.
- Imanudin, M. S., Bakri, B., Madjid, A., Warsito, W., Sahil, M. A., & Hermawan, A. (2023). Perbaikan kualitas lahan pada berbagai kelas hidrotopografi di lahan rawa pasang surut Delta Salek Banyuasin, Sumatera Selatan. *Agrikultura*, 34(3), 445-456. <https://doi.org/10.24198/agrikultura.v34i3.47018>
- Hakim, L., Tarmadja, S., & Wibowo, H. (2024). Pengaruh vegetasi penutup tanah terhadap sifat fisik tanah di kebun kelapa sawit, 1-12.
- Melinda, A. (2020). Pengaruh berbagai jenis vegetasi penutup tanah terhadap sifat fisik tanah pada kebun kelapa sawit di PT Tidar Kerinci Agung (SIAP Group), Kabupaten Muara Bungo, Provinsi Jambi.
- Destina, M., Yupi, H., & Siregar, R. H. S. (2022). Karakteristik tanah gambut tropis pada lahan perkebunan sawit serta hubungan antara parameter. *Gradasi Teknik Sipil*, 6, 306-312.
- Neneng, L. N., Sukarman, K., Ai, D., & Eni, M. (2014). *Pengelolaan tata air lahan gambut: Panduan pengelolaan berkelanjutan lahan gambut terdegradasi*.
- Pangestu, R. B. A., Suryanti, S., & Hartati, R. M. (2025). Dominance of understory vegetation and biomass production of oil palm plantations on mineral land. *Jurnal Agronomi Tanaman Tropika (Juatika)*, 7(2). <https://doi.org/10.36378/juatika.v7i2.4283>
- Qishty, M. Y., Harahap, F. S., Sepriani, Y., & Adam, D. H. (2023). Kajian beberapa unsur hara pada lahan replanting tanaman kelapa sawit (*Elaeis guineensis* Jacq.) di Kelurahan Bakaran Batu Kecamatan Rantau Selatan. *Jurnal Agro Estate*, 7(1), 54-60. <https://doi.org/10.47199/jae.v7i1.156>
- Rizal, S., Syaibana, P. L. D., Wahono, F., Wulandari, L. T., & Agustin, M. E. (2022). Analisis sifat fisika tanah ditinjau dari penggunaan lahan di Kecamatan Ngajum, Kabupaten Malang. *JPIG (Jurnal Pendidikan dan Ilmu Geografi)*, 7(2), 158-167. <https://doi.org/10.21067/jpig.v7i2.7022>
- Suryana, S., Chozin, M. A., & Guntoro, D. D. (2020). Identifikasi spesies tanaman penutup tanah pada perkebunan kelapa sawit menghasilkan. *Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy)*, 47(3), 305-311. <https://doi.org/10.24831/jai.v47i3.26980>
- Yardha. (2018). Manfaat tanaman penutup tanah sebagai tanaman konservasi di perkebunan. *Tanaman Pakan Ternak, Konservasi, dan Tanaman Penutup Tanah*, 1-8.