Research: Comparison of soil characteristics and properties that affect the biodiversity of termites in the coconut plantation and oil palm plantation in Hua Sai Sub-district, Hua Sai District, Nakhon Si Thammarat Province.
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Abstract

This study investigates the physical and chemical soil factors influencing termite's biodiversity in coconut plantations and oil palm plantations in Hua Sai Sub-district, Hua Sai District, Nakhon Si Thammarat Province, Thailand. Soil and termite samples were collected from 6 study sites. The physical characteristics of the soil were examined following the GLOBE protocols, including soil color measurement, soil texture classification, soil structure measurement, soil cohesion measurement, and chemical soil property analysis including soil pH, soil fertility (N, P, and K), as well as termite identification in the area. The results revealed that soils in both plantation types exhibited a granular structure. The coconut plantation had a silty loam texture with colors ranging from grayish brown to dark grayish brown, whereas the oil palm plantation had clay loam soil with colors ranging from dark gray to dark grayish brown. The average soil moisture content was higher in the oil palm plantation (47.78 ± 7.21%) than in the coconut plantation (28.59 ± 1.44 %), corresponding to a greater diversity of termite species in the oil palm area. Most termite species collected from both sites belonged to the family Termitidae, represented by two genera: *Macrotermes* (*Macrotermes gilvus*) and *Microcerotermes* (*Microcerotermes minutus*). *M. gilvus* was found exclusively in the oil palm plantation, while *M. minutus* occurred in both plantation types. Differences in soil properties between the two habitats influenced both the composition and abundance of termites observed. However, average soil temperature, pH, and nutrient contents did not differ significantly between sites at the 95% confidence level ($p < 0.05$). This study enhances understanding of the relationship between soil properties and termite diversity. We found that *M. gilvus* requires habitats with high soil moisture, whereas *M. minutus* can inhabit both high- and low-moisture soils. It is hoped that this research will contribute to a better understanding of environmental influences on termite biodiversity and provide useful information for ecosystem conservation, agricultural soil management, and future soil fertility assessments.

Keywords: Soil properties, termite, *Macrotermes gilvus*, *Microcerotermes minutus*, Nakhon Si Thammarat

Introduction

Termites (Isoptera) are eusocial insects comprising colonies in which individuals are divided into three main castes according to their roles: the reproductive caste (alates), which is responsible for reproduction and egg-laying; the worker caste, which forages for food and constructs the nest; and the soldier caste, which defends the colony from intruders. Termites play a crucial role in ecosystems as major decomposers of organic materials in nature (Wood and Sands, 1978; Matsumoto and Abe, 1979; Collin, 1981, 1983). This role is especially important in tropical forest ecosystems, where many termite species are widely distributed. Through the decomposition of organic matter such as wood fragments, leaves, twigs, and other plant components termites help convert these materials into soil humus, forming the foundation of nutrient cycling, particularly involving nitrogen and carbon. This process enhances soil fertility and contributes to the growth of vegetation in those forest ecosystems (Higashi et al., 1992; Lawton et al., 1996; Bignell et al., 1997). Termites also participate in complex food webs by transferring energy across trophic levels (Lapage, 1981; Deligne et al., 1981). Therefore, termite diversity in any given area may serve as an ecological indicator of soil nutrient richness (Lawton et al., 1996).

Conversely, certain termite species provide ecological benefits, particularly through their mutualistic association with the production of *Termitomyces* spp. mushrooms, which serve as a vital source of protein for humans (Jarunee and Kwanchai, 2008). However, termites also pose a significant threat as agricultural pests. Driven by their dependence on plant-derived cellulose, they attack root systems and stems across all plant growth stages. Consequently, they are regarded as serious pests of economically important crops. Numerous studies have documented termite-induced damage to key agricultural commodities in Thailand, including para rubber (Pattama et al., 2009; Chusai et al., 2018; Patcharaporn et al., 2019), oil palm (Dhileepan, 1992; Lim and Bit, 2001; Cheng et al., 2008), and coconut (Mariau et al., 1992; Akpesse et al., 2022), as well as various other field crops. Severe infestations can lead to plant mortality, resulting in substantial economic losses for farmers.

Given these ecological and economic implications, this study aims to investigate soil characteristics and their influence on termite biodiversity specifically species composition, distribution, and population density in coconut and oil palm plantations in Hua Sai Subdistrict, Hua Sai District, Nakhon Si Thammarat Province. The findings will serve as baseline data that may be applied to biodiversity assessment, soil fertility evaluation using termites as bioindicators, as well as termite conservation or population management for future ecological and agricultural research.

Research Questions

Did the physical characteristics and soil properties of different areas between coconut plantations and oil palm plantations affect the biodiversity of termite species in each area? How?

Hypothesis

Distinct soil physical and chemical profiles in coconut versus oil palm plantations are expected to result in disparate termite species assemblages.

Materials and methods

1. Materials

1. Soil Samples
2. Materials and Equipment for Soil Sampling
3. Materials and Equipment for Examining Soil Structure, Texture, and Color
4. Materials and Equipment for Measuring Soil Temperature and Moisture
5. A Guide to Soil Texture Classification by Field Test (IPST).
6. Munsell soil color charts
7. Precision Balance
8. pH Meter
9. Distilled water
10. Soil testing kits (Department of Soil Science, Faculty of Agriculture, Kasetsart University).
11. Stereo microscope
12. 80% Alcohol (for soaking termite samples)

2. Methods

2.1 Study site

The study area was surveyed by designating 6 study locations in Hua Sai Subdistrict, Hua Sai District, Nakhon Si Thammarat Province

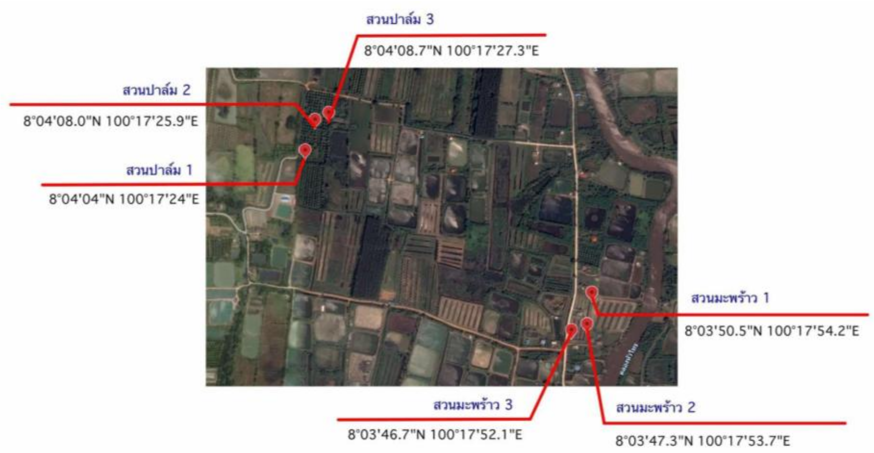


Fig. 1 Study site Hua Sai Sub-district, Hua Sai District, Nakhon Si Thammarat Province.

2.2 Soil sampling

Soil samples were collected from both study area on three sampling sites each. The sampling method was identical across all replicates. A hoe was used to excavate the soil to a depth of approximately 10 cm. The collected soil was then placed into airtight plastic bags to prevent any alteration of its physical and chemical properties. After sealing, each bag was labeled to facilitate the sample identification process.

2.3 Termite sampling

Termite sampling was conducted by excavating the mound to a depth of approximately 30 cm using a shovel. Forceps were used to collect 5–10 individuals specifically from the soldier caste. The specimens were initially placed in sealed plastic bags and subsequently transferred into 10-ml vials containing 80% ethyl alcohol for preservation.

Species identification was performed based on morphological characteristics under a stereomicroscope. The classification followed the taxonomic keys provided by Sornnuwat et al. (2004) and Thongkong (2009). This standardized sampling and identification protocol was applied across all six study sites.

2.4 Soil Physical Properties

1) Soil Structure

Soil structure was assessed by placing samples on the palm to observe aggregate size and shape, following the field manual for soil texture classification by the Institute for the Promotion of Teaching Science and Technology (IPST). The assessment was conducted across all 6 study sites. At each site, data were collected from 3 sampling points, with 2 replicates per point, and the results were recorded.

2) Soil Color

Soil color was determined using the Munsell Soil Color Charts. Soil aggregates were slightly moistened with water and split to expose a fresh surface. Color comparisons were conducted under natural light, with the sunlight directed over the observer's shoulder onto the chart and the soil sample. The matching color codes were then recorded.

3) Soil Texture

Soil texture was classified in the field using the feel method (tactile assessment). The procedure followed the protocols outlined in the field soil examination manual by IPST.

4) Soil Temperature

Soil temperature was measured using a probe-type soil thermometer. Measurements were taken at three points per study site and were repeated twice over a two-week period. At each point, temperatures were recorded at depths of 5 cm and 10 cm. The thermometer was inserted and left for approximately 2 minutes until the reading stabilized. The values were recorded, and the mean temperature was calculated.

5) Soil Moisture Content

Soil moisture was determined using the gravimetric method. Soil samples were placed in metal cans to obtain an initial moist weight of 100 g (excluding the weight of the container). The samples were subsequently dried in a hot air oven at 75°C until a constant weight was achieved (approximately 12–78 hours). After drying, the final dry weight was measured and recorded to calculate the moisture content.

2.5 Soil Chemical Properties

Soil chemical properties were analyzed using a standard soil test kit (Department of Soil Science, Kasetsart University, Thailand). The procedures for determining pH and macronutrients (N, P, K) were as follows:

1) Soil pH Measurement

Soil pH was determined using a colorimetric method. A soil sample was placed into a plastic spot plate, filling approximately half of a well. Solution No. 10 was added dropwise until the soil was saturated, followed by two additional drops. The plate was gently tilted back and forth to mix the reactants and left to stand for one minute. The resulting color at the edge of the solution was compared against a standard pH color chart.

2) Soil Fertility Assessment (Nitrogen, Phosphorus, and Potassium)

2.1) Nutrient Extraction A measured soil sample was transferred into an extraction bottle. Twenty milliliters (20 ml) of Extracting Solution (No. 1) were measured and added to the bottle. The mixture was capped and shaken vigorously for 5 minutes. The suspension was then filtered to obtain a clear soil extract (filtrate) in a receiving bottle.

2.2) Nitrogen (N) Determination A 2.5 ml aliquot of the soil extract was transferred into a test tube. Solution No. 4 (0.5 ml) was added, followed by one small spoonful of Powder No. 5. The tube was stoppered, shaken thoroughly, and allowed to stand for 5 minutes. The nitrogen level was determined by comparing the solution color with the standard nitrogen color chart.

2.3) Phosphorus (P) Determination A 2.5 ml aliquot of the soil extract was transferred into a test tube. Solution No. 6 (0.5 ml) was added, followed by half a small spoonful of Powder No. 7. The tube was stoppered, shaken thoroughly, and left to stand for 5 minutes. The phosphorus content was interpreted by comparing the developed color against the standard phosphorus chart.

2.4) Potassium (K) Determination A 0.8 ml aliquot of the soil extract was transferred into a test tube. Reagents were added in a strict sequence without agitation between steps: 2 ml of Solution No. 8, followed by 1 drop of Solution No. 9A, and finally 2 drops of Solution No. 9. Once all reagents were introduced, the tube was stoppered and shaken thoroughly to mix. The resulting turbidity or color was observed and recorded according to the standard potassium chart.

2.6 Statistical Analysis

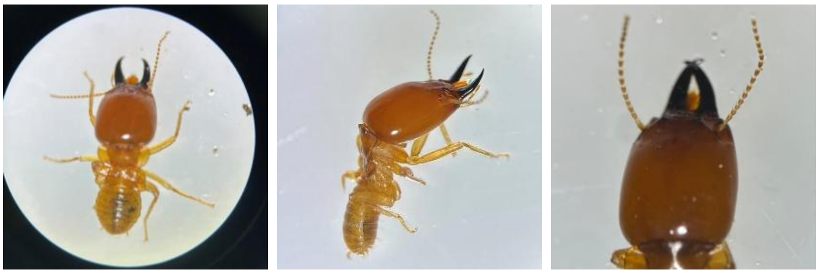
The experimental design was arranged as a Completely Randomized Design (CRD). Data were analyzed to compare the differences in means using an Independent Samples t-test at a 95% confidence level ($p < 0.05$).

Results

1. Identification of Termites

Laboratory identification revealed that termites collected from both the coconut and oil palm plantations belonged to a single family, Termitidae, representing two genera: *Macrotermes* and *Microcerotermes*. The specific species identified were *Macrotermes gilvus* and *Microcerotermes minutus*.

regarding their distribution, *Macrotermes gilvus* was observed exclusively in the oil palm plantation at sampling sites 1 and 3. In contrast, *Microcerotermes minutus* was recorded at oil palm site 2 and at all three sampling sites within the coconut plantation (Table 1; Figures 2 and 3).



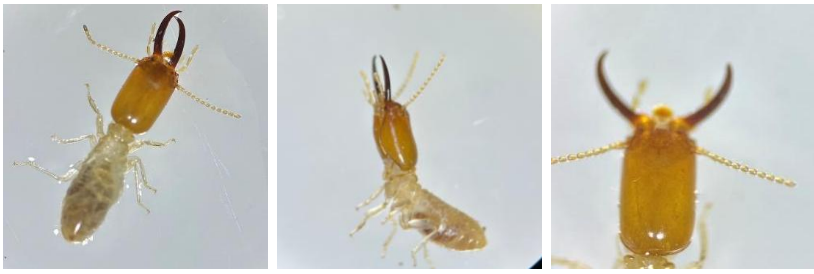
(A) (B) (C)

Figure 2 Morphological characteristics of *Macrotermes gilvus* (major soldier).

(A) General view of *Macrotermes gilvus* (major soldier).

(B) Lateral view of *Macrotermes gilvus* (major soldier).

(C) Head capsule of *Macrotermes gilvus* (major soldier).



(A) (B) (C)

Figure 3 Morphological characteristics of *Microcerotermes minutus* (soldier).

(A) General view of *Microcerotermes minutus* (soldier).

(B) Lateral view of *Microcerotermes minutus* (soldier).

(C) Head capsule of *Microcerotermes minutus* (soldier).

The study revealed the presence of *Macrotermes gilvus* at sampling sites 1 and 3 within the oil palm plantation. This species typically constructs epigeal mounds near the base of trees. Their nest structure is complex and associated with fungus cultivation. The outer casing consists of soil mixed with saliva and feces, while the internal structure features ventilation shafts, fungus combs serving as food sources, and nursery chambers. Entry and exit points are often formed as tunnels connecting to foraging grounds or concealed underground.

Conversely, *Microcerotermes minutus* was identified at oil palm site 2 and across all 3 sampling sites in the coconut plantation. This species is characterized by arboreal nesting, predominantly establishing nests on large trees. Their nest construction is less complex compared to *Macrotermes*, composed mainly of soil and fecal matter. The interior consists of an intricate network of small galleries utilized for locomotion and brood rearing. (Figures 4).

Regarding the physical attributes of termite mounds in the two study areas, mounds in the coconut plantation exhibited an average height of 0.430 ± 0.095 m, an average width of 0.280 ± 0.115 m, and an average height above ground level of 0.340 ± 0.477 m. In the oil palm plantation, mounds showed an average height of 0.843 ± 0.381 m, an average width of

0.887 ± 0.569 m, and an average height above ground level of 0.213 ± 0.370 m. Statistical analysis indicated no significant difference in mound dimensions between the two plantation types at the 95% confidence level ($p > 0.05$) (Table 1).

2. Physical Characteristics of Termite Mounds

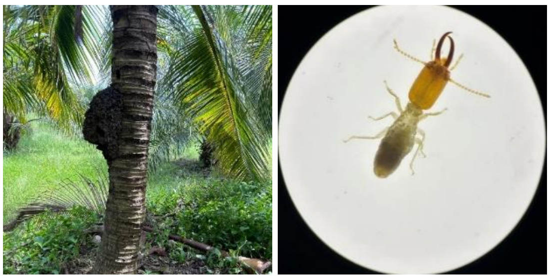
Table 1 Dimensions of termite mounds and termite species identified in coconut and oil palm plantations.

Study Area	Sampling Site	Mound Height^{ns} (m)	Mound Width^{ns} (m)	Height Above Ground^{ns} (m)	Cardinal Direction	Termite Species	Feeding Group
Coconut Plantation	1	0.37	0.40	0.89	North	*M. minutus*	W
	2	0.38	0.17	0.05	West	*M. minutus*	W
	3	0.54	0.27	0.08	Northwest	*M. minutus*	W
	Mean ± S.D.	**0.430 ± 0.095**	**0.280 ± 0.115**	**0.340 ± 0.477**			
Oil Palm Plantation	1	0.87	1.20	0.00	North	*M. gilvus*	F
	2	0.45	0.23	0.64	North	*M. minutus*	W
	3	1.21	1.23	0.00	West	*M. gilvus*	F
	Mean ± S.D.	**0.843 ± 0.381**	**0.887 ± 0.569**	**0.213 ± 0.370**			

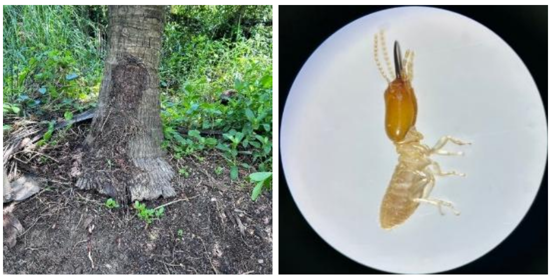
Remarks: *Values are presented as Mean ± Standard Deviation (S.D.) derived from the total experiment with 2 replicates per sampling site.

** Termite Feeding Groups: W = Wood-feeder, F = Fungus-grower.

*** ^{ns} indicates no significant difference at the 95% confidence level ($p > 0.05$).



(A)



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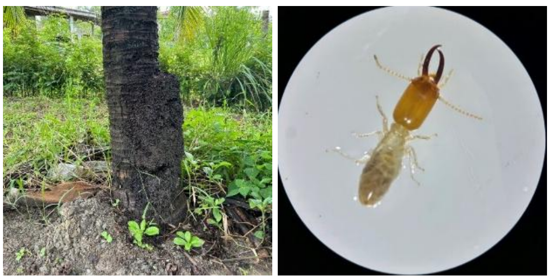
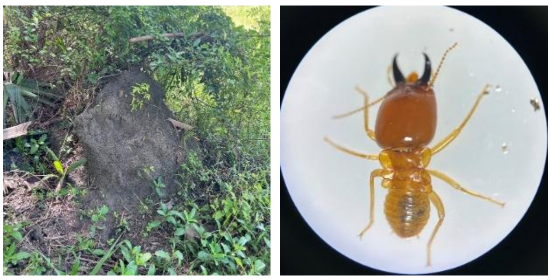
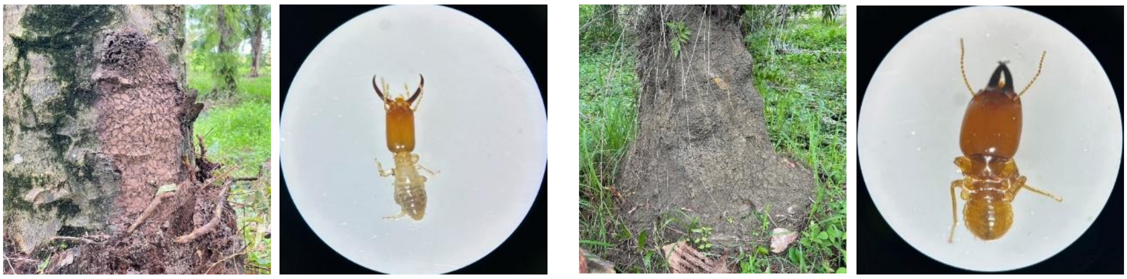


(C)



(D)



(E) (F)

Figure 4 Morphological characteristics of termite mounds and the corresponding species identified at the six study sites.

(A) Coconut plantation site 1: *Microcerotermes minutus*

(B) Coconut plantation site 2: *Microcerotermes minutus*

(C) Coconut plantation site 3: *Microcerotermes minutus*

(D) Oil palm plantation site 1: *Macrotermes gilvus*

(E) Oil palm plantation site 2: *Microcerotermes minutus*

(F) Oil palm plantation site 3: *Macrotermes gilvus*

The physical characteristics of the mounds varied significantly between the two genera. The nests of *Macrotermes gilvus* were characterized as large epigeal mounds with a complex internal architecture comprising ventilation shafts and fungus combs. In contrast, *Microcerotermes minutus* constructed smaller, less complex nests, often found as arboreal structures on tree trunks or as small mounds on the soil surface. (Figures 4).

3. Physicochemical Properties of Soil Surrounding Termite Mounds

Physical Properties The investigation of soil physical properties around termite mounds in coconut and oil palm plantations revealed certain similarities; specifically, the soil structure in both areas was characterized as granular. However, differences were observed in soil texture and color. In coconut plantations, the soil texture was classified as silt loam, with colors ranging from Grayish brown to Dark grayish brown. Conversely, oil palm plantations exhibited a silty clay loam texture, with soil colors ranging from Dark gray to Dark grayish brown. Regarding Soil temperature, measurements taken at depths of 5 cm and 10 cm yielded the following average values: Coconut plantations: 28.97 ± 0.301°C (at 5 cm) and 28.56 ± 0.326°C (at 10 cm). Oil palm plantations: 29.14 ± 0.201°C (at 5 cm) and 28.57 ± 0.287°C (at 10 cm).

Soil Moisture and Termite Diversity A significant disparity was observed in soil moisture content. The average soil moisture (percentage by mass) in coconut and oil palm plantations was 28.59 ± 1.440% and 47.78 ± 7.210%, respectively. This difference was statistically significant at the 95% confidence level ($p < 0.05$). Notably, the oil palm plantations, which possessed significantly higher soil moisture, supported a greater diversity of termite species. The predominant termites identified in both ecosystems belonged to the family Termitidae, specifically the genera *Macrotermes* and *Microcerotermes*. *Macrotermes gilvus* was found exclusively in oil palm plantations. *Microcerotermes minutus* was present in both plantation types. The elevated moisture levels in oil palm plantations may create a microhabitat that facilitates the survival of termite species with higher hygric requirements (Table 2, Figure 4).

Chemical Properties The analysis of soil chemical properties indicated that the average soil pH in coconut and oil palm plantations was 6.75 ± 0.112 and 6.92 ± 0.083, respectively. The results did not suggest a direct correlation between soil pH and termite species diversity, likely due to the minimal variation in pH levels observed across the study sites. Regarding soil fertility, nutrient levels in both plantation types were generally low. Specifically, Nitrogen (N) and Potassium (K) levels were classified as very low, while Phosphorus (P) levels were classified as low (Table 3).

Table 2 Physical properties of soil surrounding termite mounds in coconut and oil palm plantations.

	Study Area	
Physical Parameters	**Coconut Plantation**	**Oil Palm Plantation**
Soil Structure	Granular	Granular
Soil Texture	Silt loam	Silty clay loam
Soil Color	Grayish brown - Dark grayish brown	Dark gray - Dark grayish brown
Soil Temperature (°C)		
Depth 5 cm	28.97 ± 0.301	29.14 ± 0.201
Depth 10 cm	28.56 ± 0.326	28.57 ± 0.287
Soil Moisture Content (%)	28.59 ± 1.440 ^{b}	47.78 ± 7.210 ^{a}

Remarks: * Values for temperature and moisture content are presented as Mean ± Standard Deviation (S.D.).

** Different superscript letters ($^{a,\,b}$) in the same row indicate a significant difference at the 95% confidence level ($p < 0.05$).

Table 3 Chemical properties of soil surrounding termite mounds in coconut and oil palm plantations.

Study Area	Sampling Site	Replicate	pH^{ns}	Soil Nutrient Status		
				N	P	K
Coconut Plantation	1	1	7.00	Very low	High	Very low
		2	6.50	Very low	Very low	Very low
	2	1	6.50	Very low	Medium	Very low
		2	6.50	Very low	High	Very low
	3	1	7.00	Very low	Very low	Very low
		2	7.00	Very low	Very low	Very low
	Mean ± S.D.		**6.75 ± 0.112**	Very low	Very low	Very low
Oil Palm Plantation	1	1	7.00	Very low	Very low	Very low
		2	7.00	Very low	Very low	Very low
	2	1	7.00	Very low	High	Very low
		2	7.00	Very low	Very high	Very low
	3	1	7.00	Very low	Low	Very low
		2	6.50	Very low	High	Very low
	Mean ± S.D.		**6.92 ± 0.083**	Very low	Low	Very low

Remarks: *Values for pH are presented as Mean ± Standard Deviation (S.D.).

** ^{ns} indicates no significant difference at the 95% confidence level ($p > 0.05$).

*** Nutrient levels (N, P, K) are interpreted based on standard soil fertility guidelines.

Conclusion and Discussion

Termite Species Diversity and Monoculture Effects The investigation into termite diversity through laboratory identification revealed two species belonging to the family Termitidae: *Macrotermes gilvus* and *Microcerotermes minutus*. The distribution patterns showed that *M. gilvus* was present in oil palm plantation sites 1 and 3, whereas *M. minutus* was more ubiquitous, found across all three coconut plantation sites and at oil palm plantation site 2. The relatively low species richness observed-limited to only two species-can be attributed to the agricultural practices in the area, specifically monoculture farming. The cultivation of a single crop type (coconut or oil palm) simplifies the habitat, thereby disrupting the ecological balance of soil fauna and reducing overall biodiversity. This finding aligns with previous studies by Gbenyedji et al. (2011) and Vanichpakorn et al. (2020), which concluded that termite diversity is intrinsically linked to plant diversity within an ecosystem, and monoculture systems often lead to a decline in soil animal populations.

Influence of Soil Physical Properties on Termite Distribution Physical analysis of the soil revealed that while both plantations shared a similar granular soil structure, they differed significantly in texture and moisture content. The soil in coconut plantations was characterized as silt loam (grayish brown to dark grayish brown), which is considered standard for loamy soils. Soil temperatures at depths of 5 and 10 cm averaged 28.97 ± 0.301°C and 28.56 ± 0.326°C, respectively-ranges identified as optimal for coconut growth (Orawan et al., 2014). The average soil moisture content in these areas was 28.59 ± 1.440%.

In contrast, the oil palm plantations exhibited a silty clay loam texture (dark gray to dark grayish brown) with average temperatures of 29.14 ± 0.201°C and 28.57 ± 0.287°C at depths of 5 and 10 cm, respectively-conditions suitable for oil palm cultivation. Notably, the average soil moisture content in the oil palm sites was significantly higher at 47.78 ± 7.210%.

The presence of more than one termite species in the oil palm plantations suggests that soil moisture is a critical determinant of species distribution. The higher moisture levels in the oil palm sites likely support the existence of *Macrotermes gilvus*, a species that constructs epigeal mounds and requires specific moisture conditions. Meanwhile, *Microcerotermes minutus* demonstrated greater adaptability to varying moisture levels, likely due to its arboreal nesting behavior. This supports the conclusion that soil moisture is a vital factor for termite survival, nest construction, and internal homeostasis (McManamy et al., 2008; Cornelius and Osbrink, 2010).

Soil Chemical Properties Regarding chemical properties, the average soil pH in coconut (6.75 ± 0.112) and oil palm (6.92 ± 0.083) plantations was neutral to slightly acidic and showed no significant difference. These values are considered suitable for crop growth and consistent with standard values reported by Wasana (1998) and the Surat Thani Oil Palm Research Center (2022). However, nutrient analysis indicated that nitrogen (N), phosphorus (P), and potassium (K) levels were low to very low in both ecosystems. This depletion of soil nutrients may be attributed to leaching caused by rainfall during the sampling period, which washed away surface nutrients and resulted in reduced soil fertility.

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