Termites (Insecta: Isoptera) diversity in forest concession areas of PT Inhutani I, Indonesia

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Abstract Termites as wood biodeterioration agents have an important role in the ecosystem. This study aimed to observe termite diversity. A termite survey was conducted on Forest Concession Areas of PT. Inhutani I, South Sulawesi Indonesia. The termite specimens collected used the standardized transect sampling protocols at three different sites (forest with mixed vegetation, Pinus merkusii plantation, and logged-over area) and measurement of nine morphological characters of the soldier was conducted, i.e: head length without mandibles, head width at base of mandible, maximum width of head, left mandible length, pronotum length, maximum width of pronotum, postmentum length, postmentum width of postmentum, and the number of antenna segments. The results showed that there are four species found based on the morphological characteristics and morphometrical data, namely: Odontotermes javanicus., Nasutitermes sp., Schedorhinotermes sp. and Coptotermes curvignathus. The highest termite abundance was found in forest with mixed vegetation. The termite diversity in logged-over area and forest with mixed areas was moderate, while species diversity in pine plantation was low.

1. Introduction
PT. Inhutani I is a State-Owned Enterprise (BUMN) established in 1973 (PP No. 21 of 1972), a continuation of the PN Perhutani of East Kalimantan. The company’s core business is Natural Forest Management and Plantation Forest Development with locations in East/North Kalimantan (7 units) and South Sulawesi (2 units). PT. Inhutani I with Core Business of Natural Forest Management and Plantation Forest Development which currently focuses on Industrial Plantation Forest areas with the main objective of developing HTIs to ensure the availability of wood raw materials needed by the wood processing industry in Indonesia, increase foreign exchange, develop centres state/rural economic growth, providing job opportunities, and business opportunities as well as preserving the benefits of forest resources. For the South Sulawesi region, PT Inhutani has two focus areas. The forest area is in Gowa Regency and Maros Regency. Currently PT Inhutani I Plantation Forest Management Unit (UMHT) Gowa still has areas with various types of vegetation and has even developed cajuput plants as a strategy for managing non-timber forest products [1]. The variety of vegetation planted at PT Inhutani I Gowa provides conditions that allow soil organisms such as termites, worms and ants to live, develop and carry out their functions as detrivores.

Termites are known as organisms that attack cellulose-containing materials such as wood as a food source. However, termites are also part of a cycle in the ecosystem that helps maintain the
balance of nature by breaking down organic matter into nutrients in the soil. As a soil engineer, termites have many ecological benefits [2], such as the ability to improve soil and water characteristics [3] including the stability of soil aggregates which varies depending on soil properties [4] and create fertile areas in barren landscapes [5]. Termite species diversity is relatively high. In the world, termites identified has reached 3,106 species [6], and an estimated 10% of them exist in Indonesia. However, only about five per cent are harmful to humans, namely as pests for most agricultural and plantation crops [7]. Economic losses occur due to termite feeding activity in degrading building wood components and their derivative products found in a building, or attacking commercial plants. Data on losses caused by termites is estimated at 2.8 trillion rupiah [8].

As a tropical country, Indonesia provides a very suitable habitat for the breeding of termites. As part of Indonesia, the geographical position of Sulawesi Island has a unique flora and fauna that is different from the continents of Asia and Australia. This location allows the discovery of endemic species. Biodiversity expressed as richness, abundance, and diversity can be influenced by several factors, such as differences in specific locations and habitats; and PT Inhutani which is located in Gowa Regency, South Sulawesi Province, providing various habitats and vegetated areas. However, information regarding surveys and termite species in PT Inhutani 1 is not yet available. The current study aims to determine the diversity of termites collected from several habitat types in the PT Inhutani I area.

2. Methods

2.1. Study site

This study was conducted in the area of PT Inhutani I - Plantation Forest Management Unit (UMHT) Gowa at three different sites (forest with mixed vegetation, *Pinus merkusii* plantation, and logged-over area. Temperature and humidity ranged from 31-35°C, respectively, and 34-55% The altitude of the research location ranges from 118-227 meters above sea level (m asl).

2.2. Transect sampling protocol

Transect placement was carried out randomly in the IUPHHK-HTI work area of PT. Inhutani I. The standardized transect method was used for sampling termites [9,10]. A belt transect was 100 m in length and 2 m in width, divided into 20 contiguous sections (each 5 × 2 m) that were numbered sequentially. In each section, a collector searched for termites within the following microhabitats, such as: surface soil; accumulations of litter and humus at the bases of trees and between buttress roots; inside dead logs, tree stumps, branches, and twigs; the soil within and beneath very rotten logs; all subterranean nests, mounds, carton sheeting, and runways on vegetation; and arboreal nests up to a height of two m above ground level. The transects were purposively placed on three types of vegetation, namely forest with mixed vegetation, pine stands, and logged-over areas. Two transects were provided for each type of forest (Figure 1). Termites collected from each location were separately placed and preserved in vials filled with 70% ethanol.
2.3. **Determination of termite species**

Termite species were identified based on the key determination for soldiers [11,12]. Soldiers of the collected specimens were observed for their morphological characters under a STEMI 2000 stereomicroscope with an ERC 5S phototube camera (Olympus, USA). Determination of termite species was carried out through morphological observations and morphometric measurements, regarding. Morphological observations were carried out on all parts of the termite body which included shape, colour, and other characteristics found on the body parts of termites. Measurement of the head of the soldier caste refers to [11], namely: head length without mandibles (HL), head width at base of mandible (bHW), maximum width of head (mHW), left mandible length (LML), pronotum length (PL), maximum width of pronotum (PW), postmentum length (PosL), postmentum width of postmentum (PosW), and the number of antenna segments (A).

2.4. **Variabel and data analysis**

In addition to morphometric data, termite diversity index (H) data was also collected to determine the level of termite diversity. The Shannon-Weiner index (H') is used to calculate the diversity of termites. The diversity index (H') was assessed based on the following criteria: low species diversity if H' = <1 (low species diversity), moderate species diversity if H' = 1-3 (medium species diversity), and high species diversity if H' = > 3 (high species diversity). All data collected were analyzed using descriptive analysis.
3. Results

3.1. Termite identification

Identification of morphology-based specimens found 4 species of termites. These termites belong to two families (Termitidae and Rhinotermitidae), sub-families (Macrotermitinae, Termitidae, Coptotermitinae, Nasutitermitinae, Rhinotermitinae), and four genera (Odontotermes, Coptotermes, Nasutitermes, Schedorhinotermes). The morphological characteristics and morphometric size of each type of termite are described as follows:

3.1.1. Odontotermes javanicus. Odontotermes javanicus is a member of higher termites belonging to the family Termitidae and subfamily Macrotermitinae. This termite has a characteristic in the form of protruding marginal teeth. The head capsule of this termite is oval in shape and light brown in color. Measurements of 49 individual soldiers showed that the length of the head without mandible was 0.93-2.37 mm, the maximum width of the head was 0.62-1.92 mm, the width of the head at the base of the mandible was 0.23-1.34 mm. Postmentum length 0.95-1.69 mm, maximum postmentum width 0.30-0.75 mm, minimum postmentum width 0.20-0.54 mm. The length and width of the pronotum are 0.24-0.66 mm and 0.66-1.31 mm, respectively. The length of the left mandible is 0.74-1.39 mm and the number of antennas is 17 segments. The appearance of these termites is shown in Figure 2.

![Figure 2. Morphology of Odontotermes javanicus soldier: (a) body of individual soldiers, (b) head with antennae, (c) left mandible, (d) postmentum, and (e) pronotum.](image)

3.1.2. Genus nasutitermes. Nasutitermes sp. is a member of higher termites belonging to the Termitidae family with the Nasutitermitinae subfamily. The head capsule is oval in shape with a nasut at the front of the head which is short and pointed, black in color, and has a very small mandible. Measurements of the head of the 3 soldiers showed a range of head length 1.49-1.65 mm, maximum head width 1.09-1.16 mm, minimum head width 0.65-0.75 mm, postmentum length 0.26-0.36 maximum width 0.17-0.22 mm, minimum postmentum width 0.13-0.18 mm, pronotum length and width 0.21-0.28 mm and 0.50-0.53 respectively mm, the antenna is 13 segments. The appearance of Nasutitermes sp soldiers can be seen in Figure 2. The termite Nasutitermes sp was found in dead wood in logged-over stands and mixed stands.
3.1.3. *Coptotermes curvignathus*. *Coptotermes* is a member of lower termites belonging to the family Rhinotermitidae and subfamily Coptotermitinae. This termite is characterized by the presence of a milky white liquid that is released by soldiers when attacking the enemy. The head capsule is yellowish in color and oval in shape which narrows at the tip. These termites are also characterized by large fontanel openings close to the clypeus [13]. Measurements of 19 soldiers showed that the length of the head without mandibles ranged from 1.44 to 1.93 mm, the maximum width of the head from 1.23 to 1.50 mm, the width of the head at the base of the mandible from 0.51 to 0.93 mm. Postmentum length 0.94-1.13 mm, postmentum maximum width 0.38-0.60 mm, and minimum postmentum width 0.22-0.35 mm. The length and width of the pronotum are 0.20-0.59 mm and 0.90-1.31 mm, respectively. Left mandible length 1.01-1.29 mm. The number of antenna segments is 16. The appearance of these termites can be seen in Figure 3. This termite is found in dominant stands of pine, having a nest in the ground that is connected to the tree it attacks.

![Figure 3](image1.png)

**Figure 3.** Morphology of *Nasutitermes* sp. soldier; (a) body of individual soldier, (b) head with antennae, (c) left mandible, (d) postmentum, and (e) pronotum.

![Figure 4](image2.png)

**Figure 4.** Morphology of soldiers *Coptotermes curvignathus*; (a) body of individual soldier, (b) head with antennae, (c) left mandible, (d) postmentum, and (e) pronotum.
3.1.4. *Schedorhinotermes* *sp.* *Schedorhinotermes* is a member of the lower termites belonging to the family Rhinotermitidae and subfamily Rhinotermitinae. This termite was characterized by the presence of dimorphic soldiers in the colony, namely major soldiers and minor soldiers, as can be seen in Figures 3 and 4. Measurements of the six major soldiers showed a range of head length without mandibles from 1.06 to 1.59 mm, maximum head width 0.84-1.52 mm, head width at the base of the mandible 0.24-0.75 mm. Postmentum length 0.70-1.23 mm, postmentum maximum width 0.33-0.55 mm, minimum postmentum width 0.21-0.30 mm. The length and width of the pronotum are 0.58-0.93 mm and 0.43-0.53 mm, respectively. On the left mandible, the length ranges from 0.57 to 1.06 mm. This termite has two curved mandibles with very prominent marginal teeth. The number of antenna segments is 16.

**Figure 5.** Morphology of *Schedorhinotermes* *sp.* major soldiers.: (a) body of individual soldier, (b) head with antennae, (c) left mandible, (d) postmentum, and (e) pronotum.

For minor soldiers, measurements of six soldiers showed a range of head length without mandible 0.72-0.84 mm, maximum head width 0.64-0.69 mm, head width at the base of the mandible 0.41-0.46 mm. The length of the postmentum is 0.36-0.64 mm, the maximum width of the postmentum is 0.25-0.38 mm, the minimum width of the postmentum is 0.13-0.29 mm. The length and width of the pronotum are 0.17-0.50 mm and 0.19-0.43 mm, respectively. Termites have a narrow head, length parallel to the mandible, the length of the mandible ranges from 0.32 to 0.54 mm, and the number of antenna segments is 14-16. The appearance of the minor soldiers can be seen in Figure 4.

**Figure 6.** Morphology of *Schedorhinotermes* *sp.* minor soldiers.: (a) body of individual soldier, (b) head with antennae, (c) left mandible, (d) postmentum, and (e) pronotum.
3.2. Species diversity

3.2.1. Species richness. Species richness was expressed as the number of termite species found on the transect. Species richness and distribution in each habitat type can be seen in Table 1. The total richness of termites identified was four species. *Odontotermes javanicus* was found scattered in each type of habitat.

**Table 1.** Species richness of termites and their distribution based on habitat types in PT. Inhutani 1 Gowa, South Sulawesi

| No. | Species | Genera | Habitat types          | Pinus plantation | Forest with mixed vegetation | Logged-over area |
|-----|---------|--------|------------------------|------------------|-----------------------------|------------------|
| 1.  | *Odontotermes javanicus* | *Odontotermes* | +                      | +                | +                           |
| 2.  | *Nasutitermes sp.*       | *Nasutitermes* | +                      | +                | -                           |
| 3.  | *Coptotermes curvignathus* | *Coptotermes* | +                      | -                | +                           |
| 4.  | *Schedorhinotermes sp.*   | *Schedorhinotermes* | +                      | +                | -                           |

Remarks: (+) termites found; (−) No termites found

3.3. Species abundance

Termite species abundance is the total number of termite species found or encountered on the transect, where the presence of one species in a quadrat represented one encounter [14]. Species abundance in each habitat types as shown in Table 2. In that table, it can be seen that the highest abundance of termite species was found in mixed stands with a total of 17 termites. Logged-over areas had the same species abundance as a total of 13 pine stands.

**Table 2.** Distribution of species abundance based on habitat types at PT. Inhutani 1 Gowa, South Sulawesi

| No | Habitat types           | Species                  | Abundance (encounter) species | Total |
|----|-------------------------|--------------------------|-------------------------------|-------|
| 1. | Logged-over area        | *C. curvignathus*        | 3                             | 13    |
|    |                         | *O. javanicus*           | 9                             |       |
|    |                         | *Nasutitermes sp.*       | 1                             |       |
| 2. | Forest with mixed       | *Schedorhinotermes sp.*  | 3                             | 17    |
|    | vegetation              | *O. javanicus*           | 11                            |       |
|    |                         | *Nasutitermes sp.*       | 3                             |       |
| 3. | Pine Plantation         | *C. curvignathus*        | 7                             | 13    |
|    |                         | *Schedorhinotermes sp.*  | 5                             |       |
|    |                         | *O. javanicus*           | 1                             |       |

3.4. Diversity index of termites

The diversity index of the termites in various habitat types can be seen in Figure 8. Based on the Shannon Wiener index criteria (H'), species diversity in pine plantation indicated the low category, while the diversity of termites in logged-over areas and forest with mixed vegetation was classified as low in diversity.
4. Discussions

There were four species of termites identified based on morphology, namely *O. javanicus*, *Nasutitermes* sp., *C. curvignathus*, and *Schedorhinotermes* sp. These four species are invasive insects which are known to attack wood components of buildings and agricultural and forestry plants [15–18]. The species richness of termites found in the area of PT Inhutani I Gowa was only four species from six transects in three habitat types, namely *O. javanicus*, *Nasutitermes* sp., *C. curvignathus*, and *Schedorhinotermes* sp. This species richness is low than compared to similar studies conducted in other locations [19]. The low number of termite species found was caused by various factors, including the period of specimen collection, where surveys and specimen collection were carried out at the beginning of the dry season. In this condition, termites are rarely found doing foraging activities on the ground surface. Almost all specimens were collected from the ground or in wood. Termite attack activity on leaf litter, branches and wood twigs were mostly found in the form of traces and without the presence of organisms in them. The specific habitats of the termites collected were dead wood, stumps, branches/twigs, rotted wood, and litter below the soil surface. The sampling period is closely related to weather factors, such as temperature, humidity and rainfall. Temperature and humidity are factors that jointly affect the activity and behaviour of termites [20]. The optimal temperature range for termite development is 15-38 °C and optimal humidity is 95-98%, the condition of this research location is very suitable for termite development [21]. Observations and measurements of environmental conditions in the field just before collecting the specimens showed a temperature range of 31-35 °C with a humidity range of 34-55%. This shows that the water content in the air is very low, thus limiting termites to carry out foraging activities above the soil surface.

In addition to the environmental factors above, other factors such as habitat, diversity of vegetation, and litter as a food source for termites' survival are also important factors that affect activity and koloni development of termites. The termites found in this study were subterranean termites from the families Rhinotermitidae (*C. curvignathus* and *Schedorhinotermes* sp.) and Termitidae (*O. Javanicus* and *Nasutitermes*). The Rhinotermitidae family is a lower termite group [22] and all of its members are wood-feeders or group 1 based on Donovan's feeding group [23]. On the other hand, *Odontotermes* and *Nasutitermes* belong to the higher termites [22] and Group II of wood-feeder and litter-eating termites [23]. At the time of the study, the availability of food sources such as wood and litter was plentiful, especially in logged-over areas, where many piles of cut trunks, branches and twigs were scattered and covered most of the forest floor. However, dry environmental conditions and low humidity cause a lack of termite activity in degrading the wood. The termites collected were mostly found below ground level in wood piles. On the other hand, in the other two habitat types, the availability of food is relatively small in the form of branches, twigs and leaf litter.
compared to the logged-over area, but has better canopy cover so that the microclimate of the two habitat types is more supportive of finding termite activity on the ground surface. Referring to Table 1, the species richness of the three habitat types from PT Inhutani I is relatively the same. This indicates that the presence of vegetation types has less impact on the presence of a type of termite. The number of termite specimens that can be collected depends on the distribution and foraging activity. Fluctuations in termite distribution and foraging activity are influenced by temperature and humidity [24], seasonal changes [25], and rainfall or precipitation [26]; while soil type and vegetation have less impact [27].

The abundance of termite species expressed as the number of termite encounters at the study site was highest in forests with mixed vegetation (17 hits); while the other two habitats had the same abundance value (13 hits). The difference between the three types of habitat is determined by the number and composition of the constituent vegetation. Transects in the forest with mixed vegetation were composed of several types of vegetation, namely mahogany (Swietenia mahagony), acacia (Acacia mangium), and cover crops (kirinyu - Chromolaena odorata); On the other hand, in logged-over areas only a few acacia trees were found on the transect because the area had been cut down and converted to cajuput (Melaleuca leucadendra) plantations. Variations in termite encounters were significantly correlated with species richness of woody plants and soil pH [28]. In addition to the factors mentioned above, termite abundance is influenced by many other factors, such as: the relative abundance of termites decreases due to land use [29] and habitat fragmentation [30]. In addition to environmental factors such as environmental changes [31,32], the influence of vegetation on termite abundance has been widely published by researchers such as the origin of exotic and native vegetation [33], habitat type [34,35] and tree stand differences [36]. Information on the diversity of termites in an area needs to be known for the purpose of assessing the nutrient cycle in the ecosystem and controlling pests in an integrated manner.

5. Conclusion

there are four species found based on the morphological characteristics and morphometrical data, namely: Odontotermes javanicus, Nasutitermes sp., Schedorhinotermes sp. and Coptotermes curvignathus. The highest termite abundance was found in forest with mixed vegetation. The termite diversity in logged-over area and forest with mixed areas was moderate, while species diversity in pine plantation was low.

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