ISSN (Print) : 2337-9030 ISSN (Online) : 2685-2608
PILLAR OF PHYSICS
JURNAL BERKALA ILMIAH FISIKA
Vol. 19 (2), 2026, page. 126-134
DOI : https://doi.org/10.24036/3tm92j91

MICROCLIMATE ANALYSIS OF OIL PALM AND RUBBER PLANTATIONS IN SITUAK VILLAGE, WEST PASAMAN REGENCY

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ABSTRACT

Oil palm and rubber plantations are the two main monoculture commodities in West Sumatra that have the potential to create distinct microclimate conditions due to differences in canopy structure. This study aims to analyze the characteristics and compare the microclimate (air temperature, relative humidity, and wind speed) in oil palm and rubber plantations in Situak Village, West Pasaman Regency. The study was conducted using a quantitative descriptive approach through direct field measurements using a Lutron ABH-4225 portable weather station at five sampling points along a 100-meter transect in each plantation, three times a day (morning, noon, and evening) over a one-month observation period in September 2025. The results showed that air temperature in the oil palm plantation ranged from 23.6°C to 31.7°C, with relative humidity ranging from 68.7% to 87.2% and wind speed ranging from 0.0 to 0.9 m/s, whereas in rubber plantations, temperatures ranged from 22.4°C to 34.8°C, with relative humidity ranging from 57.8% to 93.5% and wind speeds ranging from 0.0 to 0.5 m/s. Oil palm plantations exhibit a more stable microclimate with a smaller daily temperature range because their canopy is denser, making it more effective at blocking solar radiation and inhibiting air circulation. In contrast, rubber plantations with a more open canopy structure show greater fluctuations in temperature and humidity, especially during the day when solar radiation intensity is high. These results confirm that canopy structure and density are dominant factors in the formation of microclimates in tropical plantation ecosystems, making them important considerations in sustainable plantation land management.

Keywords : *microclimate; oil plam plantations; rubber plantations; plan canopy; West Pasaman*

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I. INTRODUCTION

Indonesia is one of the countries with the largest oil palm plantation sectors in the world, with palm oil production reaching 31.05 million metric tons, placing Indonesia as the world's top palm oil producer [1]. In addition to oil palm, rubber plantations in Indonesia also cover a total area of approximately 3.67 million hectares, distributed across smallholder, state-owned, and private plantations. Land-use change from forest to monoculture plantations is a complex phenomenon that has a significant impact on the surrounding environment and microclimate [2], and can even lead to a significant increase in air temperature [3]. In the Sumatra region, oil palm and rubber plantations have become an important part of the economic structure and ecological landscape [4], while differences in vegetation characteristics, canopy structure, and thermal capacity between the two types of plantations have the potential to create significant variations in the microclimate.

Microclimate refers to specific climatic conditions at a small-scale location that differ from the surrounding macroclimate, influenced by factors such as air temperature, humidity, rainfall, and solar radiation intensity [5]. Vegetation structure, leaf area index, and plant composition play a crucial role in determining surface temperature, humidity, and local air circulation; thus, leaf area index and thermal capacity are key parameters influencing microclimate dynamics in plantation areas [6]. An optimal microclimate can enhance plant growth and crop yields, whereas unfavorable conditions can result in significant productivity losses [7].

Submitted: 29-08-2026 Accepted: 31-10-2026 Published: 31-10-2026

West Pasaman Regency holds great potential for oil palm development, supported by favorable climatic conditions, geographical location, and vast, fertile land—it boasts the largest oil palm plantation area in West Sumatra, spanning 163,438 ha [4]. In addition to oil palm, this regency also has a fairly extensive area of rubber plantations. Situak Village, West Pasaman Regency, is one of the areas experiencing land-use transformation due to plantation development, which has also impacted local microclimate conditions [8]. The conversion of forest land into plantations contributes to changes in the microclimate that can disrupt the balance of local ecosystems [9], and previous research has shown that oil palm plantations can significantly increase ambient temperatures compared to other types of agricultural land [10].

Comparative studies analyzing the microclimate of oil palm and rubber plantations remain very limited. Most previous studies have generally examined the microclimate of each type of plantation separately, such as the microclimate characteristics of oil palm plantations in Morowali Regency [11], the microclimate of oil palm plantations in West Sumatra [12], and the influence of microclimate on oil palm productivity [13]. In rubber plantations, similar studies have been conducted on the influence of microclimate on latex production [14], microclimate characteristics and their relationship to rubber tree growth [15], and a comparative study of agroforestry systems and monoculture rubber plantations [16]. However, no study has specifically compared microclimate characteristics between oil palm and rubber plantations that directly border each other within the same observation area; consequently, the variations in microclimate conditions resulting from differences in the ecosystem characteristics of these two types of plantations have not yet been thoroughly understood.

Understanding the dynamics of the microclimate in plantation areas is important not only for environmental reasons but also has practical implications for crop productivity, resource management, and climate change adaptation strategies [2]. Differences in thermal responses between oil palm and rubber plantations can provide important insights into the adaptation mechanisms of agricultural ecosystems [17]. Based on the above, this study aims to (1) determine the microclimate characteristics—specifically air temperature, relative humidity, and wind speed—in oil palm and rubber plantations in Situak Village, West Pasaman Regency, and (2) analyze the comparison and the influence of these three parameters on microclimate conditions in both types of plantations. The research results are expected to serve as a scientific reference for more sustainable plantation land management and strategies to mitigate negative environmental impacts [18].

II. METHOD

a. Type, Time and Location of the Study

This study is a quantitative descriptive study that describes the comparison of microclimate conditions in oil palm and rubber plantations through the direct field collection of data on air temperature, relative humidity, and wind speed. The study was conducted in two adjacent plantation areas separated by a river as a natural boundary, located in Situak Ujung Gading Village, Lembah Melintang Subdistrict, West Pasaman Regency, West Sumatra Province, at coordinates 0°33′–0°05′ N and 99°28′–99°42′ E, with an elevation range of 15–725 meters above sea level. Data collection was carried out over a one-month observation period from September 1 to 27, 2025.

b. Research Variables, Instrumen and Materials

The independent variables in this study were air temperature, relative humidity, and wind speed, while the dependent variable was the microclimate in each type of plantation. Measurements of these three parameters were taken using the Lutron ABH-4225 multifunctional (4-in-1) portable weather station, which can simultaneously measure wind speed, humidity, and air temperature, making it suitable for microclimate analysis in plantation areas. Supporting research materials included a digital camera for documentation, observation tables, and a computer for data processing.



Figure 1. Lutron ABH-4225 portable weather meter

c. Data Collection Techniques

Data were collected directly in the field (observation) using a purposive sampling method at five sampling points distributed linearly along a 100-meter transect, with a 20-meter interval between points (points T0 to T5), starting from the point nearest the river (T0) toward the farthest point (T5), in each plantation. The measurement

pattern was carried out longitudinally from the edge of the land toward the interior of the plantation to represent spatial changes in microclimate. Each point was given a physical marker and its coordinates recorded using a Global Positioning System (GPS) to maintain locational consistency across repeated measurements. Measurements were taken three times a day: a morning session (07:00–09:00 WIB) to record post-nocturnal-transpiration conditions, a midday session (12:00–14:00 WIB) to record peak solar radiation, and an afternoon session (15:00–17:00 WIB) to identify the thermal response of the land to decreasing light intensity, at a height of 1.5 meters above ground level.

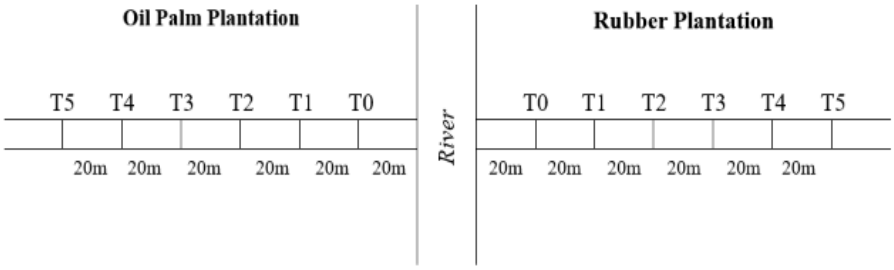

Figure 2. Schematic diagram of sampling points in the oil palm and rubber plantations

Measurements were conducted at a height of 1.5 m above ground level, three times per day: morning (07:00–09:00 WIB) representing post-nocturnal transpiration conditions; midday (12:00–14:00 WIB) capturing the peak of solar radiation; and afternoon (15:00–17:00 WIB) identifying the thermal response of the land to decreasing light intensity. Data were collected with a frequency of once every 3 days per week during the one-month observation period, resulting in a total of 12 days of effective measurement data in each plantation, as summarized in Table 1.

Table 1. Summary of Data Collection

Measurement Method	Number of Measurements (3 per Day)	Duration (per Week)	Notes
Manual (three times daily)	3 times	3 days per week	Morning, midday, afternoon
Manual per point	6 times per session	3 days per week	Average per point

d. Data processing and Analysis Techniques

The daily averages of air temperature, relative humidity, and wind speed were calculated from data collected during the three measurement sessions at five sampling points using the following equations.

$$\bar{T} = \frac{\sum_{i=1}^{N} T1_i + T2_i + T3_i}{3\ x\ N} \quad (1)$$

where $\bar{T}$ is the daily average temperature (°C); $T1_i$, $T2_i$, and $T3_i$ are, respectively, the morning, afternoon, and evening temperatures at the i-th sampling point; and N is the number of sampling points (N = 6). The same equation is also used to calculate the daily average relative humidity ($R\bar{H}$) and daily average wind speed ($\bar{V}$) by substituting the humidity ($R\bar{H}$) and wind speed ($\bar{V}$) variables for the temperature variables.

Data analysis was performed using descriptive statistics to calculate the mean, maximum, minimum, and standard deviation of each parameter using Equation (2).

$$SD = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}} \quad (2)$$

where x_i is the observed value, $\bar{x}$ is the mean, and n is the number of data points. Additionally, to determine the influence of microclimate parameters on plantation type, multiple linear regression analysis was used with the following general model form.

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \epsilon \quad (3)$$

where Y is the response variable (plantation type or microclimate indicator), $X1$, $X2$, and $X3$ are independent variables (air temperature, relative humidity, and wind speed), $\beta 0$ is the intercept, $\beta 1$, $\beta 2$, and $\beta 3$ are regression coefficients, and ϵ is the error term.

III. RESULTS AND DISCUSSION

A. Result

a. Microclimate Characteristics of Oil Palm Plantations

Measurements at the oil palm plantation during the period of 1–27 September 2025 show that air temperature overall ranged from 23.6°C to 31.7°C, with relative humidity of 68.7%–87.2% and wind speed of 0.0–0.9 m/s. The mean temperature, humidity, and wind speed at each sampling point (T0–T5) for each measurement session are presented in Table 2.

Table 2. Mean air temperature, relative humidity, and wind speed at points T0–T5 of the Oil Palm Plantation

Point	Air Temperature (°C)			Relative Humidity (%)			Wind Speed (m/s)		
	Morning	Midday	Afternoon	Morning	Midday	Afternoon	Morning	Midday	Afternoon
T0	24.8	29.7	26.5	81.4	71.8	84.2	0.10	0.10	0.10
T1	25.3	30.1	27.2	81.8	72.2	84.7	0.01	0.20	0.20
T2	25.5	30.1	27.1	81.4	72.2	86.6	0.03	0.10	0.50
T3	25.4	30.0	26.9	82.0	72.5	86.0	0.20	0.30	0.40
T4	25.3	30.0	26.8	81.4	71.4	85.9	0.10	0.20	0.20
T5	25.3	30.1	26.5	81.4	70.9	86.0	0.02	0.10	0.30

Air temperature in the oil palm plantation increased from morning to midday and then decreased in the afternoon, with a consistent diurnal pattern across all points. The temperature differentiation from T0 to T5 was relatively small: 0.5°C in the morning, 0.4°C at midday, and 0°C in the afternoon. Relative humidity showed a pattern opposite to temperature, decreasing at midday when temperature peaked and rising again in the afternoon. Wind speed beneath the oil palm canopy was generally very low and showed no consistent spatial gradient, indicating that the dense oil palm canopy provides considerable resistance to air movement within the plantation.

b. Microclimate Characteristics of the Rubber Plantation

In the rubber plantation, air temperature during the same observation period ranged from 22.4°C to 34.8°C, with relative humidity of 57.8%–93.5% and wind speed of 0.0–0.5 m/s. The temperature and humidity ranges in the rubber plantation were wider than those in the oil palm plantation, indicating greater daily microclimate fluctuation. The mean temperature, humidity, and wind speed at points T0–T5 of the rubber plantation are presented in Table 3.

Table 3. air temperature, relative humidity, and wind speed at points T0–T5 of the Rubber Plantation

Point	Air Temperature (°C)			Relative Humidity (%)			Wind Speed (m/s)		
	Morning	Midday	Afternoon	Morning	Midday	Afternoon	Morning	Midday	Afternoon
T0	23.9	30.2	26.0	86.0	71.1	86.6	0.01	0.10	0.10
T1	24.5	30.5	26.6	86.5	71.6	87.4	0.00	0.10	0.00
T2	24.5	30.9	26.3	86.0	70.0	86.4	0.00	0.00	0.04
T3	24.6	30.8	26.1	80.7	67.0	86.6	0.00	0.00	0.10
T4	24.8	31.7	26.3	84.3	66.7	87.1	0.00	0.10	0.10
T5	25.3	32.0	26.2	83.9	65.4	86.3	0.00	0.10	0.00

Unlike the oil palm plantation, the temperature differentiation from T0 to T5 in the rubber plantation was far greater: 1.4°C in the morning, 1.8°C at midday, and 0.2°C in the afternoon. The largest differentiation occurred at midday, indicating that the more open rubber canopy structure allows greater penetration of solar radiation into the interior of the plantation. Conversely, relative humidity decreased quite sharply from T0 to T5 at midday, from 71.1% to 65.4% (a difference of 5.7 percentage points), consistent with the Clausius–Clapeyron relation, which states that an increase in air temperature without a proportional increase in water vapor will lower relative humidity. Wind speed in the rubber plantation was generally very low and homogeneous across all points, and therefore cannot explain the observed temperature and humidity gradient pattern.

c. Spatial variation from the Edge Toward the Interior of the Plantation

A comparison of the spatial gradients of air temperature and relative humidity during the midday session — the session with the greatest differentiation in both plantations — is presented in Figure 3.

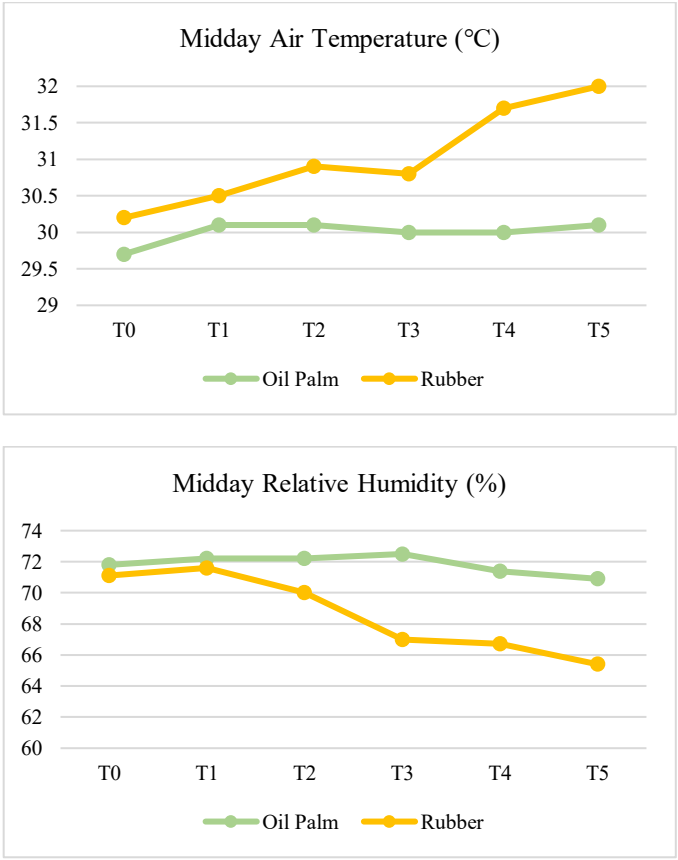

Figure 3. Midday spatial gradient of (a) air temperature and (b) relative humidity from point T0 (edge) to T5 (interior) in the oil palm and rubber plantations

Figure 1 shows that in the oil palm plantation, the temperature and humidity lines remain relatively flat along the transect, whereas in the rubber plantation both lines show a clear slope — temperature increases while humidity progressively decreases toward T5. This pattern is consistent with the numerical differentiation summarized in Table 4.

Table 4. Differentiation of air temperature and relative humidity from point T0 to T5 in the oil palm and rubber plantations

Parameter	Session	Δ Oil Palm (T0→T5)	Δ Rubber (T0→T5)
Air Temperature (°C)	Morning	+0.5	+1.4
Air Temperature (°C)	Midday	+0.4	+1.8
Air Temperature (°C)	Afternoon	0.0	+0.2
Relative Humidity (%)	Morning	0.0	−2.1
Relative Humidity (%)	Midday	−0.9	−5.7
Relative Humidity (%)	Afternoon	+1.8	−0.3

The greater temperature and humidity differentiation in the rubber plantation, particularly at midday, indicates that the microclimate from the edge toward the interior of the rubber plantation is more strongly influenced by transect position than in the oil palm plantation. This condition is consistent with the concept that canopy density and continuity play a major role in buffering thermal variation within an area, such that a denser canopy produces a more homogeneous microclimate [4], [7]. Wind speed in both plantations was relatively low and showed no consistent pattern of change from T0 to T5, so this parameter cannot be regarded as the primary indicator distinguishing edge and interior conditions at the study site.

d. Comparison of Microclimate Between Oil Palm and Rubber Plantations

A comparison of the mean air temperature, relative humidity, and wind speed between the two plantation types for each measurement session (averaged across points T0–T5) is presented in Figure 4.

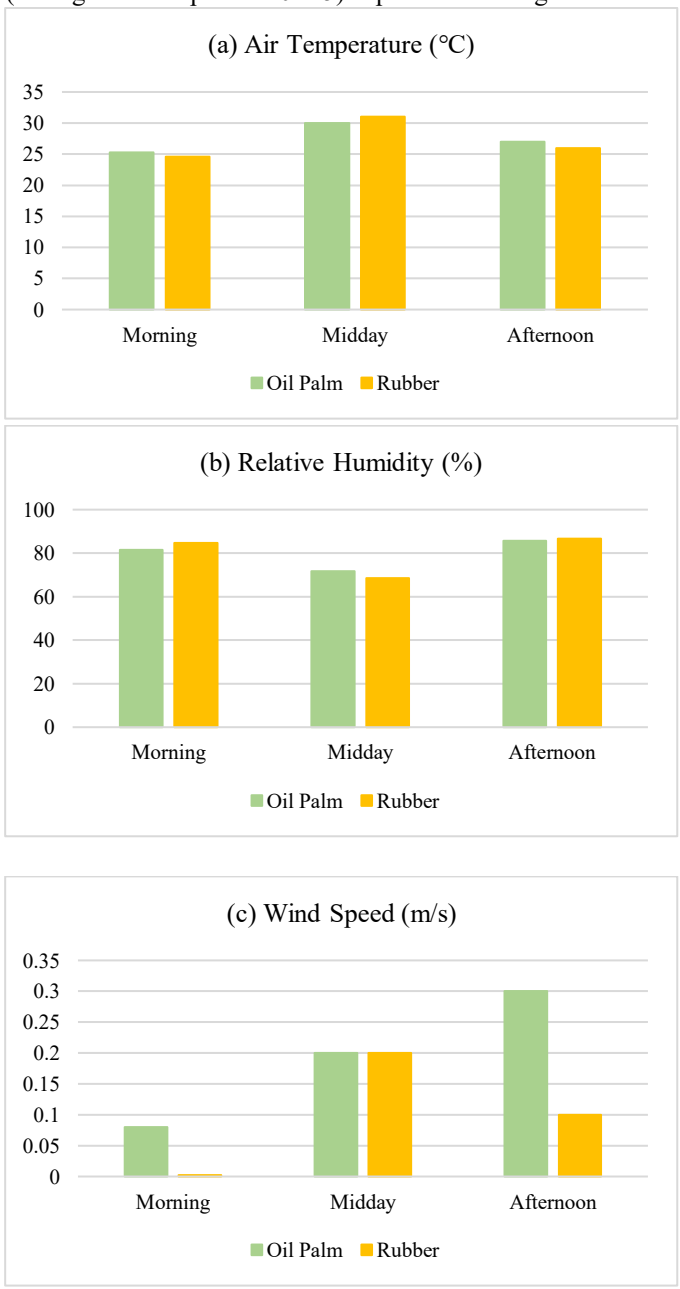

Figure 4. Comparison of mean (a) air temperature, (b) relative humidity, and (c) wind speed between the oil palm and rubber plantations during the morning, midday, and afternoon sessions

Overall, air temperature in the rubber plantation was higher than in the oil palm plantation during the midday session (31°C versus 30°C), whereas in the morning the condition was reversed, with the oil palm plantation slightly warmer. The most pronounced difference occurred at point T5 (the innermost point) at midday, when the rubber plantation reached 32°C compared with only 30.1°C in the oil palm plantation, a difference of 1.9°C. At the same point and session, relative humidity in the rubber plantation was 65.4% compared with 70.9% in the oil palm plantation, a difference of 5.5 percentage points. The oil palm plantation exhibited a consistently more stable microclimate along the transect, while the rubber plantation showed stronger spatial differentiation, particularly when solar radiation intensity was high at midday.

B. Discussion

Microclimate Characteristics of Oil Palm Plantations. The narrow temperature range recorded in the oil palm plantation (23.6°C–31.7°C), together with the small point-to-point differentiation reported in Table 2, indicates a sub-canopy environment that is well buffered against external radiative forcing. This buffering is consistent with the dense, overlapping arrangement of oil palm fronds, which intercepts a large share of incoming solar radiation before it reaches ground level and thereby limits the amount of energy available to heat the air beneath the canopy at any single point along the transect. The correspondingly narrow range of relative humidity (68.7%–87.2%) follows directly from this restricted heating, since less warming leaves less room for relative humidity to fall. The uniformly low wind speed (0.0–0.9 m/s) further points to a canopy that is aerodynamically closed, offering considerable resistance to air movement regardless of position along the transect. Taken together, these results support earlier findings that a dense, continuous canopy is the primary mechanism producing a stable, low-amplitude microclimate in oil palm stands [4], [9], [10], [12].

Microclimate Characteristics of the Rubber Plantation. The wider temperature range found in the rubber plantation (22.4°C–34.8°C) and the correspondingly wider swing in relative humidity (57.8%–93.5%), as summarized in Table 3, reflect a canopy that offers considerably less resistance to solar penetration than that of oil palm. Because individual rubber crowns are more vertically discontinuous and leave larger gaps between neighboring trees, more direct radiation reaches the sub-canopy layer, particularly around midday when the solar angle is highest, producing both the higher peak temperatures and the sharper humidity decline observed in this plantation. Wind speed in the rubber plantation was, notably, even lower on average than in the oil palm plantation (0.0–0.5 m/s), which rules out air movement as an explanation for its wider thermal and humidity range; the greater fluctuation must instead originate from radiative rather than advective processes. This pattern aligns with previous studies reporting that a more open canopy structure in rubber stands is associated with greater diurnal variability in near-surface climate compared with denser tree-crop canopies [4], [7], [15].

Spatial Variation from the Edge Toward the Interior of the Plantation. The contrast between the nearly flat T0–T5 profile in the oil palm plantation and the clear midday slope in the rubber plantation, summarized in Table 4 and illustrated in Figure 3, provides the clearest evidence that canopy structure, rather than the position of a point relative to the river boundary, governs the spatial pattern of microclimate at this site. If proximity to the river or general exposure at the plantation edge were the dominant factor, a comparable gradient would be expected in both plantations; instead, the gradient of +1.8°C in temperature and −5.7 percentage points in relative humidity from T0 to T5 was observed only in the rubber plantation at midday, coinciding precisely with the session of highest solar radiation. This is consistent with the Clausius–Clapeyron relation, under which a rise in air temperature without a corresponding increase in atmospheric water vapor content necessarily lowers relative humidity, and it confirms that canopy openness allows progressively more radiation to reach the plantation interior as one moves away from the edge. Wind speed showed no comparable spatial trend in either plantation, reinforcing that the observed gradients are radiative rather than aerodynamic in origin, consistent with the view that canopy density and continuity are the principal factors buffering thermal variation within tropical plantation ecosystems [4], [7].

Comparison of Microclimate Between Oil Palm and Rubber Plantations. The direct comparison in Figure 4, and particularly the 1.9°C temperature difference and 5.5 percentage-point humidity difference recorded at the innermost point (T5) during the midday session, demonstrates that the divergence between the two plantation types is not confined to their overall ranges but is most pronounced exactly where canopy effects would be expected to accumulate: farthest from the edge and under the most intense solar loading. This finding extends earlier work that examined oil palm and rubber microclimates separately [11], [13], [14] by showing, within a single continuous observation area, that canopy-driven differences between the two commodities become more, rather than less, apparent toward the plantation interior. Because unfavorable microclimate extremes have been linked to reduced growth and yield in both commodities [7], [13], [15], the greater midday exposure identified in the interior of the rubber plantation suggests that canopy density and closure deserve particular attention in rubber plantation management, for example through appropriate planting density, timely pruning, or the retention of partial shade along plantation borders, following approaches discussed in prior agroforestry-based comparisons [16]. These conclusions should nonetheless be read in light of the one-month observation period, which covered only the dry-to-transitional season of September 2025 and did not include direct measurement of canopy structural parameters such as leaf area index; future work spanning multiple seasons and incorporating such measurements, together

with solar radiation intensity and soil temperature, would help establish how consistently these canopy-driven differences hold across the year [2], [17], [18].

IV. CONCLUSION

The microclimate characteristics of the oil palm and rubber plantations in Situak Village, West Pasaman Regency show a clear difference. The oil palm plantation has a more stable microclimate from the edge toward the interior, with a temperature differentiation of only 0–0.5°C, whereas the rubber plantation shows a far greater differentiation, reaching 1.8°C at midday. The difference in microclimate conditions between the two plantation types is most evident at midday in the interior of the plantation (T5), with a temperature difference of 1.9°C and a humidity difference of 5.5 percentage points, while wind speed in both plantations is relatively low and shows no consistent spatial pattern of change. This difference is thought to be closely related to the canopy characteristics and density of each vegetation type, which affect the reception of solar radiation, temperature, humidity, and air movement within the plantation. The results of this study can serve as a basis for plantation managers in maintaining canopy density and land management to keep the microclimate stable, as well as a reference for further research covering a longer observation period, seasonal variation, and additional microclimate parameters such as solar radiation intensity and soil temperature.

ACKNOWLEDGMENT

The author would like to thank the Physics Study Program, Department of Physics, Faculty of Mathematics and Natural Sciences, Padang State University, for providing research facilities; the academic advisor for guidance and supervision during the research; and the community and plantation managers in Situak Village, West Pasaman Regency, for granting permission and providing assistance during the field data collection process.

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