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The Impact of Implementing Agarwood Agroforestry System (*Aquilaria malacensis* Lamk.) on Soil Texture, Topsoil Depth, and Water Retention Capacity in Oil Palm Lands (*Elaeis guineensis* Jacq.)

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Abstract

The impact of implementing an agroforestry system in oil palm plantations by integrating agarwood-producing plants (Aquilaria Malacensis Lamk.) with oil palm plants on the physical properties of the soil needs to be assessed. This study is crucial due to the shared land use by agarwood-producing and oil palm plants. The study aims to evaluate the effects of integrating agarwood-producing plants into oil palm plantations on soil physical properties, including soil texture, topsoil depth, and water retention capacity. The research was conducted from September 2024 to November 2024 in agroforestry land (1 ha) and monoculture land (1 ha) in Bukit Kemuning Village, Tapung Hulu Kampar - Riau. The study utilized survey methods and systematic sampling for soil sample collection. The findings indicated that the agroforestry system positively impacted soil physical properties, with improved soil texture (54.67% sandy clay), increased topsoil depth, and enhanced water retention capacity compared to oil palm monoculture land. This improvement can be attributed to the higher organic matter content resulting from the decomposition of agarwood plant litter. Therefore, the agroforestry system enhances soil fertility and promotes sustainable environmental management.

Keywords: Agroforestry, Oil Palm and Agarwood, Soil Physical Properties, Topsoil, WHC

1. Introduction

Oil palm cultivation is a significant contributor to the national economy, with Riau Province home to extensive oil palm plantations in Indonesia. However, the monoculture system often employed in these plantations can have detrimental effects on soil fertility. Studies have shown that oil palm cultivation on mineral soil can lead to soil compaction, making it more susceptible to surface flow and erosion (Suryanto & Wawan, 2017). This compaction also reduces infiltration rates, water movement, and soil aeration (Muhdi, 2014). Continuous planting of only one crop, such as oil palm, can further degrade soil quality over time (Badrun & Mubarak, 2010) .

To mitigate the negative effects of oil palm plantations, one effective approach is to implement an agroforestry system. This system involves integrating trees with plantation crops to enhance land productivity. Agroforestry systems offer environmental benefits such as supplying organic matter, nutrient cycling, and erosion control through canopy coverage and litter (Young, 1997). They also contribute to soil fertility by cycling biomass through root systems, enhancing soil biological activity and nitrogen mineralization through tree shading, and protecting the soil surface from erosion with tree canopies.

A suitable plant species that can be integrated into oil palm plantations using an agroforestry system is the agarwood plant (*Aquilaria malacensis* Lamk). Agarwood plants require shade during their growth phase and have high economic value in both national and international markets. The lucrative nature of agarwood cultivation has spurred interest, particularly in the Riau region (Suharti, 2010). Given the economic potential of agarwood

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cultivation, this study aims to investigate the impact of incorporating agarwood cultivation in oil palm plantations on soil physical properties, including soil texture, topsoil thickness, and water retention capacity in oil palm and agarwood agroforestry systems.

2. Material and Methods

2.1. Time and Place

This research was conducted in the Bukit Kemuning area, Tapung Hulu District, Kampar Regency, Riau, with the research location coordinates of 0 o 38' 51.42" N and 101 o 55' 44.53" E. With rainfall of ± 2000 - 3000 mm/year, an average temperature of 26 o – 28 o C and humidity 78 o – 85 o C. The research land used was oil palm plants (1 ha) with a planting age of 20 years and agarwood plants (1 ha) at the age of 10 years. The research period lasted for 3 months, from September to December 2024.

2.2. Research Methods

The research methodology encompasses applying both survey and systematic sampling methods to extract soil samples. The soil sampling procedure is executed at a depth ranging from 0 to 20 centimeters. Six plots are established within each designated land area, with each plot comprising four soil samples. These samples include those collected from live palm tree (GH), dead palm tree (GM), oil palm discs (PS), Gaharu discs (PG), and empty space (RK) within the context of an oil palm monoculture system. The total number of soil samples collected from both land areas is 48. The collected data were then subjected to analysis using a 5% t-test, with the IBM SPSS Version 30.0.0 application serving as the statistical software of choice.

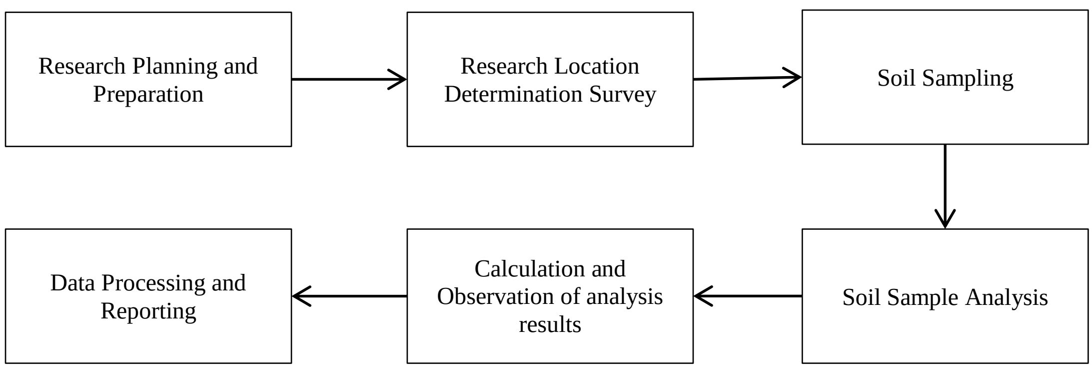

Figure 1. Research flow diagram

3. Results and Discussion

The implementation of shade-tolerant plant species within agroforestry systems on oil palm plantations exerts a substantial influence on the physical characteristics of the soil, both through the distribution of diverse root systems and the indirect provision of organic matter to soil organisms. The application of mixed planting patterns or agroforestry systems on oil palm plantations exerts a significant influence on the physical properties of soil, with particular regard to soil texture, topsoil thickness, and water retention capacity.

3.1. Soil Texture

Soil texture can be compared relatively, thereby demonstrating the percentage value of the composition in the soil between the percentage of sand, dust, and clay fractions. This result can be used as a measure of soil fineness or fertility. The findings pertaining to the soil texture values observed in agroforestry land and oil palm monoculture land are presented in Table 1.

Table 1. Average value of soil texture on agroforestry land and monoculture land

Land	Sample	Faction			Texture Class
		%Sand	%Dust	%See	
Agroforestry	Living Goal (GH)	53.20	32.60	14.20	LB
	Dead Goal (GM)	48.22	25.93	25.85	LB
	Agarwood Tree (PG)	61.50	17.50	21.00	LLB
	Oil Palm Tree (PS)	55.75	27.81	16.44	LB
Average		54.67	25.96	19.37	Sandy Loam (LB)
Monoculture	Living Goal (GH)	42.82	20.58	36.60	LBL
	Dead Goal (GM)	46.90	17.70	35.40	LiB
	Empty Space (ESP)	54.10	31.70	14.20	LB
	Oil Palm Tree (PS)	52.90	32.17	14.93	LB
Average		49.18	25.53	25.29	Sandy Clay Loam (SCL)

Description: LB: Sandy Loam, LLB: Sandy Clay Loam, LBL: Clayey Loam LiB : Sandy Clay

The findings revealed that agroforestry land had a predominant sand fraction of 54.67%, followed by silt (25.96%) and clay (19.37%), resulting in a sandy loam (LB) texture type. In contrast, monoculture land exhibited a lower sand fraction (49.18%) and higher clay content (25.29%), leading to a sandy clay loam (LLB) soil texture type. Previous studies have indicated that agroforestry land tends to have a higher sand fraction, which enhances soil permeability (Naharuddin et al., 2020). The soil texture in the agarwood agroforestry system within oil palm plantations differs from that in oil palm monoculture land. Varied land uses exhibit distinct soil texture conditions influenced by factors such as vegetation type, presence of organic matter, human activities, soil fractions, and environmental conditions (Solekhah et al., 2024).

Implementing the agarwood agroforestry system in oil palm plantations results in the accumulation of litter from agarwood leaves and twigs, including dead branches, around the plantations. This litter contributes to increased soil organic matter content, improving soil texture towards sandy clay (loose soil structure). Shade trees serve as litter producers and primary suppliers of organic matter in garden land by shedding leaves or pruning residues (Risma Sari & Yusmah, 2023). According to Husein et al. (2023), organic matter is believed to enhance soil aggregate stability by binding soil particles through decomposition, thereby loosening the soil. Organic matter plays a crucial role in enhancing soil texture, structure, fertility, and overall soil health (Nangaro et al., 2021). Other studies suggest that decomposing leaf litter on the soil surface can enhance physical soil properties, including soil texture and structure (Tolaka et al., 2013).

The average soil texture on oil palm monoculture land is sandy clay loam, while on agarwood agroforestry land, it is sandy clay. Sandy clay soil is richer in nutrients and organic matter than Gaharu litter. Hanafiah (1995) previously noted that sandy clay soil, with its sand dominance, contains numerous macropores, facilitating water and air circulation (drainage and aeration). This result indicates that sandy clay soil is more favorable for oil palm growth than sandy clay soil due to its coarser texture and abundance of macropores.

3.2. Topsoil Depth

Topsoil, defined as the layer of soil visible at the earth's surface, is characterized by its high organic material content. The observation of topsoil typically involves the utilization of a soil sampler, which is a tool designed for the extraction of soil samples. These samples are subsequently measured using a ruler to ascertain their dimensions. Topsoil is typically defined as the uppermost layer of soil, characterized by a dark coloration and a substantial presence of organic material that has undergone decomposition. The outcomes of the T-test analysis on the depth of topsoil are presented in Table 2, while Figure 1 provides a graphical representation of the comparison of topsoil depth across different land areas.

Table 2. Comparison of average topsoil depth values of agroforestry land and agricultural land. Monoculture

Location Sampling	Agroforestry (cm)	Monoculture (cm)	t-count	t-table	S/NS
Live palm tree (GH)	3	2.67	2,447	1,812	S
Dead palm tree (GM)	18.5	17.83	2.48	1,812	S
Agarwood (PG) / Space Empty (RK)	16.33	13.50	4.239	1,812	S
Oil Palm Tree (PS)	13.33	10.83	2.495	1,812	S

Information: S: Significant NS: Non-Significant

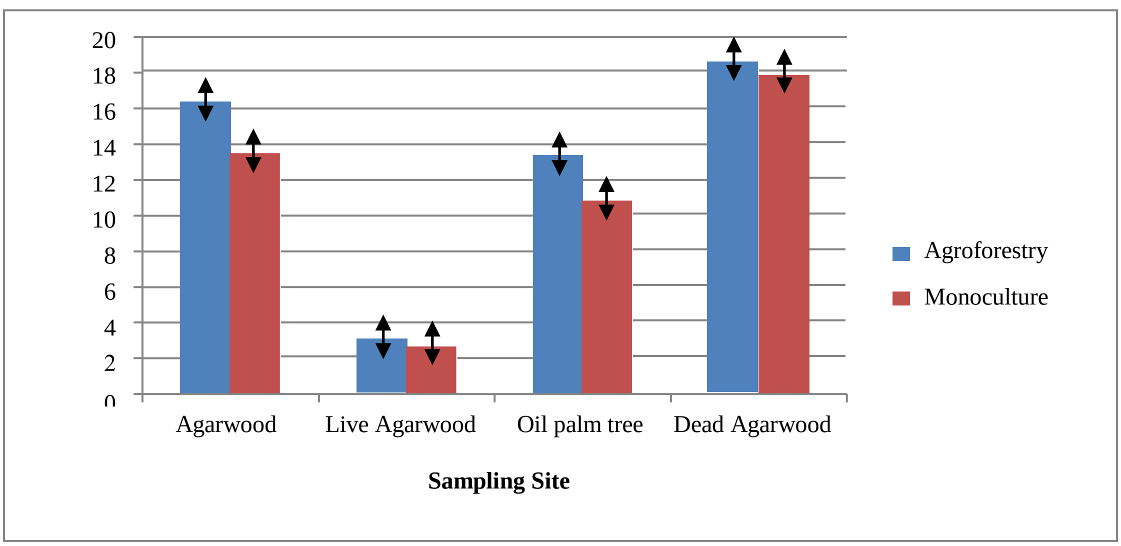

Figure 2. Graph Average Comparison Depth Topsoil in Land Agroforestry and Monoculture Coconut Palm oil

Table 2 and Figure 1 show that the topsoil depth in all sample locations of Gaharu agroforestry land is greater than that of oil palm monoculture land. The average topsoil depth at the Gaharu plant (PG) sampling location in agroforestry land is 16.33 cm, while in the open space (RK) of oil palm land, the topsoil depth is 13.50 cm. Similarly, the topsoil depth at the oil palm tree (PS) sampling location on agroforestry land is 13.33 cm, compared to 10.83 cm on oil palm monoculture land. However, the difference in topsoil depth at the living fence (GH) and dead fence (GM) sampling locations between agroforestry land and oil palm monoculture land is insignificant.

The observations indicate that the topsoil depth in agroforestry systems shows more pronounced differences than oil palm monoculture land. This result suggests that implementing agroforestry systems has a notable impact on topsoil depth, attributed to the accumulation of organic matter from litter decomposition and agarwood tree roots. Janudianto (2004) highlighted that agroforestry systems contribute organic matter year-round through fallen leaves, twigs, and branches, known as dead plant parts. Hardjowigeno (2003) also noted that soil organic matter content decreases with increasing soil depth, with lower organic matter levels in deeper soil layers. This is consistent with research indicating that reduced litter supply and root density with depth lead to lower organic matter content in subsoil compared to topsoil (Jobaggy & Jackson, 2000; Schoning & Kogel-Knabner, 2006; Schenk, 2008).

3.3. WHC (Water Holding Capacity) (%)

The investigation findings into water holding capacity (WHC) at each sample location at a 0-20 cm depth in Gaharu agroforestry land and in monoculture land exhibited significant disparities on average (see Graph 2). The findings further indicate that the WHC value, or water holding capacity, in the soil of agroforestry land, exceeds that of land designated for oil palm monoculture. The findings of the WHC analysis are presented in Figure 3.

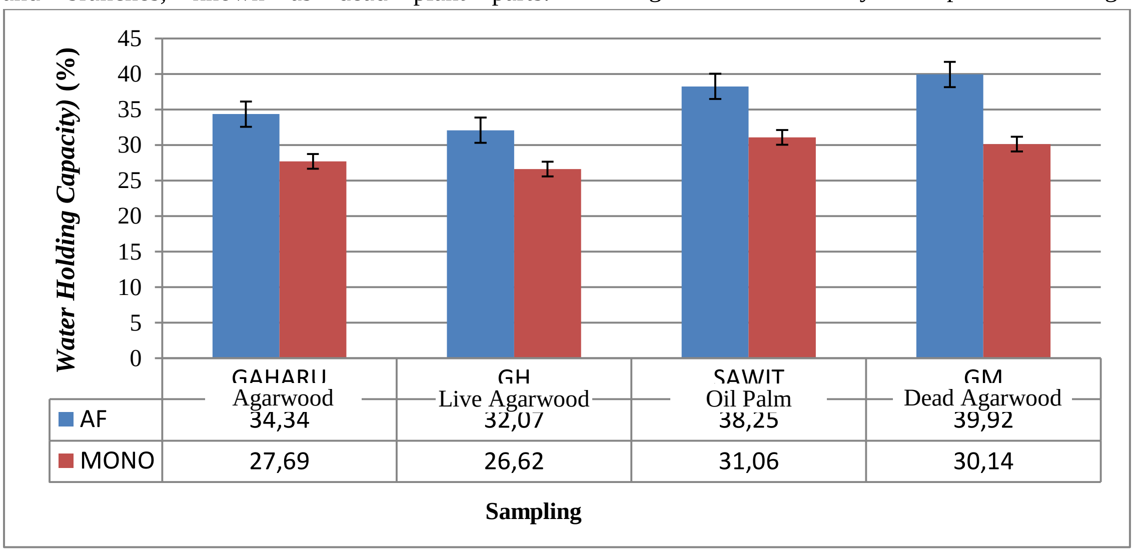

Figure 3. Graph Water Holding Capacity (WHC) value in Land Agroforestry and Monoculture Coconut Palm oil

Figure 3 illustrates that the water holding capacity (WHC) percentage is higher in agroforestry system land compared to oil palm monoculture land. The soil's ability to hold water is influenced by the organic matter present in the planting medium. A higher WHC value in the soil of the agroforestry system indicates an increase in organic matter content. It is known that adding organic matter enhances the soil's water retention capacity, thereby improving water availability for plants and microorganisms (Yulina et al., 2023). Organic matter also enhances water-binding capacity, facilitates water movement, and aids in surface runoff and erosion control (Lapadjati et al., 2016). The higher the organic matter content in the planting medium, the better the soil's water absorption. This result aligns with Stevenson's assertion (1997) that weathered organic materials have a high water-holding capacity due to their hydrophilic nature, ensuring continuous water availability.

4. Conclusion

Implementing agarwood agroforestry on oil palm land positively impacts the soil's physical properties, including soil texture, topsoil depth, and water-holding capacity. Studies indicate that the soil texture in agroforestry land, characterized by sandy loam, is superior to the sandy clay loam texture found in oil palm monoculture land. This improvement is attributed to the increased organic matter from agarwood plant litter and roots, enhancing soil structure and fertility. Moreover, agroforestry land exhibits greater topsoil depth due to the organic input from fallen leaves, twigs, and branches of agarwood plants.

Furthermore, the water-holding capacity of the soil is enhanced in agroforestry systems. The abundance of organic matter in agroforestry land boosts the soil's ability to absorb and retain water, ensuring adequate water supply for plants and soil microorganisms. Consequently, the adoption of agarwood agroforestry on oil palm land has been shown to enhance overall soil quality, promote soil fertility, and uphold environmental sustainability.

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