

Termites community as environmental bioindicators in highlands: a case study in eastern slopes of Mount Slamet, Central Java

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ABSTRACT

Pribadi T, Raffiudin R, Harahap IS (2011) Termites community as environmental bioindicators in highlands: a case study in eastern slopes of Mount Slamet, Central Java. *Biodiversitas* 12: 235-240. Termites ecological behavior is much affected by land use change and disturbance level. Their variation in diversity can be used as bioindicator of environmental quality. However, termite community response to land use changes and habitat disturbance in highland ecosystems remains poorly understood. This study was conducted to investigate the response of termite community to land use intensification and to explore their role as environmental bioindicator in Mount Slamet. A standard survey protocol was used to collect termites in five land use types of various disturbance levels, i.e. protected forest, recreation forest, production forest, agroforestry, and urban area. It was found two termite families i.e. Rhinotermitidae and Termitidae with seven species, i.e. *Schedorhinotermes javanicus*, *Procapritermes* sp, *Pericapritermes semarangi*, *Macrotermes gilvus*, *Microtermes insperatus*, *Nasutitermes javanicus*, and *N. matangensis*. Termite species' richness and evenness, Shannon-Wiener index, relative abundance, and biomass of termite were declined along with the land use types and disturbance level from protected forest to urban area. Habitat disturbance was the main declining factor of termite diversity. Termite composition changed along with the land use disturbance level. Soil feeding termites were sensitive to the disturbance – they were not found in urban area. Hence, their presence or absence can be used as environmental bioindicator to detect habitat disturbance.

Key words: termite community, bioindicator, land use, environmental disturbance, Mount Slamet.

INTRODUCTION

Land use is a major cause of human ecological change in an ecosystem (NRC 2000). Changes in land use and intensity play major role on the destruction of habitat and biodiversity decline (Dale 1997; NRC 2000). Destruction of habitat and decline in biodiversity affect the ecosystem health and functions. Therefore, early detection mechanism that rapidly identifies changes in ecosystem conditions must be made. Early detection can be performed using a group of organisms in an ecosystem or habitat that describes the response to these changes.

An organism that can give respond (Weissman et al. 2006), indication (McGeoch 1998), early warning (Jones and Eggleton 2000; Dale and Bayeler 2001), or representation (Hilty and Merenlender 2000; Vanclay 2004), reflection (Noss 1990; Vanclay 2004), and information (McGeoch 1998) and also evaluation (Burger and Gochfeld 2001; Carignan and Villard 2002) of the condition and/ or changes that occur in an ecosystem called bioindicator. Bioindicator is an important component in ecosystem management and biodiversity conservation (Andersen 1999). The rationale of the existence of a bioindicator is the close relationship between the presence of these indicator organisms with biotic and abiotic parameters of an ecosystem (McGeoch et al. 2002). In

general, organisms that are promoted to be used as a bioindicator in terrestrial ecosystems are insects (Andersen 1999; McGeoch 2007).

One group of insects that could potentially be used as a bioindicator to assess the condition of ecosystems is termite. Termites have a key role in tropical ecosystems function (Bignell and Eggleton 2000). Termites are one of the main decomposer in tropical terrestrial ecosystems (Bignell and Eggleton 2000), and ecosystem engineers through their activities which help improve soil structure and nutrient cycling (Jones et al. 1994; Lavelle et al. 1997). In addition, termite species richness showed a high correlation to the diversity of other taxon groups in the same habitat (Vanclay 2004), and the complexity of vascular plants (Gillison et al. 2003). Termites also showed high sensitivity to environmental conditions, both biotic and abiotic that exposed them, as well as on ecosystem processes (Jones and Eggleton 2000).

Termite species richness declined due to land use (Eggleton et al. 2002; Jones and Prasad 2002; Jones et al. 2003; Attignon et al. 2005), habitat disturbance (Eggleton et al. 1995, 2002) and habitat fragmentation (Davies 2002). Relative abundance of termites has decreased due to land use (Jones et al. 2003), and fragmentation of habitat (Davies 2002). The structure of termite species composition was changed due to land use and habitat

disturbance. The group was a group of soil-eating termites which is the most sensitive group to habitat disturbance (Eggleton et al. 1995, 2002; Davies 2002; Jones and Prasad 2002; Jones et al. 2003). However, information on termite response to habitat disturbance or land use in the highlands (> 1000 ASL) was still lacking. In general, research on termite community response to land use was mostly conducted in the lowlands.

This study investigated the response of termites to land-use in Mount Slamet, the second largest mountain in Java. Eastern slopes of Mount Slamet (ESMS), is one of the areas with high variation of land use. In this area, there are protected forests, ecotourism, limited production forest managed by the Perum Perhutani, dry farmland, and settlements. This study aims to investigate the response of termite communities in ESMS of land use and review its role as a bioindicator of environmental quality.

MATERIALS AND METHODS

Location of the study. The research was conducted in the region eastern slopes of Mount Slamet (ESMS), from June to September 2008. Five locals were chosen for observation diversity of termites based on the level of habitat disturbance due to land use activities as defined by Bickel and Watanasit (2005) and Koneri (2007). The assessment was based on the level of habitat disturbance, namely: (i) the number of trees with large diameter (ϕ 20 cm), (ii) the existence of lower plants, (iii) the amount of canopy stratification, (iv) the direct exposure of sunlight to the ground, and (v) the level of accessibility to the region. Characteristics of each type of land use are presented in Table 1.

Termite sampling technique. The method used to observe the termites in the study was a method developed

by Jones and Eggleton (2000). Data obtained from this procedure was the taxonomic composition and functional groups of termites (eating or feeding groups) (Eggleton et al. 2002; Jones et al. 2005). Two termite transect was placed at each site, transects were placed in a purposive reason (placed on habitats that were invisible uniform) and cut the contour lines. Termites transect size of 100 m x 2 m, consisting of 20 sections (sections) with a size of 5 m x 2 m. Each section was examined and termites were caught on their microsite. The explored microsities were ground (inside and surface), litter, logs, and trees. Time needed to explore the existence of termites in each section was 30 minutes per person for two collectors (Jones and Eggleton 2000).

The observation points in every part of the termite transect consists of twelve areas on the surface of the land with an area of $\pm 50 \text{ cm}^2$. Each area was excavated at a depth of approximately 5 cm and the termites were collected. Dead wood with a diameter 1 cm found in every part of transect were dismantled and the termites in it were collected. Banir and pepagan layer were opened and termites found at the height of up to $\pm 2 \text{ m}$ were collected. Nest and mound (mound) in the open ground and termites that are found there were also collected (Jones and Eggleton 2000).

The collected termites were inserted in a tube containing 70% alcohol and labeled. The next step was specimens sorting and identifying. Initial identification was done until the level of morphospecies genus. Identification of termite specimens refer to the identification key of Ahmad (1958), Tho (1992) and Sornuwat et al. (2004). Relative Abundance (KR) was calculated based on the number of termites from the same species caught in each section along transect, so the KR values ranged from 0-20 for each transect. Relative abundance was compared with other locations. Termite biomass was measured by wet weight of 20 termites.

Table 1. Descriptions of each type of habitat of study sites.

| | Protected forests HL (I) | Wanawisata WW (II) | Forest production HP (III) | Agroforestry AF (IV) | Settlements PM (V) |
|---|--|--|--|--|--|
| Location | Gunung Keris, 07 ^o 15'22.9" S, 109 ^o 16'71.6" E. 1152 m asl | Pesanggrahan, 07 ^o 14'70.6" S, 109 ^o 17'50.5" E. 1012 m asl | Brubahan, 07 ^o 14'50.3.9" S, 109 ^o 17'71.7" E. 1124 m asl | Kali Pring, 07 ^o 15'18.1" S, 109 ^o 17'0.59" E. 1087 m asl | Brubahan, 07 ^o 14'84.6" S, 109 ^o 17'86.6" E. 1001 m asl |
| Plants | 3050/ha, LBD 115.95 m ² /ha. Dominated by pusa stands | 1200/ha, LBD 76.06 m ² /ha. Dominated by stands of dammar | 850/ha, LBD 92.20 m ² /ha. Dominated by stands of pinus | 1050/ha, LBD 21.98 m ² /ha. Dominated by stands of dammar | 900/ha, LBD 9.17 m ² /ha. |
| Canopy | 3 layers, tight | 2 layers, tight | 2 layers, open | 2 layers, more open | 1-2 layers, very open |
| Belowground plants | Land tightly covered, belowground plants high, 168.5/m ² | Land tightly covered, but belowground plants small, 90.5/m ² | Land tightly covered, but belowground plants small, 133.0/m ² | Land openly covered, belowground plants small, 270.5/m ² | Land mostly opened, belowground plants small, 155.3/m ² |
| Accessibility | Veryrare; hunting and looking for grass | Rarely; look for grass, an alternative route | Often; tapping pine, there is a field, near the settlement ($\pm 200 \text{ m}$) | Often; seasonal agricultural land | Very often; agriculture and settlement |
| Availability (early opening of the habitat) | Unknown | 1980 | 1980 | 1995 | Unknown |

Note: roman numerals on the types of land use information indicates the level of habitat dependence.

Table 2. Relative abundance of species of termites in five different types of land use in ESMS.

| Species | Land use type | | | | | Note |
|---|---------------|----|----|----|----|----------------|
| | HL | WW | HP | AF | PM | |
| <i>Pericapritermes semarangi</i> Holmgren | 16 | 3 | 6 | 6 | 0 | 31 TE, Te1, T |
| <i>Schedorhinotermes javanicus</i> Kemner | 9 | 4 | 8 | 1 | 1 | 23 RH, Rh1, K* |
| <i>Nasutitermes javanicus</i> Holmgren | 10 | 4 | 1 | 2 | 4 | 21 TE, Te3, K |
| <i>Macrotermes gilvus</i> Hagen | 0 | 0 | 0 | 0 | 5 | 5 TE Te2, K |
| <i>Microtermes insperatus</i> Kemner | 0 | 1 | 2 | 0 | 0 | 3 TE, Te2, K |
| <i>Procapritermes</i> sp. | 2 | 0 | 1 | 0 | 0 | 3 TE, Te1, T* |
| <i>Nasutitermes matangensis</i> Haviland | 2 | 0 | 0 | 0 | 0 | 2 TE, Te3, K |
| Total | 39 | 12 | 18 | 9 | 10 | 88 |

Note of land use type codes refer to Table 1. RH (Rhinotermitidae), Rh1 (Rhinotermitinae), TE (Termitidae), Te1 (Termitinae), Te2 (Macrotermitinae), Te3 (Nasutitermitinae). K (wood-eaters), T (feeds the soil). * Termite functional groups based on the classification of Donovan et al. (2000a). Signs (0) means not found termite species.

Analysis of data. Termite species richness (S) was calculated based on the number of species found per transect. Shannon-Wiener Index (H), Smith and Wilson evenness index (E) calculated with the help of the software Ecological Methodology (Krebs 1999). The relationship between land use (PL) and the level of habitat disturbance (TG) of the termite community (S, KR, H, E, and BM) were analyzed by ordination of Redundancy Analysis (RDA). Environmental parameters on the RDA which were most influential to the termite community structure were analyzed using Forward Selection method and were tested using Monte Carlo Permutation with 199 random permutations. The second analysis was conducted using Canoco Version 4.5 software (Ter Braak and Smilauer 2002). Log (x + 1) transformation was used to meet the parametric assumptions.

RESULTS AND DISCUSSION

The structure and composition of termite communities

Of the five sampling sites, there were totally seven species from two families of termites (Table 2). Rhinotermitidae Family was represented by the subfamily Rhinotermitinae, while Termitidae family was by three subfamilies, namely Termitinae, Nasutitermitinae and Macrotermitinae. *Nasutitermes javanicus* and *Schedorhinotermes javanicus* were found in all types of land use. While the termite species found only in one location was *M. gilvus* (settlements) and *Pericapritermes* sp. (Protected forest). The highest relative abundance of termites was in forest protection with 39 findings and lowest was in the settlements (10 findings). Termites biomass of on the type of land use of HL, WW, HP, AF and AM in a row was 1.33 ± 1.09 , 0.31 ± 0.15 , 0.81 ± 0.36 , 12.49 ± 0.20 and 0.34 ± 0.35 gr.m⁻² (Figure 1). At PM location, there were no eating soil termites and they were mostly found in HL and HP (Figure 2).

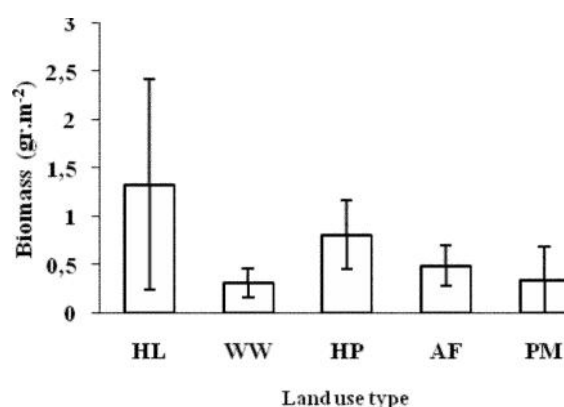


Figure 1. Biomass of termites in each of the different types of land use in ESMS. The value shown is the average value (x) with standard errors.

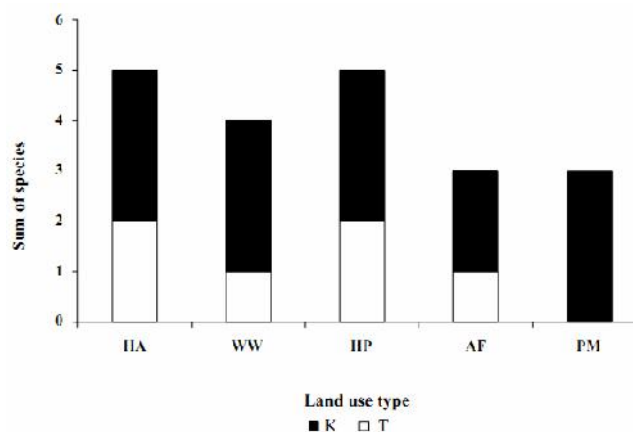


Figure 2. Comparisons between groups of wood-eating termites (K) with land eater (T) in each of the different types of land use in ESMS.

Termite species richness found in this study was much less compared to some researches on the diversity of termites in Sunda shelf biogeography for the plateau ecosystem conducted by Jones (2000) and Gathorne-Hardy et al. (2001). This was assumed to be caused by the reduction of natural forest existence and the effect of altitude. Gathorne-Hardy et al. (2001) suggested that the higher the location of the termite species, the richness decreased. Decline in termite species richness was due to reduced environmental temperature so that it slowed metabolism of termites. Extreme environmental conditions caused less species to survive. This was evidenced by the unavailability of Kalotermitidae Family in ecosystems at an altitude over 1000 m asl (Gathorne-Hardy et al. 2001) as well as in this research. In addition, the pool species theory could explain this phenomenon (Donovan et al. 2000b). Tho (1992) mentioned that the species of termites in Java (54 species) was less than in Borneo (90 species) and Sumatra (89 species). This was supported by research of Gathorne-Hardy et al. (2001) which stated that the size of an island contributed to the composition of termite species.

Subfamily of Rhinotermitidae, Macrotermitidae, Termitidae, subfamily Nasutitermitidae were commonly found in the Sunda Shelf (Tho 1992; Jones 2000; Gathorne-Hardy et al. 2001). Groups of soil-eating termites in the plateau were generally much less than in the lowlands. Groups of soil-eating termites on the plateau were Genus *Pericapritermes* and *Procapritermes* (Jones 2000; Gathorne-Hardy et al. 2001). Both genera were usually found in forested areas and it was different with *M. gilvus* which was associated with open or disturbed habitats (Gillison et al. 2003).

Negative effect of altitude on the presence of species had an association with soil-eating termites foraging strategy of each group of termites (Gathorne-Hardy et al. 2001). Soil-eating termites obtained energy from a mixture of mineral soil and humus and it brought to a result of less energy for a lower metabolic activity than the one obtained by wood-eating termites (Jones 2000). The increase of height correlated with the low temperature and it became the limiting factor in the metabolism of termites. Eating land termites had lower reserve of energy than the wood-eating termites so that soil-eating termites were more sensitive to the altitude change (Jones 2000; Gathorne-Hardy et al. 2001).

This study showed that different types of land use had caused a decrease in termite species richness, relative abundance of termites and termite biomass gradually from protected forest to the settlement area. Shannon-Wiener index did not correlate with the type of land use (Figure 3). Some studies also reported a decrease in species richness and relative abundance of termites (e.g. Eggleton and Bignel 1995; Eggleton et al. 1995; 1996; 1999; 2002; Jones and Prasad 2002; Gillison et al. 2003; Jones et al. 2003) and biomass termites (Eggleton et al. 1996; 1999) in response to changes in land use. However, in this study the response of land use on community structure (biodiversity) of termites did not show any significant effect ($\lambda = 0.00$, $p = 0.965$, $F = 0.07$) (Table 3). This was also suit with the study of Gathorne-Hardy et al. (2002) who concluded that

the decline in biodiversity termites are not influenced by the type of land use. But monoculture cropping systems (high habitat disturbance) significantly caused a decrease in termite species richness. Monoculture cropping system caused a decrease in the diversity of termites because it lowered microhabitat diversity to support the life of termites (Jones et al. 2003).

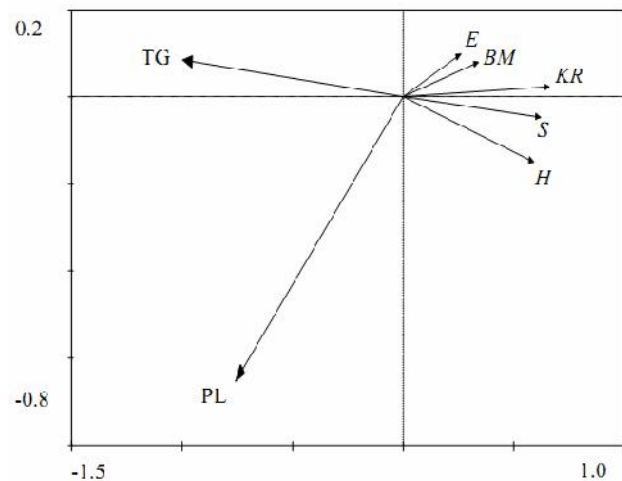


Figure 3. RDA ordination between levels of habitat disturbance (TG), types of land use (PL) with species evenness (E), biomass (BM), relative abundance (KR) and species diversity (H) and species richness (S) termites in five types of usage different land in ESMS. Description: The long arrows indicate the strength of correlation between parameters. Parameters with the same direction arrows mean positive correlation, whereas in the opposite direction of arrows means negative correlation and the direction perpendicular arrows between the parameter mean not correlated. The smaller the angle formed between two parameters means that the higher correlation (Ter Braak and Smilauer 2002).

Table 3. Summary results of the RDA ordination of environmental parameters influence the structure of termite communities in five different types of land use in ESMS.

| | Axis | | | |
|---|-------|---------------------|-------|-------|
| | 1 | 2 | 3 | 4 |
| Characteristic roots (eigen value) | 0.268 | 0.080 | 0.303 | 0.192 |
| Correlation termite community structure-environmental | 0.825 | 0.656 | 0.000 | 0.000 |
| Total inertia = 1.000 | | | | |
| Percentage variation (%) | 77.0 | 100.0 | | |
| Environmental parameters | | P | F | |
| The level of habitat disturbance (TG) | 0.38 | 0.038* | 4.84 | |
| Types of land use (PL) | 0.00 | 0.965 ^{un} | 0.07 | |

The level of habitat disturbance and its influence had significant negative correlation to the structure of termite communities ($\lambda = 0.38$, $p = 0.038$, $F = 4.84$) (Table 3). This was agreeing with research of Gathorne-Hardy et al. (2002). Disturbance of habitat is the main cause of decline of termites diversity in the Sunda Shelf. The mechanisms causing a decrease in diversity due to termite habitat disturbance were: (i) depreciation of canopy closure which

could lead to direct sunlight on the soil surface. These changes resulted in a decrease in humidity and an increase in environmental temperature so they formed a more extreme microclimate. The variation between daily temperature and high humidity affected the activity of termites; (ii) habitat disturbance affecting the decrease in the number and quality of the microhabitat. Reduced micro-habitats of termites might reduce the food supply of termites and their ability to nest; (iii) bulk density increase causing the soil to be denser and lowering the activity of termites, particularly subterranean termites. If more and more disturbed habitats, which have been affected first were the group of soil-eating termites (Eggleton et al. 1995, 1996, 1999; Jones and Prasad 2002; Jones et al. 2003). Groups of soil-eating termites required more stability of moist soil conditions and soil temperatures than wood-eating termites. The ideal habitat condition for groups of soil-eating termites was a tropical rain forest with dense canopy closure (Eggleton et al. 2002).

Termites community as a bioindicator

The group of soil-eating termites was the most sensitive one to habitat disturbance. Disturbed habitats reduced the proportion of soil-eating termites to wood-eating termites. In habitats with a high level of disturbance, the soil-eating termites did not exist at all. Some same studies also reported that the group of soil-eating termites was the group mostly affected by level of habitat disturbance such as termites group of genus *Procapritermes*, *Pericapritermes* and *Termes* (Eggleton and Bignell 1995; Eggleton et al. 1995, 1996, 1999, 2002; Gathorne-Hardy and Jones 2000; Gathorne-Hardy et al. 2002; Jones and Prasad 2002; Davies et al. 2003; Gillison et al. 2003; Jones et al. 2003). Thus, the response of soil-eating termites group on the level of habitat disturbance could be used as a bioindicator of environmental quality.

This was in accordance with the opinion of McGeoch (1998) which has stated that the bioindicator was an organism (or group of organisms) showing the sensitivity or tolerance to environmental conditions that make it possible to be used as an assessment tool of environmental conditions. Indicator species was a species that had amplitude on one or several influences of narrow environmental factors.

The proposal to use termites as a bioindicator has been proposed by Speight et al. (1999), Jones and Eggleton (2000), and Vanclay (2004). Basic information of termites has also been obtained as a comparison with other levels of disturbance. Hilty and Merenlender (2000) stated that organisms that serve as a bioindicator should show changes in response to pressure changes that occur. However, if the response was too strong it would provide inappropriate information. Groups of soil-eating species of termites had a response to a gradual level of pressure change. It is characterized by decreasing relative abundance and number of species of soil-eating termites that decreased gradually in response to changes in the level of habitat disturbance.

The determination of termites as a bioindicator was also supported by the standard method of observation (i.e. transect method) that could be used widely (Jones et al.

2006), and easily, and the results could be analyzed statistically (Hilty and Merenlender 2000; Hodkinson and Jackson 2005). Termites were easily measured, abundant, and had clear taxonomy.

CONCLUSION

Termite community was potential to be used as a bioindicator of habitat disturbance. The improvement of habitat disturbance was responded by the termite community with a decrease of termite community parameters (species richness, relative abundance, termite composition, termite biomass, termite species distribution and termite species diversity). However, the tendency was not detected significantly. The tendency that could be observed from this study was the absence of land-eating termite species in residential areas (most disturbed habitat). The absence of land-eating termite species in a habitat could be used as bioindicator for disturbed habitats (environmental quality).

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