



Original Article

Effect of a rubber plantation on termite diversity in Melawi, West Kalimantan, Indonesia

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ABSTRACT

One of the negative effects of rubber plantation expansion is the loss of biodiversity in the area. One of the widely used rubber plantation systems is rubber forest agroforestry, which is known to have little effect on biodiversity. This study compared termite species in rubber forest with those in the primary forest within Bukit Baka Bukit Raya National Park in Melawi, Indonesia. Two rubber forest sites (newly opened) and unproductive/old rubber forest, were chosen to estimate the long term effects of rubber forest on termite biodiversity. A standardized transect method was used for termite collection. In total, 35 termite species belonging to eight sub families were collected. Termite species richness in the old rubber forest decreased up to 62.5% compared to that in primary forest sites. In the newly opened rubber forest site, termite species richness was only slightly less than that of the primary forest sites. Termite species richness results corresponded with their functional groups, with no soil feeders found in the old rubber forest. Furthermore, the calculation of several diversity indices also confirmed the results. The results indicated that the expansion of rubber forest in the area appears to have adversely affected termite diversity more than expected.

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Introduction

Despite its social and economic contributions, rubber plantation expansion may have devastating environmental consequences and threaten biodiversity. The high demand for natural rubber for manufacturing industries in China has led to rapid land conversion for rubber plantation in continental Southeast Asia. Furthermore, unsustainable rubber plantation systems such as shifting cultivation and monocultures could immensely reduce biodiversity and water resources in the region (Ziegler et al., 2009; Ahrends et al., 2015).

Indonesia is the second largest rubber producer and exporter country in the world with an annual production of more than 3 million t (Indonesian Ministry of Agriculture, 2014). One of the main regions for rubber production is Melawi, West Kalimantan province. Although the introduction of rubber trees in the province started in the early 1900s (De Jong, 2001), studies on biodiversity in rubber plantations/forest areas are still limited. Melawi is located in

the “Heart of Borneo” area that is known to have high biodiversity (Normile, 2010).

Arthropods are commonly used to study the effects of plantations or other agricultural activities on biodiversity since they are one of the groups that are directly influenced by forest disturbance. The arthropods in rubber plantations which are commonly studied include beetles (Meng et al., 2012), canopy spiders (Zheng et al., 2015), ants (Sanabria et al., 2016), and termites (Arifin et al., 2016). The strong association between land use and arthropod communities is likely due to changes in habitats resulting from agricultural practices such as canopy clearance, tillage, lime addition and fertilization (Neoh et al., 2015).

Considering their ecological function as decomposers and soil engineers, and their sensitivity to environmental changes, termites are frequently used as a bioindicator for environmental quality (Pribadi et al., 2011). The effect of land conversion into plantations on diversity is often studied through the presence of termites. Compared to other plantations such as coffee, palm oil, and annual crops, termite diversity is less affected by rubber plantations (Neoh et al., 2015; Sanabria et al., 2016). A study on the effects of a rubber plantation on termite diversity showed that rubber plantations, especially in a rubber forest system, only slightly reduced termite

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diversity compared to secondary forest (Jones et al., 2003). Furthermore, the presence of *Macrotermes gilvus* and its nests in rubber plantation is known to have positive effects in the area since the termite can alter the soil physico-chemical characteristics to be more favorable to plants (Arifin et al., 2016).

Generally, termite diversity will decrease along with the disturbance level. However, alteration in termite diversity in rubber plantations and the surrounding areas within a given period is underexplored. In the present study, termite species diversity in a newly opened and old rubber forest sites was compared to the adjacent tropical primary forest in Melawi, West Kalimantan, Indonesia. Species richness and its functional group were analyzed, including calculation of several ecological diversity indices.

Materials and methods

Study sites

Data were collected in Melawi district, on the border of West Kalimantan and Central Kalimantan provinces (Fig. 1). Termites were collected from four sites during April 2013. The sites represent undisturbed tropical forests compared with old and new rubber plantations nearby. The location for the tropical rainforest was Bukit Baka Bukit Raya National Park (BBBRNP). This national park is a 181,090 ha conservation area located between 112°12'12.345"–112°56'31.295"E and 0°28'41.32"–0°56'22.252"S in the heart of Borneo Island (Bukit Baka Bukit Raya National Park, 2012). Annual rainfall in this area is more than 3000 mm without a distinctive dry season (Indonesian Agency for Meteorology Climatology and Geophysics, 2016). Sampling sites in the BBBRNP were conducted in a dipterocarp forest ecosystem. This type of ecosystem constitutes 46% of the total area of the national park. The old rubber plantation was located next to the nearest village from the BBBRNP border (around 10 km), while the new rubber plantation area was located in the buffer zone of the BBBRNP. The environmental characteristics of each study site are summarized in Table 1.



Fig. 1. A map of Borneo, termite sampling location (X) in Melawi, West Kalimantan, Indonesia.

Site 1. Rubber forest (RF) consisting of old secondary/regenerating closed canopy forest located approximately 1 km from Belaban Ella village, sub district Menukung, district Melawi, West Kalimantan province. The village was established in the mid-1970s and has a population of around 800 people. This site was basically an unproductive rubber plantation. The trees were planted in the early 1980s by the villagers. This location was dominated by rubber trees (*Hevea brasiliensis*), with several fruit plants such as durian (*Durio zibethinus*), jackfruit (*Artocarpus heterophyllus*) and mango (*Mangifera indica*). In some parts, there were trees that had been cleared by the locals for their daily needs.

Site 2. New rubber forest (NRF) consisting of young secondary/regenerating forest with disturbed canopy. The site was originally a primary forest illegally cleared by the locals for rubber plantation in 2009. In addition, the area was treated with herbicide (glyphosate based) before planting the rubber trees. Dead logs, stumps and dead wood were abundant on this site, which has resulted in the location having a higher light intensity, lower humidity, and higher temperature than the other sites. The site had an area of at least 1 km² dominated by young rubber trees and a few big trees of *Shorea virescens* and *Sandoricum koetjape*.

Site 3. Primary forest 1 (PF1). This site was in a lowland dipterocarp forest located inside the BBBRNP. The forest was dominated by high-value trees like *Calophyllum kunsteri*, *Octomeles sumatrana*, *Shorea laevifolia*, *Cratoxylon* spp., *Dryobalanops* spp., *Dryobalanops beccarii*, *Diterocarpus* spp., *Litsei* spp., *Shorea* spp. and *Shorea atrinervosa*. The termite sampling site was next to a stream of the Ella River (around 20–50 m from the water).

Site 4. Primary forest 2 (PF2). Another site was chosen in the BBBRNP area for comparison. This area was also in lowland dipterocarp forest. The site was chosen because it was located deeper into the forest and quite far from the nearest water source (about 750 m from the water) and separated by cliffs. The trees were dominated by *Shorea* spp., *Sterculia foetida*, *Litsea* spp., *Quercus* sp. and *Shorea virescens*.

Termite collection and identification

A standardized transect method described by Jones and Eggleton (2000) was used at each site. The protocol provides a semi-quantitative measure of relative abundance based on the number of encounters of each termite species in a transect. This method could be used for comparing species richness and abundance among sites since the method standardizes sampling effort and area. Since the RF and NRF sites were less than 1 km², only one transect on each site was established. In the primary forest, two sites were chosen to have differences in their microhabitats. Furthermore, these two primary forest sites were approved by the BBBRNP for research purposes.

Each transect was 100 m × 2 m and divided into 20 sections of 5 m × 2 m. In each section, 1 h (two people for 30 min) was spent in search of termites. The collectors searched for all types of microhabitats in which termites were likely to appear in each section. This included termite mounds and nests, inside tree stumps, roots, dead logs, branches and twigs up to 2 m above the ground. The soil beneath logs and some soil scrapes (12 cm × 12 cm–10 cm depth) were also sampled. Termites encountered were kept in tubes containing 70% ethanol.

Soldier castes of termites were used for identification. Termites were identified and sorted to the species level whenever possible based on termite identification keys by Ahmad (1958), Ahmad (1965), Sornnuwat et al. (2004), and Engel (2011), and other relevant references.

Table 1
General environmental characteristics of the four sampling sites.

	Site 1 (RF)	Site 2 (NRF)	Site 3 (PF1)	Site 4 (PF2)
Ecosystem	Old secondary closed canopy forest	Secondary/regenerating forest with disturbed canopy	Primary lowland dipterocarp forest	Primary lowland dipterocarp forest
Coordinates	00°31'53.0" S; 112°11'27.5" E	00°34'50.9" S; 102°13'09.9" E	00°36'06.3" S; 112°14'43.7" E	00°37'37.6" S; 112°15'34.2" E
Temperature	31 °C	30 °C	27 °C	29.5 °C
Relative humidity	96.50%	75%	99%	95%
pH	6	5	6.5	5
Altitude (m above mean sea level)	107	353	364	300

Functional groups

Collected termites were categorized into one of the four feeding groups following the classification by [Donovan et al. \(2001\)](#). The classification is based on the worker gut and mandibles characteristics, which correlate to feeding preferences along a humification gradient of the dietary substrate. The feeding groups were: Group I, termites that feed only on wood, particularly lower termites of Kalotermitidae and Rhinotermitidae; Group II, some Termitidae species that have a wide range of feeding habits, including wood-feeding, litter-feeding and microepiphyte-feeding; Group III, species of the Termitidae that feed on organic-rich soil or highly decayed soil-like wood; and Group IV, species of the Termitidae that feed on soil with low organic content or true soil-feeders.

Data analysis

Different indices were calculated to identify the diversity pattern of the sites. Diversity indices at each site were analyzed based on [Magurran \(1998\)](#). Eight diversity indices comprising three dominance indices (Simpson's D, McIntosh D, and Berger-Parker d), three evenness indices (McIntosh E, Shannon E, and Brillouin E) and two diversity indices (Shannon H' and Brillouin HB) were calculated using R 3.0.0 ([R Core Team, 2013](#)). Then, each set of indices was ranked and Kendall's coefficient of concordance (W) was calculated based on [Siegel and Castellan \(1988\)](#).

Results

Termite assemblage and functional groups

In total, 35 species of termites were collected from the four study sites ([Table 2](#)). The termites consisted of 2 families, 8 sub families, and 19 genera. The Nasutitermitinae and Termitinae were the dominant sub families; with compositions of 29% and 26%, respectively. Meanwhile, The Mirocapritermitinae was the least-represented subfamily, with only one species found.

Generally, no genus predominated, but the most species-rich genus was *Bulbitermes* with five species. Termite collection was dominated by feeding Group II (54%). The wood nesting termites dominated (57%). Furthermore, arboreal nest termites were absent in NRF which might have been caused by the lack of big trees on the site.

The PF1 site had the highest species richness with 16 species, while PF2 and NRF had similar species richness with 13 species. The lowest species richness was recorded at the RF site where only six species were found ([Fig. 2](#)). NRF was the most diverse site with seven subfamilies, followed by PF1 and PF2 (both had five sub families) and RF was the least diverse site with only four sub families.

Additionally, the Nasutitermitinae and Amitermitinae were present at all sites. The Termitinae, as the second largest taxonomic group, were absent only at the RF site, while the Mirocapritermitinae were only present at PF2. The Termitinae and Nasutitermitinae were the dominant sub families at primary forest sites (PF1 and PF2). It was also interesting that the Coptotermitinae were only present at sites with rubber trees (RF and NRF) ([Fig. 2](#)).

When comparing functional groups, wood feeding species had the highest proportion (74%). Feeding Group II was found at all sites while feeding Group I was absent at PF2. Group III was common at the PF1 and PF2 sites, with a few in the NRF but absent in the RF ([Fig. 3](#)). In other words, wood feeding termites (Groups I and II) dominated the RF and NRF sites (rubber forest sites). In the primary forest sites (PF1 and PF2), the composition of wood- and soil-feeding species was relatively similar. Furthermore, termite relative abundance (encountered) was the highest in PF1 and the lowest in RF, which was expected because termites in the primary forest should be more abundant than those in rubber forest.

Effect of rubber plantation on termite species richness

Several indices were calculated to compare termite diversity and abundance between sites ([Table 3](#)). The dominance and evenness indicated that the NRF, PF1 and PF2 sites had similar species richness and the species were more evenly distributed than in the RF. Termite species composition in the RF seemed more disturbed than for the other sites. Furthermore, this was confirmed by the Shannon and Brillouin diversity indices. The Shannon diversity index (H') of 1.474 at the RF site was far less than for the other sites which ranged from 2.415 to 2.463. The Brillouin diversity index also showed a similar pattern among sites.

Kendall's coefficient of concordance (W) was calculated to measure the agreement among indices and was 0.58 ($p < 0.0029$), indicating reasonably good consensus among indices. According to the diversity indices calculated, termite diversity in the transect decreased from PF1 > PF2 > NRF > RF. Higher diversity indices in PF1 than PF2 and NRF might also indicate that a water source is an important factor for termite diversity.

Discussion

To study the long term effect of the rubber forest on termite diversity, termite species richness was compared at two rubber forests sites of different ages. Termite species richness in the primary forest in the BBRNP was used as a control. Rubber forest or jungle rubber is a manmade forest with a high concentration of rubber trees, complemented with temporary food and cash crops. It is a balanced and diversified system usually derived from swidden cultivation ([Gouyon et al., 1993](#)). It is a widely used system in West Kalimantan for natural rubber production and has been used since the introduction of rubber plants to the area in the early 1900s ([De](#)

Table 2

List of 35 termite species collected and number of encounters at the four study sites, Melawi, West Kalimantan.

	Feeding group	Nesting group	RF	NRF	PF1	PF2
Rhinotermitidae						
Coptotermitinae						
<i>Coptotermes curvignathus</i> (Holmgren)	I	W	2	1	—	—
<i>Coptotermes havilandi</i> (Holmgren)	I	W	—	1	—	—
Heterotermitinae						
<i>Reticulitermes chinensis</i> (Snyder)	I	E	—	—	1	—
<i>Reticulitermes flaviceps</i> (Oshima)	I	W	—	1	—	—
Rhinotermitinae						
<i>Schedorhinotermes bidentatus</i> (Oshima)	I	W	—	4	—	—
<i>Schedorhinotermes longirostris</i> (Brauer)	I	W	—	2	—	—
<i>Schedorhinotermes</i> sp1.	I	W	—	1	2	—
Termitidae						
Amitermitinae						
<i>Globitermes globosus</i> (Haviland)	II	W	—	—	—	1
<i>Globitermes sulphureus</i> (Haviland)	II	W	—	—	—	1
<i>Microcerotermes distans</i> (Haviland)	II	a/s/w	—	—	—	3
<i>Microcerotermes serrula</i> (Desneux)	II	W	1	1	—	—
<i>Prohamitermes mirabilis</i> (Haviland)	II	E	—	—	1	—
Macrotermitinae						
<i>Hypotermes winifredae</i> (Ahmad)	II	S	—	1	—	2
<i>Macrotermes malaccensis</i> (Haviland)	II	S	1	1	—	3
<i>Odontotermes latigula</i> (Snyder)	II	E	—	1	—	—
Mirocapritermitinae						
<i>Pseudocapritermes</i> sp1.	III	W	—	—	—	2
Nasutitermitinae						
<i>Bulbitermes borneensis</i> (Haviland)	II	A	1	—	1	—
<i>Bulbitermes gedeensis</i> (Kemner)	II	A	6	—	3	—
<i>Bulbitermes kraepelini</i> (Holmgren)	II	A	—	—	—	1
<i>Bulbitermes sarawakensis</i> (Haviland)	II	W	1	—	—	—
<i>Bulbitermes</i> sp.1	II	A	—	—	1	—
<i>Hospitalitermes diurnus</i> (Kemner)	II	W	—	3	—	—
<i>Hospitalitermes hospitalis</i> (Haviland)	II	S	—	—	1	1
<i>Longipeditermes longipes</i> (Haviland)	II	W	—	2	3	—
<i>Nasutitermes longinasus</i> (Holmgren)	II	W	—	—	—	2
<i>Nasutitermes taylori</i> (Light & Wilson)	II	S	—	—	2	—
Termitinae						
<i>Angulitermes obtusus</i> (Holmgren, K & N)	II	e/s	—	—	5	—
<i>Capritermes distinctus</i> (Holmgren)	III	E	—	—	—	1
<i>Dicupiditermes makhamsensis</i> (Ahmad)	III	a/s/w	—	—	8	—
<i>Discupiditermes</i> sp1.	III	W	—	—	1	—
<i>Pericapritermes buitenzorgi</i> (Holmgren)	III	W	—	—	—	1
<i>Pericapritermes semarangi</i> (Holmgren)	III	s/e	—	—	2	4
<i>Pericapritermes latignathus</i> (Holmgren)	III	s/w	—	1	7	2
<i>Pericapritermes</i> sp1.	III	W	—	—	1	—
<i>Termes comis</i> (Haviland)	III	S	—	—	1	—

RF = rubber forest, NRF = new rubber forest, PF1 = primary forest 1, PF2 = primary forest 2, Feeding groups: I and II = wood-feeders, III = humus soil-feeders. Nesting groups: nesting in wood (w), subterranean nests (h), epigeal mounds (e), arboreal nests (a).

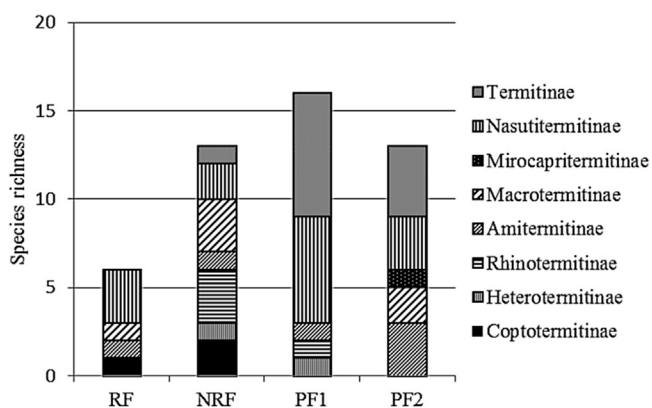


Fig. 2. Relative species richness of termites collected at the four study sites, Melawi, West Kalimantan. Each bar represents sub families found on each site, where RF = rubber forest, NRF = new rubber forest, PF1 = primary forest 1, PF2 = primary forest 2.

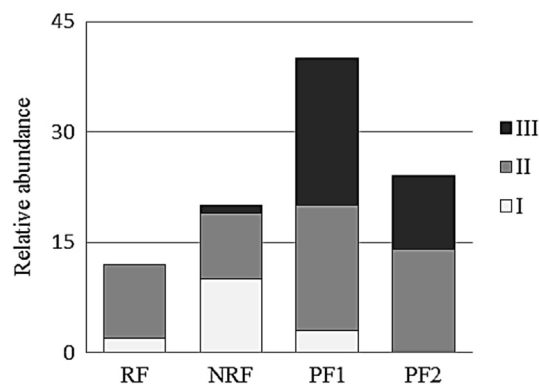


Fig. 3. Termite feeding group and its relative abundance at the four study sites, Melawi, West Kalimantan. Relative abundance is the number of termite encounters with each species in a transect, where RF = rubber forest, NRF = new rubber forest, PF1 = primary forest 1, PF2 = primary forest 2.

Table 3

Several ecological diversity indices calculated for the four study sites, Melawi, West Kalimantan.

Site	N	S	N _{max}	N _{min}	Dominance			Evenness			Diversity	
					Simpson (D)	McIntosh (D)	Berger-Parker (d)	McIntosh (E)	Shannon (E)	Brillouin (E)	Shannon (H')	Brillouin (HB)
RF	12	6	6	1	0.242	0.629	0.500	0.756	0.822	0.803	1.474	1.060
NRF	20	13	4	1	0.058	0.871	0.200	0.935	0.942	0.850	2.415	1.799
PF1	40	16	8	1	0.087	0.794	0.200	0.891	0.888	0.814	2.463	2.019
PF2	24	13	4	1	0.058	0.865	0.167	0.952	0.952	0.826	2.441	1.885

RF = rubber forest, NRF = new rubber forest, PF1 = primary forest 1, PF2 = primary forest 2, N = total number of encounters, S = number of species, N_{max} = maximum number of encounters of each species, N_{min} = minimum number of encounter each species.

Jong, 2001). The main advantage of this land use system is its function as a reservoir of functional diversity and stability in monoculture-dominated production landscapes (Mumme et al., 2015). As mentioned earlier, two sites were chosen to represent the area near water (PF1) and far from water (PF2) in the BBRRNP area. The microclimatic differences between the two sites were similar. At the PF1 site, a considerable amount of dead logs carried down by the stream were also found. Consequently, plant diversity and human activity were also higher in this area than at the PF2 site.

The lowest termite species richness was in the RF where it was 62.5% compared to that at the PF1 site. On the other hand, termite species diversity seems less affected in the NRF. Aside from the environmental conditions of original forest that might still be present in the NRF, the canopy cover condition at this site seemed to be different from previous studies. A complete or near complete canopy would result in higher termite species richness in West Africa and Cameroon, even though the area is disturbed. (Dibog et al., 1999; Eggleton et al., 2002). Wong et al. (2016) also showed that termite biomass in oil palm plantations, which have a nearly closed canopy, was similar to that in secondary forest. The canopy condition at Melawi seems to contradict this concept. However, a study by Jones et al. (2003) mentioned that in sites where dense swards are available, as in the present study, overhead vegetation might have less impact on the microclimate. The presence of dense swards of *Imperata* grass in the NRF site might have created a multi-layered canopy structure that might be beneficial to termites.

The negative effect of the newly opened rubber forest in Melawi was seen on the loss of arboreal nests and diminished forager termites (Nasutitermitinae). The lack of big trees and other overhead vegetation might have resulted in a higher temperature and lower humidity that were not suitable for arboreal nesting termites nor foraging termites. Additionally, the presence of *Coptotermes* species at the rubber trees sites (RF and NRF) also confirmed that this termite is closely related to rubber trees. *Coptotermes*, particularly *C. curvignathus*, is a termite species called the rubber termite because its economic importance was first identified in the rubber industry. *C. curvignathus* is more destructive of rubber trees/wood compared to other species such as teak (*Tectona grandis*), casuarina pine (*Casuarina equisetifolia*), acacia (*Acacia mangium*), and other exotic woods (Wong et al., 1998).

High termite diversity at the primary forest sites (PF1 and PF2) was as expected. Higher species richness in PF1 than PF2 was probably caused by the water availability which seems to create a favorable microclimate for termites. At both primary forest sites, foraging termites were easily spotted. They were found foraging from morning until late evening. The domination of the Termitinae and Nasutitermitinae in the primary forest in this study corresponded to other studies conducted in other parts of Indonesia and Malaysia, such as in South Kalimantan (Jones and Prasetyo, 2002), Sumatra (Gathorne-Hardy and Eggleton, 2001; Jones et al., 2003; Neoh et al., 2016), Sabah (Eggleton et al., 1997, 1999; Jones, 2000) and Sarawak (Vaessen et al., 2011). However, compared to other

Southeast Asian countries, the primary forests in Thailand and Vietnam are generally dominated by the Termitinae and Macrotermitinae (Davies, 1997; Inoue et al., 2006; Manh Vu et al., 2007; Neoh et al., 2015).

In terms of feeding groups, a balanced composition of wood- and soil-feeding termites at the primary forest sites was found as predicted. However, the absence of soil feeding termites in the RF indicated that there little or no organic-rich soil or highly decayed soil-like wood at the site. A few soil feeding termites present in the NRF also indicated that there was far less organic-rich soil or highly decayed soil-like wood at the site than in PF1 and PF2 but a little more than in the RF. This condition suggested that rubber forest in Melawi might have a more adverse effect than anticipated on termite diversity. A study by Jones et al. (2003) showed that the composition of soil-feeding termites in rubber forest and rubber plantation within a similar age in Jambi, Central Sumatra was more than 50%. Compared to other plantations, soil-feeding termites also constituted more than 50% of all feeding group in the reforestation area of teak and in mango orchards (Coulibaly et al., 2016; De Paula et al., 2016). A lower soil-feeding termite composition was observed in an oil palm plantation (Luke et al., 2014; Wong et al., 2016).

In summary, the existence of rubber forest in Melawi might have more adverse effects on termite species richness as well as its functional diversity. A decrease of more than 60% in species diversity and the loss of the soil-feeding group in the rubber forest in Melawi was far worse than in any other area that has been studied. In Central Sumatra, termite species loss in rubber jungle was 38% (Jones et al., 2003), while in Vietnam, termite species richness in rubber plantation was slightly higher compared to that in natural forests (Neoh et al., 2015). Unfortunately, due to the lack of environmental parameters recorded in the present study, factors that may affect species richness in rubber forests cannot be identified. Furthermore, since the termites do not seem to affect the rate of decomposition in rubber forests in the area studied, research to determine factors affecting decomposition in rubber plantations should be conducted.

Conflicts of interest

The authors declare that there are no conflicts of interest.

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