

THE DIVERSITY AND ACTIVITY OF SUBTERRANEAN TERMITES IN THE RESIDENTIAL AREA OF BOGOR, WEST JAVA, INDONESIA

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Received: 25 January 2024, Revised: 15 January 2025, Accepted: 25 January 2025

THE DIVERSITY AND ACTIVITY OF SUBTERRANEAN TERMITES IN THE RESIDENTIAL AREA OF BOGOR, WEST JAVA, INDONESIA. The housing demands in Bogor City have been on the rise, leading to environmental changes affecting pest organisms, especially subterranean termites. This research aimed to identify various species of subterranean termites in Bogor City, analyze soil and weather conditions, and evaluate termite attack frequency and severity. The study spanned 12 designated sub-districts. In each area, 25 bait wood (2 x 2 x 46 cm) crafted from pine wood and treated with water vapor pressure (105°C, 1 bar, 5 hours) were installed. Soil samples were gathered from each sampled village, while weather data was specifically documented in one sub-district. Findings uncovered three termite species inhabiting residential zones of Bogor City: *Microtermes insperatus*, *Macrotermes gilvus*, and *Schedorhinotermes javanicus*, with *Microtermes insperatus* emerging as the predominant species. The soil and weather conditions significantly favored termite existence in Bogor City. Termite attack prevalence stood at 38%, and the degree of wood damage ranged from 4 to 9.

Keywords: Attack frequency, damage intensity, *Pinus merkusii*, Soil characteristics, water vapor pressure

KEANEKARAGAMAN DAN AKTIVITAS SPESIES RAYAP TANAH DI LINGKUNGAN PERMUKIMAN KOTA BOGOR, JAWA BARAT, INDONESIA. Kebutuhan masyarakat Kota Bogor akan tempat tinggal semakin meningkat, sehingga mengubah kondisi lingkungan yang dapat memengaruhi keberadaan organisme pengganggu, terutama rayap tanah. Penelitian ini bertujuan untuk mengidentifikasi spesies rayap tanah dan keanekaragamannya di Kota Bogor, mengetahui karakteristik tanah dan cuaca, serta mengetahui intensitas kerusakan dan frekuensi serangannya. Penelitian dilakukan di 12 kelurahan contoh. Setiap kelurahan ditanam 25 kayu umpan (2 x 2 x 46 cm) dari kayu pinus yang sebelumnya telah diberi perlakuan tekanan uap air (105°C, 1 bar, 5 jam). Di setiap kelurahan contoh diambil tanah contoh. Data cuaca diukur di salah satu kelurahan contoh. Hasil penelitian menunjukkan bahwa spesies rayap yang ditemukan ada 3 jenis yaitu *Microtermes insperatus*, *Macrotermes gilvus*, dan *Schedorhinotermes javanicus*. Spesies rayap tanah di lingkungan permukiman Kota Bogor didominasi oleh *Microtermes insperatus*. Karakteristik tanah dan cuaca sangat mendukung kehidupan rayap di Kota Bogor. Nilai frekuensi serangan rayap sebesar 38% (tinggi) dan nilai intensitas kerusakan kayu adalah 4-9.

Kata kunci: Frekuensi serangan, intensitas kerusakan, karakteristik tanah, *Pinus merkusii*, tekanan uap panas

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I. INTRODUCTION

Termites play an essential ecological role, but some termites become nuisance pests and destroy buildings (Novita et al., 2020). According to Krishna et al. (2013) there are approximately 3,106 termite species spread worldwide, with 9.7% or about 300 of these species found in Indonesia (Nandika et al., 2015). About 28 termite species have developed outside their native range and are considered invasive (Evans et al., 2012). The massive activity of termites causes high economic losses. Economic losses due to termite infestation in buildings with residential functions in DKI Province (cases in West Jakarta and East Jakarta) are estimated at 66.2 billion rupiah per year, and the economic loss due to termite infestation in residential buildings in Indonesia in 2015 was 8.86 trillion rupiah (Nandika et al., 2015). Termite attacks occur in any type of building containing cellulosic materials. This includes timber-framed residential houses as well as the non-structural wooden elements (e.g., trim, partitions, and cabinetry) found in commercial high-rise buildings (Arinana et al., 2025).

Bogor is one of the major cities in Indonesia. The area of Bogor City is 11,850 ha. The monthly average temperature in Bogor City is 23.2°C (the lowest temperature is 21.8°C and the highest temperature is 37.6°C), with the humidity is 35.3-98.5% (Arinana et al., 2020a; Nurhadi et al., 2023) and average annual rainfall of around 3,000 – 6,000 mm (Tarigan and Dasanto, 2022). Geographically, Bogor City is located between 106° 48' East and 6° 26' South. The geographical position of Bogor City is in the middle of Bogor Regency. Its location, which is very close to the capital city of Indonesia, Jakarta, has strategic potential for the development and growth of the economy and services. Bogor city also serves as the center of national activities for industry, trade, transportation, communication, and tourism (Ilhami et al., 2022). According to data from Badan Pusat Statistik (2018), the population growth rate of Bogor City from 2010 to 2017 was 1.53%, with a population of 1,081,009

people. The community's need for housing has increased based on this population growth, thus changing the surrounding environmental conditions. Environmental changes will affect the presence of pest organisms, including termites (Jouquet et al., 2018).

Pest organisms, such as termites, often thrive when natural ecosystems are disturbed by human activities, such as urbanization, which creates favorable new conditions for them. Until now, information on subterranean termite diversity in residential areas of Bogor City is limited. This information is essential for designing strategies to protect buildings from termite infestation in the residential environment. Therefore, research on the diversity of subterranean termites in residential areas representing Bogor City is urgently needed. This study focuses on determining the diversity of subterranean termite species, identifying subterranean termite species that attack bait wood in residential areas in Bogor City, evaluating the environmental factors (soil and weather), and analyzing the intensity of damage and frequency of subterranean termite attacks in Bogor City, West Java, Indonesia.

II. MATERIAL AND METHOD

A. Time and Location

The research was conducted from September 2019 to July 2020. The field portion of the study involved the installation of bait wood samples, which were all placed simultaneously in September 2019 across the 12 sub-districts. These baits were left in the field for a three-month exposure period and were subsequently collected in December 2019. Laboratory activities, including sample processing and termite identification, were carried out from January to July 2020 at several facilities. The test samples were made at the Sawmill and Wood Workshop Laboratory of the Faculty of Forestry and Environment, IPB University. Treatment of bait wood and identification of termite species were carried out in laboratories located in the Wood Quality Improvement Technology Division (IPMK) of the Faculty

of Forestry and Environment and the Pilot Plant Laboratory of the Faculty of Agricultural Technology, IPB University (Institut Pertanian Bogor). Soil characteristic testing was conducted at the Indonesian Center for Biodiversity and Biotechnology (ICBB) Bogor. Bait wood installation was conducted in 12 sub-districts in Bogor City, namely Situ Gede, Sindang Barang, Pasir Jaya, Empang, Cikaret, Batu Tulis, Katulampa, Kedung Halang, Tanah Sareal, Sukaresmi, Kebon Kelapa, and Tegallega.

B. Equipment and Materials

The equipment used in this study consists of a circular saw, grinder, autoclave, moisture meter, fan, calipers, digital scales, brushes, soil drill, crowbar, Global Positioning System (GPS), LCD digital temperature humidity data recording logger meter, and digital microscope endoscope camera magnifier 800X 8 LED. The materials used in this study consisted of pine wood (*Pinus merkusii*) from Cikalancing Cinangneng Housing, oil paint, specimen bottles, plastic clips, 70% alcohol, and sandpaper.

C. Research Sample Area

The study sites were selected using a multi-stage random sampling method. Bogor City comprises a total of 6 districts and 68 sub-districts. First, all six districts were included in the study. From each district, two sub-districts were randomly selected using Excel's randomization function, for a total of 12 sub-districts. Finally, one Neighborhood Association (Rukun Tetangga) from each of the 12 selected sub-districts was randomly chosen as the location for bait wood installation and soil sampling. This method ensured a diverse and representative selection of study sites. Air temperature and humidity data were taken from one of the representative neighborhoods.

D. Preparation of wood Sample Test

Pine (*Pinus merkusii*) logs were obtained from one of the housing estates in Cinangneng Village. The pine logs were cut at sawmills into two-meter-long logs. The logs were brought to

the workshop to be sawn into test samples (bait wood). According to the American Society for Testing and Materials (2006), the bait wood size is 2 cm x 2 cm x 46 cm in air-dried condition. Before treatment, the bait woods were sanded to remove the fibers on its surface. The bait woods were given a hot vapor pressure treatment for 5 hours with a temperature of 105°C and a pressure of 1 bar. The hot vapor pressure treatment was used, following the protocol of Arinana et al. (2020b), to reduce wood resin content and standardize the moisture level, which can make the bait more uniformly palatable to termites compared to simple oven-drying. After that, the bait woods were conditioned to air dry and sanded again to remove the resin on the surface. Each bait wood was painted a bright color (red) on one end to make it easier to locate the bait wood after it had been installed for three months. The installation of bait wood refers to Arinana et al. (2022). Before installation at the research site, the bait wood was measured for thickness and weighed (W1) using a digital analytical balance (Ohaus PX224, ± 0.001 g).

E. Analysis of Soil Characteristics

The international pipette method was used to investigate soil texture properties (Taghizadeh-Mehrjardi et al., 2021). Soil samples of at least 1 kg were collected in each sample sub-district at 0-25 cm depth. Soil samples were collected from the vicinity of the bait wood installed. All soil samples were then analyzed at the ICBB Laboratory in Bogor for soil characteristics consisting of soil pH, soil C-organic content, and the percentage composition of sand, silt, and clay.

F. Temperature and Humidity Measurements

Temperature and humidity measurements were taken using a Digital Temperature Humidity Data Recording Logger Meter DWL-20 series. The device records air temperature and humidity every five minutes and was placed in one of the sample urban village offices for three months.

G. Termite Species Identification

Identification of subterranean termites was conducted based on the morphology of the soldier caste, following the identification keys from Nandika et al. (2015) and Krishna et al. (2013), the identification of subterranean termites was carried out based on the morphology of subterranean termites.

H. Analysis

The species diversity of subterranean termites in the residential area of Bogor City was approached with the parameters of the index of species richness, index of heterogeneity, and index of evenness. Margalef’s formula, as modified by Arinana et al. (2019), was adapted to calculate subterranean termite species richness (*Ri*). Species diversity (*H'*) was calculated by adapting the Shannon-Weiner formula, and species evenness (*E1*) was calculated using the Pielou formula, which also followed modifications suggested by Arinana et al. (2019). The data processed were from all sample sub-districts in Bogor City. The formula is as follows:

$$Ri = \frac{S - 1}{\ln(N)} \dots\dots\dots(1)$$

$$H' = \sum_{i=0}^s pi \cdot \ln(pi); pi = \frac{ni}{N} \dots\dots\dots(2)$$

$$E1 = \frac{H'}{\ln(S)}; \dots\dots\dots(3)$$

Description:

Ri: species richness

H': species diversity

E1: species evenness

Pi: proportion of the number of individuals of type *i*

S: number of species

N: Total number of bait wood-infested

ni: number of bait wood infested by the *i*-species

I. Frequency of Subterranean Termite-Infested Bait Wood

Infestation frequency is the ratio of the number of samples infested by subterranean termites at the study site to the total number of samples installed at the study site, expressed

as a percentage. Infestation frequency data were averaged per sample sub-district and classified into six classes based on modified-Cookson & Trajstman (2002) as presented in Table 1.

Table 1. Classification of Subterranean Termite Infestation Frequency

No.	Frequency	Description
1.	0	No attack
2.	1-10	Very low
3.	11-20	Low
4.	21-30	Intermediate
5.	31-40	High
6.	> 40	Very High

J. Weight Loss

Weight loss (WL) is the reduction in mass of a test sample after a feeding period, calculated as a percentage of its initial mass. It is determined using the following equation:

$$WL = \frac{W1 - W2}{W1} 100 \dots\dots\dots(4)$$

Description:

WL: Weight Loss (%)

W1: Weight of air-dried wood before feeding (g)

W2: Weight of air-dried wood after feeding (g)

K. Percentage of Damage

Damage to a bait wood is the ratio between the length of the tested sample’s damaged cross-section due to subterranean termite infestation and the initial width or thickness of the bait wood, expressed as a percentage. According to the American Society for Testing and Materials (2006), this damage is classified into seven categories, ranging from no attack to cross-sectional damage greater than 75%.

L. Value of Damage

The value of damage was then determined through a visual assessment of the percentage of the cross-sectional area consumed by termites. This estimation was performed at the point of the most severe termite attack on each sample. To ensure consistency across all samples, the assessment was conducted by the same technician using a transparent grid overlay

to aid in quantifying the damaged area. Based on the estimated percentage of wood loss, each sample was assigned a rating from 10 (no attack) to 0 (>75% damage), corresponding to the ASTM D3345-06 standard (Table 2).

Table 2. Classification of damage value sample test against subterranean termite

Value	Damage Percentage
10	No Attack, 1-2% minor damage allowed
9	Penetration reached 3% of the cross-section
8	Penetration 4-10% of the cross-section
7	Penetration 11-30% of the cross-section
6	Penetration 31-50% of the cross-section
4	Penetration 51-75% of the cross-section
0	Penetration >75% of the cross-section

To assess the damage, all bait wood samples were transported from the field sites to the TPMK of the Faculty of Forestry and Environment, IPB University. In the laboratory, each sample was carefully brushed clean of soil, debris, and any attached termite galleries to reveal the wood surface.

III. RESULT AND DISCUSSION

A. Soil Characteristic

The results showed that soil pH in the 12 sub-districts in Bogor City ranged from 5.15 to 7.82. This value indicated that soil pH was not a limiting factor in subterranean termite infestation activity. This is supported by the findings of Arif et al. (2020), whose research found that soil pH in Makassar City ranged from 6.03-8.84. In fact, termites affect soil pH and nitrogen and phosphorus content (Tilahun et al., 2021). This result is in line with the research of Indrayani et al. (2021), who stated that termites significantly impact the chemical composition of soil and can increase land productivity. Additionally, their actions raise the pH, potassium, C-organic content, total Nitrogen, accessible Phosphorous, and Cation Exchange Capacity of the soil by more than 100% (Kathbaruah et al., 2024).

The results showed that the C-organic content of Bogor City ranged from 0.6%-

6.51%. This value is higher than the research of Arinana et al. (2019) in DKI Jakarta and Subekti et al. (2018) in Semarang, where the C-organic content found in DKI Jakarta ranged from 1.32%-2.51% while in Semarang it ranged from 0.83%-3.18%. Termites are one of the groups of organisms that play a vital role in the decomposition process of organic materials derived from plants. Termite activity significantly influences the chemical properties of soils, including nutrient availability. Enagbonma & Babalola (2020) reported that soils in and around termite mound are enriched in essential nutrients such as potassium, magnesium, and phosphorus, in addition to increased organic carbon content. Termite densities and specific chemical properties of the soil are correlated, indicating microorganisms' significant functions in accumulating soil nutrients (Musbau & Ayinde, 2021). Thus, the presence of subterranean termites can help plants provide the nutrients they need.

Table 3 presents the complete results of the soil characteristics for Bogor City, including soil pH, C-organic content, and soil texture. The soil texture which is the relative ratio of sand, silt, and clay fractions classified using the soil texture triangle. The test results showed that most of the soil texture in Bogor City is clay (found in 9 sub-districts), followed by clay loam (1 sub-district), sandy clay loam (1 sub-district), and one sub-district could not be identified because the C-organic content is above 5%, which was 6.51%. This research showed that the soil texture in Bogor City has an average clay content (43%- 66%), so the soil texture of Bogor City is categorized as clay. According to Lee and Wood (1971), termites dislike sandy soil and choose soil types that contain much clay. This is supported by research by Arinana et al. (2019) in DKI Jakarta, who found that subterranean termites are found in clay textures. According to Jalaludin et al. (2018), termites that decomposed wood are attracted to clay-textured soil. The preference for clay soils can also present challenges for the control of termites. The binding properties of clay

can reduce the bioavailability of termiticides, thereby making it more difficult to manage termite populations in clay-rich environments (Wang et al., 2015). The complete results of soil characteristics (soil pH, C-organic content, and soil texture) can be seen in Table 3.

The research demonstrated that soil characteristics and their relationship to termite diversity are important factors influencing infestation rates in different sub-districts. In Situ Gede, where the soil type is clay loam, the result was a higher diversity of termite species. The termite species identified included *M. insperatus*, *M. gilvus*, and *S. javanicus*, indicating that this specific soil type may foster the proliferation of diverse termite species. This could be attributed to the optimal equilibrium between moisture retention and soil aeration, which is conducive to the survival of multiple termite species.

In contrast, Empang, which had a sandy clay loam soil type, exhibited a markedly lower diversity of termites, with only *M. insperatus* species identified. The sandy clay loam soil is characterized by inferior moisture retention and enhanced drainage compared to clay loam, which may restrict the suitability of the habitat for a greater number of termite species. The scarcity of moisture may render it less appealing to other species that require a more humid environment, such as *M. gilvus* and *S. javanicus*.

Other areas with clay soils showed a moderate diversity of termites, typically

with two species present, except for Cikaret. Interestingly, Cikaret, known for its frequent flooding due to irrigation canals and a high concentration of decomposing organic waste, had a predominantly soft clay soil. Only one type of termite was found in this area, suggesting that extreme environmental conditions—such as constant moisture and flooding, may create a hostile environment for a wider variety of species. The high termite attack frequency in Cikaret (56%) may be linked to the presence of soft clay soil, which is favorable for termites but limits the diversity of species that can survive under such fluctuating conditions (Nurhadi et al., 2023; Wardhani & Rufina, 2022).

These findings underscore the pivotal role of soil type in shaping the frequency of termite attacks and the diversity of termite species present. The disparate termite populations observed across these regions are likely the result of variations in soil characteristics, including texture, moisture retention, and aeration. These soil attributes collectively influence the suitability of termite habitats (Subekti et al., 2018). Table 5 presents a comprehensive overview of the attack frequency data across the various sub-districts.

B. Temperature and Humidities Characteristic

The results showed that temperature and humidity in Bogor City are very favorable for

Table 3. Soil Texture in each sub-district in Bogor City

Sub-district	pH	C-organic (%)	Texture 3 Fraction			Soil Texture
			Sand	Silt	Clay	
Situ Gede	6.81	1.93	23	39	38	Clay Loam
Sindang Barang	6.65	0.6	19	16	65	Clay
Pasir Jaya	5.96	2.34	20	14	66	Clay
Batu Tulis	5.15	4.65	22	22	56	Clay
Cikaret	6.3	6.51	_*	_*	_*	_*
Empang	7.55	2.66	55	19	26	Sandy Clay Loam
Katulampa	7.82	1.68	16	28	56	Clay
Kedung Halang	6.48	2.38	11	23	66	Clay
Kebon Kelapa	7.35	3.74	32	25	43	Clay
Tegallega	5.9	0.87	19	19	62	Clay
Sukaesmi	5.56	0.89	28	21	51	Clay
Tanah Sareal	7.42	3.42	24	19	57	Clay

termite development. The highest temperature in the research location was 31.5°C, and the lowest was 25.3°C. Meanwhile, the highest air humidity was 91.9%, and the lowest was 67.6%. Fluctuations in the average daily temperature and humidity can be seen in Figure 1.

According to Mairawita et al. (2022), the optimal temperature and humidity for most termites are 16-35°C and 75-90%, respectively (Subekti et al., 2019). Meanwhile, the research by Arinana et al. (2016c) stated that the average temperature in *Coptotermes curvignathus* termite nests ranged from 29.4-33.8°C. High termite-consuming activity is driven by humidity and temperature within optimal ranges (Woon et al., 2019; Andika et al., 2025). Environmental factors that affect termite development are temperature, humidity, rainfall, and food availability. These factors interact and influence each other. Pratiknyo et al. (2020) state that termites thrive in air temperatures between 15 and 38°C and relative humidity levels between 75 and 90%. Areas with relatively high temperatures and humidity are suitable for

developing wood-destroying organisms such as termites (Subekti & Raydityamilanio, 2023).

C. Species Identification of the Subterranean Termites

Figure 2 showed that the whole-body morphology of at least three species of subterranean termites were found in twelve sample sub-districts in Bogor City. The termites found consist of two families, Termitidae and Rhinotermitidae. The three termite species found are *Microtermes insperatus* Kemner, *Macrotermes gilvus* Hagen, and *Schedorhinotermes javanicus* Kemner. Table 4 shows the detailed morphometrics for the soldier caste of each species of termite.

Based on the study's findings, termite species from the Termitidae family were the most dominant compared to those from the Rhinotermitidae family. The two species from the Termitidae family were *M. gilvus* and *M. insperatus*. The Rhinotermitidae family was represented by *S. javanicus*.

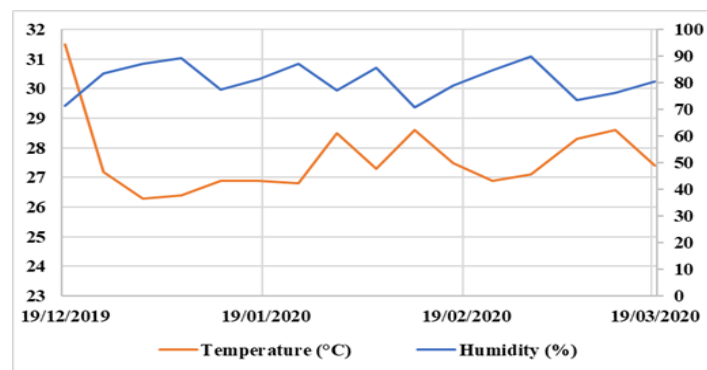


Figure 1. Fluctuation of air temperature and humidity in Bogor City during research



Figure 2. Morphology of subterranean termite species found in the residential area of Bogor City: (a) *Microtermes insperatus* Kemner; (b) *Macrotermes gilvus* Hagen; and (c) *Schedorhinotermes javanicus* Kemner

Table 4. The morphometrics of the soldier caste subterranean termites found in each sub-district in Bogor City

Termite Species	Body part			
	Total body length (mm)	Head with mandibles, length (mm)	Head without mandibles, length (mm)	Head, width (mm)
<i>M. gilvus</i>	8.78±0.73	5.12±0.41	3.95±0.23	2.75±0.2
<i>M. insperatus</i>	4.34±0.42	1.5±0.08	1.06±0.02	0.91±0.03
<i>S. javanicus</i>	5.41±0.24	2.21±0.16	1.62±0.16	1.29±0.09

The number of termites from the Termitidae family collected from Bogor City's sub-districts was higher, coming to 70 (cumulative of two species), or 86.42%. On the other hand, termites from the Rhinotermitidae family were detected in smaller quantities in the field, a total of 11 (comprising one species) or 13.58% (Table 5). The Termitidae family is often more prevalent than the Rhinotermitidae family. For instance, species such as *Reticulitermes flavipes* a member of the Rhinotermitidae family, are commonly found in temperate regions, but they are often out-competed by higher termites like *Nasutitermes* and *Odontotermes* from the Termitidae family, which are more adaptable to various environmental conditions, including urban settings (Berlanga et al., 2018; Mikaelyan et al., 2014). The family Termitidae is a high-level termite group, representing three-quarters of the total number of termites. While the lower level consists of more families (Rhinotermitidae, Serritermitidae, Kalotermitidae, Archotermopsidae, Hodotermitidae, Stolotermitidae, Kalotermitidae, and Mastotermitidae), and the number in the field is less when compared to the higher level termite groups (Nandika et al., 2015).

Table 5 shows further information about the termites present in each sub-district. The results demonstrated that different termite species were obtained in each sample sub-district. Three termite species were discovered in Situ Gede: *M. insperatus*, *M. gilvus*, and *S. javanicus*. While in Kedung Halang, *M. insperatus* was discovered simultaneously from eight bait wood.

Table 5. Number of termites found in each village in Bogor City

No	Village	Species	Quantity
1	Situ Gede	<i>M. insperatus</i> .	5
		<i>S. javanicus</i> .	2
		<i>M. gilvus</i>	1
2	Sindang Barang	<i>M. insperatus</i> .	5
		<i>S. javanicus</i> .	2
		<i>M. insperatus</i> .	5
3	Pasir Jaya	<i>S. javanicus</i> .	2
		<i>M. gilvus</i> .	1
4	Empang	<i>M. insperatus</i> .	1
		<i>M. insperatus</i> .	9
5	Cikaret	<i>M. insperatus</i> .	3
		<i>S. javanicus</i> .	2
		<i>M. gilvus</i> .	1
6	Batu Tulis	<i>M. insperatus</i> .	3
		<i>M. gilvus</i> .	1
7	Katulampa	<i>M. insperatus</i> .	8
		<i>M. gilvus</i> .	1
8	Kedung Halang	<i>M. insperatus</i> .	8
		<i>M. insperatus</i> .	8
9	Tegallega	<i>S. javanicus</i> .	2
		<i>M. insperatus</i> .	5
10	Kebon Kelapa	<i>M. insperatus</i> .	5
		<i>M. insperatus</i> .	5
11	Tanah Sareal	<i>M. insperatus</i> .	9
		<i>M. insperatus</i> .	1
12	Sukaresmi	<i>M. insperatus</i> .	9
		<i>S. javanicus</i> .	1

This study discovered three subterranean termite species that were irregularly dispersed among twelve urban communities. *M. insperatus* was found in all twelve communities, *S. javanicus* was found in six of them, while *M. gilvus* was observed in four communities. *M. insperatus* is notably the predominant subterranean termite

species, as evidenced by its presence in every settlement where bait woods were installed. The results of this study are similar to those of Arinana et al. (2016a), with a research location in South Jakarta, where *M. insperatus* species were found in 76.2% of bait wood. Research on subterranean termite diversity was conducted by Arinana et al. (2016b) in Darmaga Permai I Park, Ciampea, Bogor, and Mubin et al. (2017) on termite diversity at IPB University. The results of the research by Arinana et al. (2016b) stated that subterranean termite species *Macrotermes gilvus*, *Odontotermes javanicus*, *Coptotermes curvignathus*, *Schedorhinotermes javanicus*, and *Schedorhinotermes sarawakensis* were found at the research site, while Mubin et al. (2017) found subterranean termite species *Macrotermes gilvus*, *Microtermes insperatus*, *Odontotermes javanicus*, *Capritermes mohri*, *Schedorhinotermes javanicus* and *Coptotermes curvignathus* at the research site. Research by Arinana et al. (2016b) and Mubin et al. (2017) was conducted in Bogor, but the termites found differed from this recent study. This study did not find *Odontotermes javanicus*, *Capritermes mohri*, and *Coptotermes curvignathus* termite species in the twelve urban sub-districts.

D. Diversity of Subterranean Termites

The richness index (R_i) of termite species in the residential area of Bogor City is 0.46. Figure 3 shows the distribution map of subterranean termites. Species richness is the number of species in a community. The greater the number of species found, the greater the richness index. Margalef's richness index, as modified by Arinana et al. (2019), divides the number of species by the natural logarithm function of the amount of bait wood infested by termites. The species richness value of subterranean termites in the residential area of Bogor City is slightly lower than that in East Jakarta and South Jakarta. The research by Arinana et al. (2019) stated that the species richness index in East Jakarta was 0.48, while in South Jakarta, it was 0.51. The value of the species richness index in these three locations is different even though the number of species found in each location

is the same, namely three species. This is due to the different amounts of bait wood infested by subterranean termites.

In Bogor City, the amount of bait wood infested by subterranean termites was higher than in East Jakarta and South Jakarta. The diversity index of subterranean termite species in residential areas in Bogor City is 0.62. This is lower than in East Jakarta (0.74) and South Jakarta (0.88) (Arinana et al., 2019). The evolutionary and ecological processes that underlie the difference in termite species richness can be directly impacted by temperature (Pontarp et al., 2019). The diversity index of subterranean termites in Bogor City is lower than in East Jakarta and South Jakarta because the number of bait wood infested by subterranean termites per subterranean termite species is not uniform, which can be seen from the evenness value of subterranean termites in Bogor City of 0.56 which is smaller than in East Jakarta (0.67) and South Jakarta (0.80) (Arinana et al., 2019). Prastyaningsih et al. (2020) found that factors such as soil moisture and canopy cover positively correlate with termite diversity and abundance. In urban area, where these environmental factors may be altered, the resulting changes in termite diversity can lead to shifts in infestation patterns. For instance, a higher diversity of termites may result in a more significant range of feeding behaviors, which can complicate pest management efforts and increase the likelihood of structural damage.

The evenness index shows the degree of evenness in the abundance of individuals among species. The community has a maximum evenness value if each species has the same number of individuals. Conversely, if the evenness value is small, the community contains dominant, sub-dominant, and dominated species. Hence, the community has minimum evenness. The evenness value ranges from 0-1. If the index value obtained is close to one, the distribution is evener. The evenness index of subterranean termites in the residential area of Bogor City also differs from the study of Pratiknyo et al. (2020) in southern Gembong

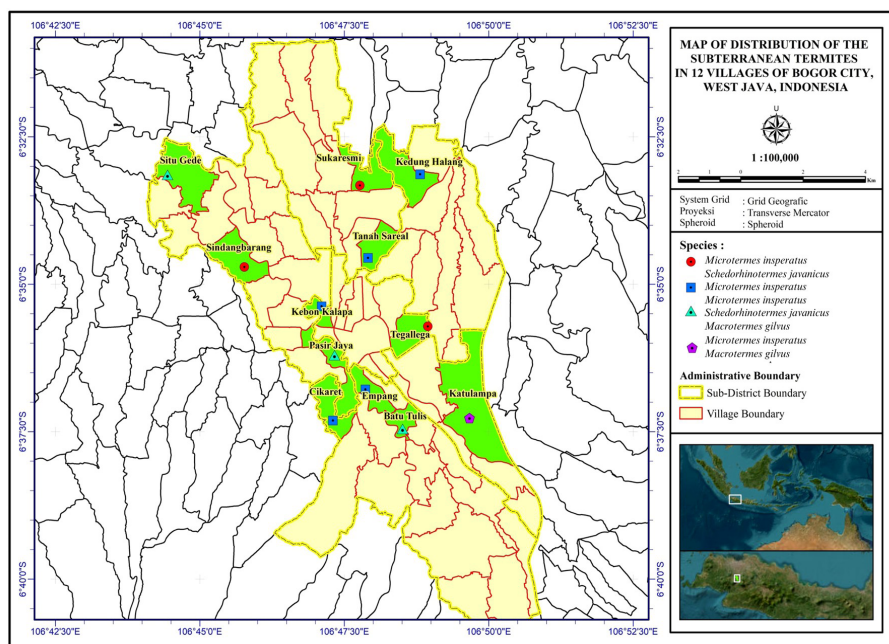


Figure 3. Distribution map of subterranean termites in Bogor City, West Java, Indonesia

(Central Java), where the termite evenness index was 0.73. This indicates that *M. insperatus*. is a dominant termite species in Bogor City. The conversion of land from natural ecosystems to urban has significant implications for the presence and diversity of subterranean termite pests. Land-use changes, particularly forest conversion, resulted in decreased termite diversity, likely due to the loss of suitable habitats and food sources (Liu et al., 2019).

E. Frequency and Distribution of Subterranean Termite Attacks on Wooden Monitors

Table 6 describes the frequency of subterranean termite attacks on wooden monitors installed in 12 urban sub-districts in Bogor City, Indonesia. A total of 300 wooden monitors were installed, with 25 placed in each sub-district. After the three-month exposure period, 48 monitors were unrecoverable, potentially due to environmental conditions or human/animal disturbance, leaving 252 samples for analysis.

Of the 252 remaining monitors, 114 showed signs of subterranean termite attack, such as visible feeding marks and the presence of

live termites. Within this group, termites were found to be actively feeding on 81 of the monitors. The overall attack frequency across all sites was calculated to be 38%. According to the classification by Cookson & Trajstman (2002), this frequency is categorized as 'High' (Table 1). This result, however, was notably lower than the 68.5% attack frequency reported by Arinana et al. (2020a) in a nearby residential area.

The frequency of infestation varied significantly between sub-districts. Cikaret sub-district experienced the highest attack rate (56%), while Empang sub-district had the lowest (4%), as detailed in Table 5. The discrepancy in attack frequency could be attributed to various factors, such as different soil types and environmental conditions (Subekti et al., 2018). For instance, Cikaret is an area prone to flooding, which can create softer clay soil conditions favorable to some termite species (Nurhadi et al., 2023; Wardhani & Rufina, 2022). The frequent attacks and the dominance of *M. insperatus*. across these sub-districts indicates their significant role in wood degradation, while the localized presence of *S. javanicus*. in Sindang Barang may contribute to

Table 6. The frequency of subterranean termite infestation of test samples in each urban Sub-district in Bogor City

Village	BW	BWL	WI	WNI	Freq.* (%)
Situ Gede	25	1	11	13	44
Sindang Barang	25	2	13	10	52
Pasir Jaya	25	2	9	14	36
Batu Tulis	25	0	9	16	36
Cikaret	25	3	14	8	56
Empang	25	12	1	12	4
Katulampa	25	3	7	15	28
Kedung Halang	25	10	13	2	52
Kebon Kelapa	25	2	6	17	24
Tegallega	25	7	12	6	48
Sukaresmi	25	6	12	7	48
Tanah Sareal	25	0	7	18	28
Total	300	48	114	138	

variations in damage patterns. These findings emphasize the need for targeted management strategies based on species composition and infestation frequency in each area.

F. Weight Loss

Figure 4 shows the average weight loss of wood eaten by subterranean termites in monitors for 12 sub-districts in Bogor City, Indonesia. According to the results, bait woods from every sub-district had an average weight loss ranging from 5.70% to 29.45%. With a weight loss percentage of 29.45%, Kedung Halang had the most significant weight loss, indicating intense termite activity primarily driven by *M. insperatus*. Meanwhile, the Empang Sub-district recorded the lowest weight loss value, at 5.70%, despite also identifying a case of *M. insperatus* activity. The single occurrence in Empang suggests that environmental factors, resource availability, or other ecological conditions may limit the impact of termites in this area compared to Kedung Halang. Prior studies in Cibinong, Bogor Regency area, found that weight loss of bait woods was between 9.23% and 22.92% (Nurhadi et al., 2023).

The notable discrepancy in weight loss values across the sub-districts can be attributed to several factors influenced by termite activity.

For instance, the elevated level of weight loss observed in Kedung Halang is corroborated by the prevalence of termite infestations, with thirteen recorded attacks in this subdistrict, compared to a single instance in Empang. The presence of *M. insperatus* is often linked to the availability of wood and other cellulose materials, which serve as food sources. Arinana et al. (2020) found that *M. insperatus* actively attacked untreated wood samples, indicating their preference for certain types of timber. Termite activity is significantly influenced by local environmental conditions, including soil type, vegetation cover, and the availability of moisture and food sources (Subekti et al., 2018). The clay soil in Kedung Halang, which typically retains more moisture, may provide a more conducive environment for termites compared to the sandy clay loam found in Empang, resulting in elevated termite activity and, consequently, more substantial weight loss.

Another crucial element is the presence of vegetation and human-made structures. In Cikaret, for instance, the number of buildings is less than in Empang. Additionally, open areas are more susceptible to termite activity than densely built-up areas (Mardiansyah et al., 2023; Nurhadi et al., 2023). This indicates that the more open landscape in Kedung Halang

may have contributed to the observed elevated termite activity and weight loss, as termites tend to flourish in areas with minimal urban development and greater access to organic matter. *M. insperatus*. was sensitive to changes in their habitat, which can affect their foraging behavior and colony dynamics (Ajayi et al., 2020). Higher soil moisture levels typically enhance their activity, as these conditions facilitate their movement and feeding. Conversely, drought conditions can lead to decreased activity and even colony mortality (Anyango et al., 2020).

The observed variation in weight loss values is reflective of the complex interplay between termite behavior, environmental conditions, and the characteristics of the local landscape. Figure 4 illustrates the total weight loss value for each sub-district.

G. Percentage of Damage

Figure 5 shows the average percentage of damage for each tested site. A one-way ANOVA revealed a statistically significant difference in the percent weight loss among the 12 sub-districts. The average percentage of damage in each sub-district ranged from 1.22±6.09% to 48±50.99% (Figure 5). Kedung Halang showed a score of 71.79% and was the

most damaged. Meanwhile, Empang Village saw the lowest proportion of damage, totaling 2.34%. The thirteen termite attacks in Sindang Barang were responsible for the higher value compared to only one assault in Empang. This high level of damage in Sindang Barang can be linked to both the number of attacks and the type of termites present. Termites such as *M. gilvus*. and *S. javanicus*., which are known for their aggressive wood-damaging behavior, were found in higher numbers in areas like Kedung Halang compared to the single species of *M. insperatus*. found in Empang. This aligns with the high termite activity and the presence of *M. insperatus*, these termites are significant pests that require effective management strategies to mitigate their impact (Iqbal et al., 2016). Termites present a dual role in urban ecosystems. While they are crucial for nutrient cycling, their wood-damaging behavior creates a direct conflict with human interests. Addressing the conflict between their beneficial ecological functions and their pest status is a critical consideration for developing effective urban pest management strategies (Anyango et al., 2020).

The damage value percentage in this study, which ranges from 1.22±6.09% to 48±50.99, is

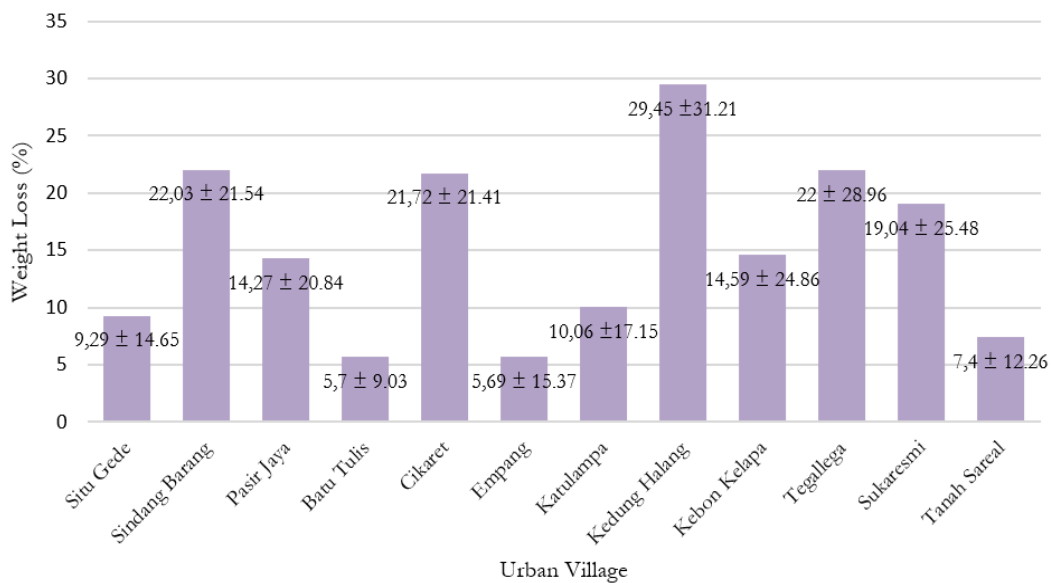


Figure 4. The weight loss +/- the standard error of bait wood in 12 sub-districts, Bogor city

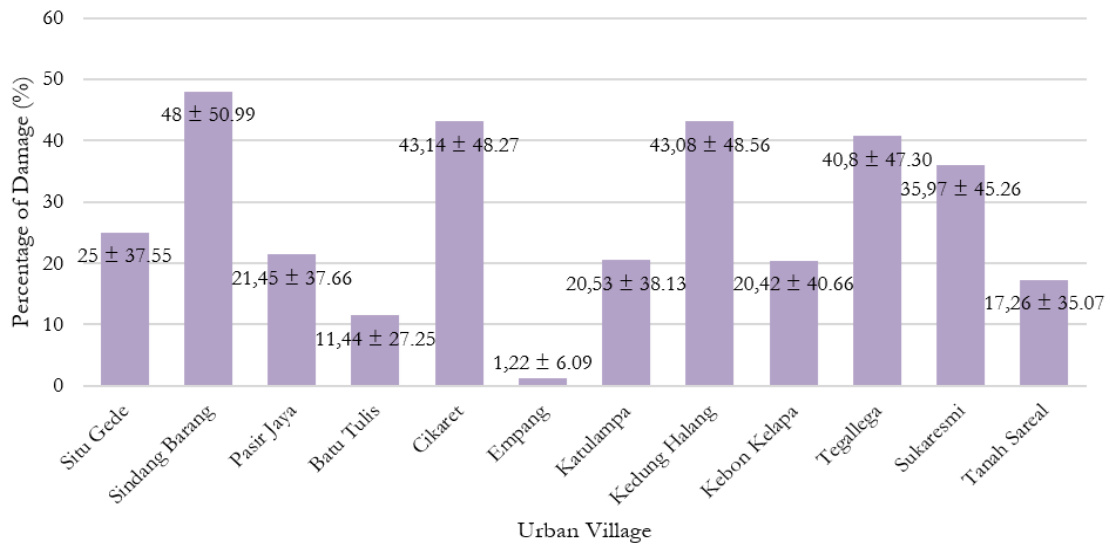


Figure 5. Percentage of damage of bait wood in 12 sub-districts, Bogor city

higher than in the prior study, which was 18,9% in the residential site (Nurhadi et al., 2023). This increased level of damage could result from the unique environmental factors in the site test areas, such as soil moisture and organic matter content, which are crucial in supporting higher termite populations and more severe infestations. Additionally, the frequency of attacks correlates directly with the degree of damage, with more attacks leading to higher damage percentages.

Figure 6. Shows the form of damage to the wood bait in each sub-district. The variation in damage percentages highlights the importance of local environmental and ecological conditions in determining the intensity of termite damage. Soil composition, moisture content, and landscape features all play a role in either mitigating or exacerbating the impact of termite infestations.

H. Damage Value Index

The average damage value of each sub-district ranged from 4 to 9. Empang Sub-district had the highest damage value at 9, while Sindang Barang, Kedung Halang, and Tegallega had the lowest damage value at 4. The higher the damage value that occurs in bait wood, the

lower the percentage of damage that occurs in said bait wood, and vice versa. Differences in termite species and location can cause variations in damage value (Fajar et al., 2021).

Table 7 displays the damage values for each sub-district. Each sub-district had a different value of damage to bait wood. Wood consumption by subterranean termites caused weight loss of the bait wood. This was determined by weighing each wood sample before installation and after the three-month exposure period, once cleaned of debris. Subterranean termites consume the whole transverse portion of the bait wood and create transverse holes. Calipers can be used to measure the depth of attack and evaluate the extent of damage to the wood based on eye inspection. Termites' preference for wood is evident in the extent of damage they cause. Moreover, the presence of termites can also affect property values, as potential buyers may be deterred by the risk of infestation and the associated costs of treatment and repair (Gazal et al., 2019). The economic losses attributed to *Reticulitermes* species are significant, with estimates suggesting that termite damage costs homeowners billions of dollars each year (Botch & Houseman, 2018).

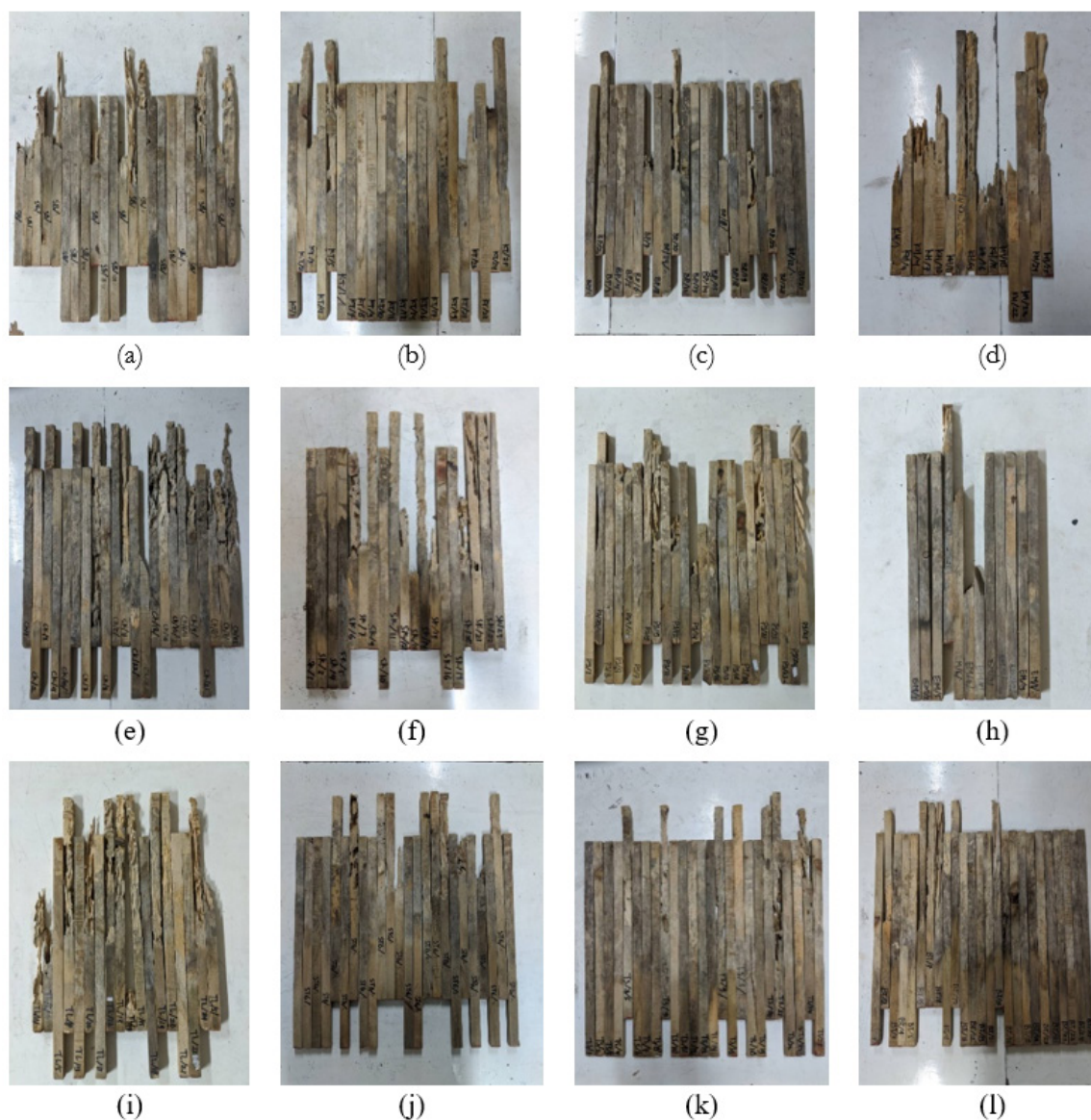


Figure 6. The form of damage to the wood bait in each sub-district, (a) Sindang Barang, (b) Katulampa, (c) Kebon Kelapa, (d) Kedung Halang, (e) Cikaret, (f) Sukaresmi, (g) Pasir Jaya, (h) Empang, (i) Tegallega, (j) Situ Gede, (k) Tanah Sareal, and (l) Batu Tulis

IV. CONCLUSION

The residential area of Bogor City is home to at least three different species of subterranean termites: *M. insperatus*, *M. gilvus*, and *S. javanicus*. The species richness index of 0.46 classifies the species richness as medium, while the diversity index of 0.62 indicates the area's low diversity of subterranean termites. The evenness index of 0.56 shows a medium level of species distribution. *M. insperatus* is the dominant

species found in the urban environment of Bogor City. The presence of termites is strongly influenced by environmental factors such as soil composition, temperature, and humidity, which support their survival in this area. These results provide new insights into the ecological dynamics of termites in urban environments, particularly in densely populated areas like Bogor City.

Table 7. Percentage of Damage in the Cross-section Direction and Value of Damage for Different Sub-district

Villages	Percentage of Damage (%)	Value of Damage*
Situ Gede	26.04	7
Sindang Barang	52.17	4
Pasir Jaya	23.31	7
Batu Tulis	11.44	7
Cikaret	49.01	6
Empang	2.34	9
Katulampa	23.33	7
Kedung Halang	71.79	4
Kebon Kelapa	22.19	7
Tegallega	56.66	4
Sukaresmi	47.32	6
Tanah Sareal	17.26	7

*Based on the ASTM D3345-06 rating scale.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to IPB University for its support; thus, this study could be conducted. Also, we appreciate the sub-district officials' giving permission so the research can be carried out smoothly.

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