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Termite diversity and abundance based on altitude in Mount Ungaran, Central Java, Indonesia

NIKEN SUBEKTI[1,♥], RODERIKUS RAYDITYA MILANIO[2]
[1]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang. Jl. Raya Sekaran, Gunungpati, Semarang 50229, Central Java, Indonesia. Tel./fax.: +62-24-8508033, ♥email: nikensubekti@mail.unnes.ac.id
[2]Program of Biology, Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang. Jl. Raya Sekaran, Gunungpati, Semarang 50229, Central Java, Indonesia

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Abstract. *Subekti N, Milanio RR. 2023. Termite diversity and abundance based on altitude in Mount Ungaran, Central Java, Indonesia. Biodiversitas 24: 3319-3324.* Termites are social insects whose main diet is the cellulose and lignocellulose found in rotting wood and in some fungi. As the Mount Ungaran area in Central Java, Indonesia, has been converted to agriculture and other purposes, termite habitat has become increasingly narrow, with a reduction in the insects' food sources. The purpose of this study was to analyze the species of termites found on Mount Ungaran and the factors that influence their lives. In addition, the differences in species according to slope (north, south, east, and west) and altitude were assessed. This research was conducted in three stages: termite collection, termite identification, and data analysis. The main species found in this study were *Coptotermes curvignathus* Holmgren, 1913, *Odontotermes javanicus* Holmgren, 1912, *Macrotermes gilvus* Hagen, 1858, *Nasutitermes matangensis* Haviland, 1898, and *Bulbitermes constrictiformis* Holmgren, 1914. Based on a Shannon-Wiener analysis, the west slope had the highest diversity index, which was primarily influenced by four environmental factors (soil pH, soil temperature, soil moisture, and rainfall). In the canonical relationship correspondence analysis, soil pH, light intensity, and canopy cover were the environmental factors that most affected the diversity and abundance of termites on Mount Ungaran. The conclusions that can be drawn from this study are that termite richness varied between slopes and the environmental factors that were the most associated with the variation were soil pH, light intensity, and canopy cover.

Keywords: Altitude, identification, insect, slopes

INTRODUCTION

Termites are social insects whose main diet is the cellulose and lignocellulose present in rotting wood, leaf litter, and some fungi. Earth is home to 2800 species of termites, mainly found in the tropics (Syaukani 2018). Termites are the main decomposers in natural forests in these areas, and their presence is highly dependent on soil pH, water, decomposition media, and the level of the food web, as well as the surface area for microbial colonization (Subekti and Saniaturrohmah 2020). The country of Indonesia has a tropical climate, and its forests are very suitable for termites. Indonesia has 200 termite species in the area between Sabang and Merauke, and about 20 of these species are classified as pests (Cancello 2014).

Termites, also referred to as white ants, are insects with a very rapid life cycle. Nymphs emerge approximately 5 days after eggs are laid, and they subsequently develop as reproductive castes, workers, or soldiers (Hadijono 2007). Reproductive castes that have wings are considered moths. Laron, or winged "ants," emerge from termite nests at the beginning of a rainy season or at the end of a dry season. A pair of moths will fall to the ground, break off their wings, and then form a new colony. Gradually, the abdomen of the female moth will enlarge and become larger than its head. The female then serves as the colony queen and continues to lay eggs all her life (Nowacki 2018).

Wood-eating termites can be pests. It is estimated that there are approximately 2.8 trillion rupiahs in losses due to termite attacks (Nurrachmania and Rozalina 2021). *Coptotermes curvignathus* Holmgren, 1913 is one of the most common types of termites causing damage to wood and wooden structures worldwide (Kamarudin et al. 2022). For most organisms, the presence of a species decreases with air temperature and is correlated with an increase in altitude (Widhiono et al. 2017). Termite species composition and abundance usually decrease with increasing altitude (Cavieres 2014).

Air temperature represents a primary factor affecting termite species composition in tropical Southeast Asia (Subekti et al. 2019). The pattern defined by species composition decreasing as a result of increasing altitude is monotonic (Weinstein 2018). For example, research on the Leuser Ecosystem, Aceh Province, Indonesia, showed that the air temperature decreased by 1°C for every 100 m increase in altitude. Under this phenomenon, termite species became less abundant and populations were reduced as the temperature declined, because of the metabolic rate of termites as ectothermic animals. However, other factors may cause the composition of termite species to decrease monotonically (Afzal and Rasib 2022). The monotonic decrease in termite species richness with mirror height is often associated with productivity and area use, as well as the decrease in temperature (Kurniawan et al. 2015). In addition, there is yet another pattern associated with an increasing altitude gradient and the decline in the composition of termite species, whereby the species composition is initially high at both low to mid elevations and then decreases gradually at higher elevations. This pattern shows the influence of the mid-domain elevation. The richness patterns of other species, which were observed to be closely related to increasing elevation, were the mid-elevation peak, or head-shaped curve (Lomolino 2001), a pattern that is often explained by the presence of an optimal climate at mid-altitude, by ecology influences, and/or by mid-domain effects.

The Mount Ungaran area in Central Java, Indonesia, is hilly and has many steep valleys. These conditions make the area a natural habitat for many rare animals and plants, but the habitat on Mount Ungaran is not completely original, because many locations have been converted to settlements, rice fields, coffee plantations, and tea plantations. Tourists also come to the area to climb Mount Ungaran. With the increase in the converted area, termite habitat has become increasingly narrow, reducing food sources for termites. Therefore, termites have expanded their range to find food, consequently causing damage to buildings, furniture, wood, cloth, paper, and other goods that contain cellulose (Subekti et al. 2018).

MATERIALS AND METHODS

Study area

This research was conducted in the north, south, east, and west slopes of the Mount Ungaran forest area, Central Java, Indonesia. This area is located at 7°10′48″S, 110°19′48″E, and it has an altitude ranging from 700 to 1300 m above sea level. This area was chosen because the location on Mount Ungaran has been converted into a residential area, rice fields, and others. The increase of the conversion area, the termite habitat becomes narrower and reduces the food source for termites, so that to find food, termites will expand their home range and look for food by eating whatever they find.

Procedures

Termite collection

Termites were sampled following the standard transect method (Viana-Junior et al. 2014). Mount Ungaran Forest was divided into four slopes (south, east, north, and west), and each slope was divided into six elevations (700-800, 801-900, 901-1000, 1001-1100, 1101-1200, and 1201-1300 m above sea level). Altitude is identified using GPS tools. A belt transect (100 m × 2 m^2) was placed in each height range vertically, and each 100 m belt transect was divided into 20 sections (5 m × 2 m^2).

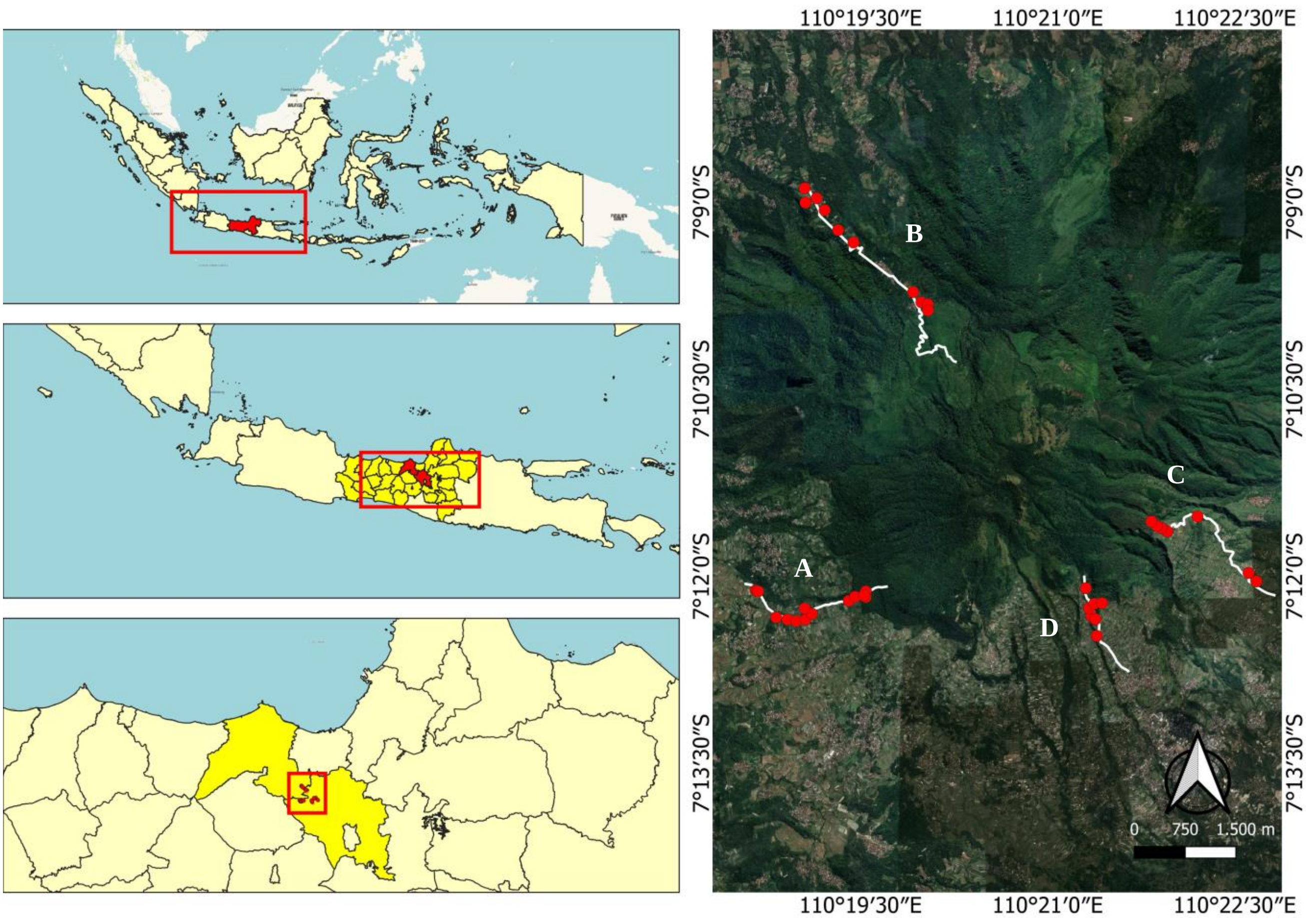

Figure 1. Location of termites found on Mount Ungaran: A. West line, B. South line, C. East route, D. North line. The yellow line indicates the exploration path, and each red dot indicates where termites were found

Sampling was carried out for 1 month, 1 week per slope, the number of people who took part in sampling on the 4 slopes was a team of 5 people, at each sampling point the 5 people spread from the specified point to take samples. In each section, 1-h searches were conducted for termites on the soil surface or humus, trees, roots, branches, and stumps, including arboreal nests up to 2 m above the ground. Nesting termites build hypogeal nests, which occur completely underground or partly above ground, while epigeal nests are aboveground mounds; arboreal nests are located in trees. Mainly soldiers and working castes were gathered. Collected specimens were stored in 70% alcohol for identification. The location of each termite found (hit) along the transect was marked using GPS, and locations were later used as an indicator of the relative abundance of a species in the plot. An encounter was defined as the presence of a species in one section (5 m × 2 m). Thus, the relative abundance of a species per transect was maximally 20 individuals (Muvengwi et al. 2017).

Termite identification

Specimens were photographed with a macro digital camera, and the original samples were identified using a microscope with a magnification of ×400. Termite samples were classified according to species identity, using information provided by Diba et al. (2013), Subekti and Syahadan (2021), and relevant references. Termites were also identified by matching their characteristics with the key of determination in the book Biology of Termites by Kumar Khrisna and Frances M. Weesner Volume II 1969.

Data analysis

All field data were analyzed descriptively, using the key of determination created by Khrisna and Weesner (1969). Data on the number of species diversity in GPS were attached in the form of a map to analyze the distribution of termites. Data were collected on the factors that affect various castes, including air temperature, humidity, air pressure, soil pH, soil moisture, and the state of vegetation. The statistical method used is the normalization test and one way ANOVA test, the program used is SPSS 17. The dependent variable was an environmental factor. Environmental factor data were collected every 100 m of the height reached, using GPS, soil sampling, and temperature and humidity measurement. Vegetation, air, and humidity data were collected using the plot square method. Temperature data were collected using a thermohydrometer. The tool was hung or placed around the sampling location, and measurements were collected 5-10 minutes later. Soil pH was measured using a soil tester; the electrode was inserted into the soil and results were recorded after a wait of 5-10 minutes. Soil moisture was measured as a percentage by inserting the electrode of a soil tester into the soil, pressing the white button on the soil tester, and then waiting 5-10 minutes to read the results.

RESULTS AND DISCUSSION

Termite diversity

The termite samples that were collected included two families, Rhinotermitidae and Termitidae. The family Rhinotermitidae consists of one subfamily, Coptotermitinae, and the species found was *C. curvignathus*. The Termitidae family consists of two subfamilies, Macrotermitinae and Nasutitermitinae. The subfamily Macrotermitinae consists of two genera: (i) *Macrotermes*, which has one species, *Macrotermes gilvus* Hagen, 1858 and (ii) *Odontotermes*, which has one species, *Odontotermes javanicus* Holmgren, 1912. The subfamily Nasutitermitinae consists of two genera: (i) *Nasutitermes*, which consists of the species *Nasutitermes matureensis* and (ii) *Bulbitermes*, which consists of the species *Bulbitermes constrictiformis* Holmgren, 1914.

Among the four slopes at Mount Ungaran, termites were found at 67 points. On the north slope, there were 21 points; the south slope had 18; the east slope had 18; and the west slope had 11. The list of termite species found on all slopes is presented in Table 1. The termite diversity and dominance indices on all slopes are shown in Table 2.

The effect of slope on termite diversity was significant, as seen from the one-way ANOVA (P=0.026). Before the ANOVA test was carried out, a normality test was first carried out on each slope, the Shapiro Wilk normality test for the eastern slope (P=0.656), the western slope (0.459), the northern slope (0.025), the southern slope (0.023). The effect of slope on the abundance of termites (hits) was likewise significant, with the exception of the altitude range 1201-1300 m asl where only a few termite species were found. The altitude gradient also had a significant effect on termite diversity (P<0.05) for all altitude ranges (700-1300 m asl) and termite abundance, except for the northern slope, where few termite species were found.

Table 1. Termite species dominance on each slope of Mount Ungaran, Central Java, Indonesia

Species	Slopes (%)			
	North	South	East	West
Coptotermes curvignathus	19.90	16.92	35.52	20.46
Odontotermes javanicus	00.00	11.53	17.19	18.34
Macrotermes gilvus	00.00	00.00	0.00	4.31
Nasutitermes matangensis	65.37	59.90	46.35	40.09
Bulbitermes constrictiformis	24.94	11.65	00.00	17.12

Table 2. List of Shannon-Wiener indices (H′) and dominance (Sorensen) indices (D) in each slope. This figure shows the percentage of termites on each slope

Data analysis	Slopes			
	North	South	West	East
Shannon-Wiener indices (H′)	1.217878836	1.137661	1.36608	1.44607
Dominance indices (D)	0.329924278	0.258881077	0.26077	0.25076

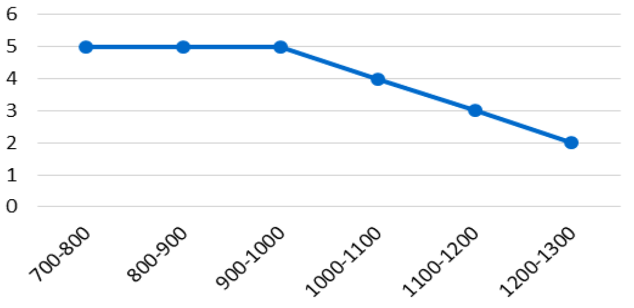

Figure 2. Correlation between the number of termite species and the altitude. Y-axis: Number of species found, X-axis: Slope height (masl)

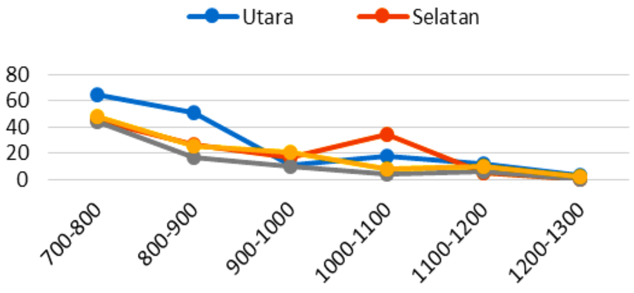

Figure 3. The pattern of correlation between altitudinal gradient with abundance (hits). The gray line is west, blue line is north, red line is south and yellow line is east

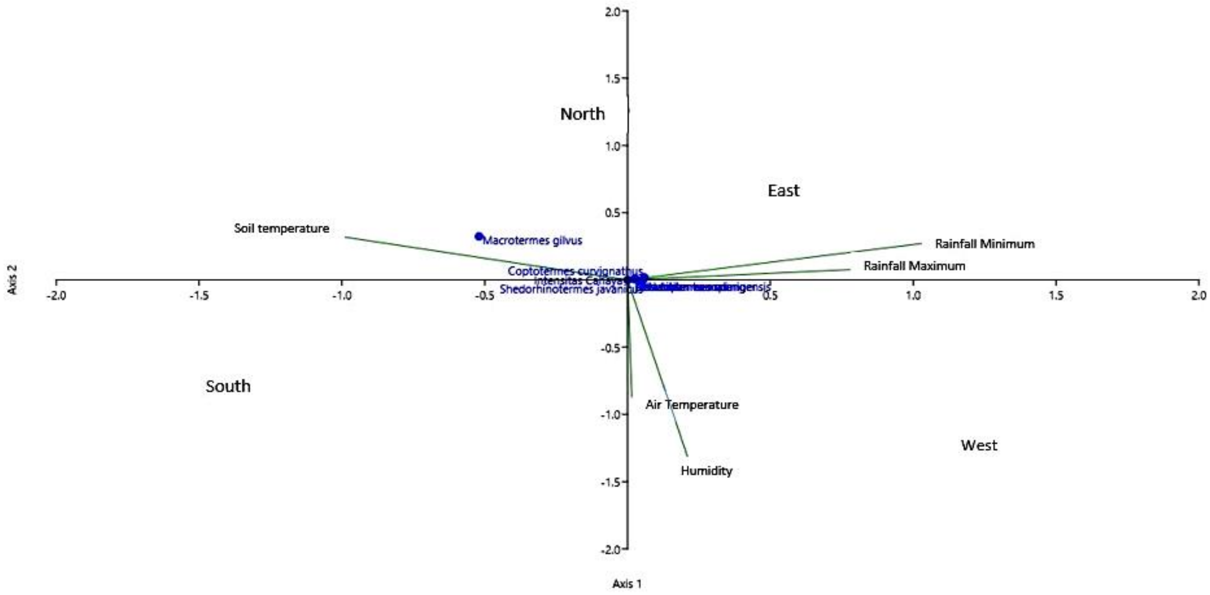

Figure 4. Visualization of ordination of eight environmental factors that have an impact on termite diversity and abundance. The termites are *Coptotermes curvignathus*, *Odontotermes javanicus*, *Macrotermes gilvus*, *Nasutitermes matangensis*, and *Bulbitermes constrictiformis*

The influence of eight environmental factors on the diversity and abundance of termites is shown in canonical correspondence analyses, as presented in Figure 4. The dependent variable in each analysis was an environmental factor. The closer the canonical correspondence of the dependent factor to the termite species, the more influential it is. The environmental factors that most influenced the abundance of the Rhinotermitidae and Termitidae families on Mount Ungaran were soil pH, light intensity, and canopy cover.

Discussion

Termite activity is influenced by several factors, including soil, vegetation type, climatic factors, food availability, and water. In their natural habitat, subterranean termites serve as a link connecting very important biogeochemical cycles, owing to their role as organic matter decomposers (Subekti et al. 2018). Consequently, it is important to understand the impact of the environment on termites.

Environmental variables

Termites are very susceptible to environmental conditions around them, especially temperature and humidity, both in the soil and in the air. Environmental factors that lead to conditions being less than what the termites need or exceed their tolerance limit will affect their survival, by wind/dry air, thus requiring stable humidity (Subekti et al. 2017). The results of observations of environmental factors can be seen in the table below.

Air temperature and soil temperature decrease with increasing altitude. In the current study, the average air temperature dropped from 30.5°C in the lower residential areas (700 m asl) to 22.5°C in the highest sampling area (1300 m asl), except on the west slope, which had the coldest temperature. This lower temperature was due to fog, which tends to be thick on the western slope. In foggy conditions, the soil temperature was 21°C, while the air temperature ranged from 22.4°C to 24.5°C; termites have an optimal temperature between 16°C and 35°C (Mairawita et al. 2022). The temperatures on the four slopes corresponded to the optimal temperature for termites, however, so many termites were living on the four slopes. The optimal temperature significantly affects the activity of the termite colony starting from 15°C to 38°C (Yang et al. 2020).

Soil pH is another factor that has a major influence on termite life. The pH of the soil on the four slopes in the current study ranged from 4.5 (acidic) to 7 (neutral). According to Subekti et al. (2019), the optimal pH for the growth and development of a termite colony is 6-7. However, the Termitidae and Rhinotermitidae families can tolerate acidic conditions and the acid and alkaline changes in the soil near the colony caused by the activity of the termites themselves (Li et al. 2017).

Humidity is an important environmental factor in termite cruising activity. Humidity serves as a signal for termites so that they do not venture to drier places. Subterranean termites such as Coptotermes and Macrotermes require high humidity. Coptotermes and Macrotermes colonies will develop optimally if they are at 75%-90% humidity (Subekti et al. 2019). Humidity on each slope was relatively the same in the current study at 70%-90%, except on the west slope, which had the highest humidity (up to 94%). Therefore, the humidity conditions on Mount Ungaran are very suitable for termite colonies.

Canopy cover on the north, west, and east slopes (75%, semi-open forest) was significantly different (p=0.026) from that on the south slope (25%), especially at moderate elevation locations (800-1100 m asl). Annual rainfall on the north and west slopes (5900-7900 mm) was higher at all elevations (700-1300 m asl) compared with the south and east slopes (5300-6300 mm). In addition, the light intensity on the east and west slopes was higher than on the north and south slopes (Table 2).

Altitude had a significant effect on termite abundance on each slope, as shown by the one-way ANOVA ($P<0.05$). Likewise, altitude had a significant effect on termite abundance (hits) on each slope, except in the altitude range of 1201-1300 masl, where only a few termite species were found. The effect of altitude gradient on termite diversity and termite abundance was also significant ($P<0.05$) for all altitude ranges (700-1300 m asl).

From December 2021 and January 2022, the study area received >500 mm of rainfall, indicating that the location of Mount Ungaran has an appropriate amount of moisture to support termite life. Rainfall triggers the development of termite colonies by stimulating reproductive castes to leave a nest and establish new ones (Subekti and Syahadan 2021). Reproductive castes will not leave a nest if rainfall is low, but rainfall that is too high can also reduce termite activity. In summary, rainfall has a direct physical effect on the life of termite colonies and especially on the process of nest building and colony formation.

Termites and slopes

The effect of slope on termite diversity was significant, as seen from the one-way ANOVA (0.001<0.05). The abundance of termites (hits) was also significantly different between slopes, except in the altitude range of 1201-1300 masl, where only a few termite species were found. The influence of slopes on termite diversity was also significant ($P<0.05$) for all slopes (north, south, east, west) and termite abundance, except for the northern slope where there were not too many termite species found.

Figure 2 shows that the number of species was relatively the same at an altitude of 700-1000 m asl but started to decrease at an altitude of 1100 m. This phenomenon is called the mid-elevation effect (Lomolino 2001). The majority of species richness studies in tropical invertebrate animals, including termites, show a moderate elevation peak pattern (Pratiknyo et al. 2018), which is attributed to factors such as anthropogenic disturbances and the limited study altitude range. This result is different from the research of Gathorny-Hardy (2001) in the Leuser Ecosystem, where the pattern of decreasing diversity with increasing altitude gradient is monotonic.

Each slope in the study area had high rainfall and high temperature. Based on the canonical correspondence analysis, rainfall was one of the environmental factors most correlated with the abundance of termites. Species *O. javanicus* and *M. gilvus*, which belong to the Macrotermitinae subfamily, had a small amount of dominance compared with this termite species. This finding can be explained by Macrotermitinae being a subfamily that is harmed by high rainfall, and species in this subfamily will be replaced by those of the subfamilies Nasutitermitinae and Termitinae in places with high rainfall.

The most abundant termite species on all slopes was *N. matangensis*. This species builds nests on the top of trees and on trunks, twigs, and undersides of trees. Their nests develop into lumps of earth that enlarge as the population increases (Haneda et al. 2017). The results showed that there were 5 different species of termites, namely *Coptotermes curvignathus*, *Odontotermes javanicus*, *Macrotermes gilvus*, *Nasutitermes matureensis* and *Bulbitermes constrictiformis*. Of the 4 slopes explored, the western slope is the slope with the highest termite abundance, while the diversity of termites on each slope is relatively the same. The most influencing environmental factors are soil pH, light intensity, and canopy closure.

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