J. MANUSIA DAN LINGKUNGAN, Vol. 17, No.1, Maret 2010: 26-36

IMPACT OF TROPICAL RAIN FOREST CONVERSION ON THE DIVERSITY AND ABUNDANCE OF TERMITES IN JAMBI PROVINCE

(Dampak Konversi Hutan Tropika Basah Terhadap Keragaman Jenis dan Kelimpahan Rayap di Provinsi Jambi)

Suryo Hardiwinoto*, Sri Rahayu P., Widyatno*, Haryono Supriyo** and F.X. Susilo*****

*Faculty of Forestry, Universitas Gadjah Mada, Yogyakarta, Indonesia,
Email: suryohardiwinoto@yahoo.com

** Faculty of Forestry, Universitas Lancang Kuning, Pekanbaru, Riau, Indonesia,

*** Faculty of Agriculture, Universitas Lampung, Bandar Lampung, Indonesia

Diterima: 30 April 2009 Disetujui: 29 Juli 2009

Abstract

The degradation of tropical rain forest might exert impacts on biodiversity loss and affect the function and stability of the ecosystems. The objective of this study was to clarify the impacts of tropical rain forests conversion into other land-uses on the diversity and abundance of termites in Jambi, Sumatera. Six land use types used in this study were primary forest, secondary forest, rubber plantation, oil-palm plantation, cassava cultivation and *Imperata* grassland. The result showed that a total of 30 termite species were found in the six land use types, with highest species richness and abundance in the forests. The species richness and the relative abundance of termites decreased significantly when the tropical rain forests were converted to rubber plantation and oil-palm plantation. The loss of species richness was much greater when the forests were changed to cassava cultivation and *Imperata* grassland, while their abundance greatly decreased when the forests were degraded to *Imperata* grassland. Termite species which had high relative abundances in primary and secondary forests were *Dicuspiditermes nemorosus, Schedorhinotermes medioobscurus, Nasutitermes longinasus* and *Procapritermes setiger.*

Keywords: tropical rain forest, land-use conversion, termite, diversity, abundance

Abstrak

Kerusakan hutan tropika basah dapat menimbulkan dampak lingkungan berupa penurunan keanekaragaman hayati serta terganggunya fungsi dan stabilitas ekosistem. Tujuan dari penelitian ini adalah untuk mengetahui dampak konversi hutan tropika basah menjadi bentuk penggunaan lahan lain di Jambi Sumatra terhadap keragaman jenis dan kelimpahan rayap. Enam tipe penggunaan lahan yang digunakan dalam penelitian ini adalah hutan primer, hutan sekunder, tanaman karet, tanaman kelapa sawit, kebun ketela pohon dan padang alang-alang. Hasil penelitian menunjukkan bahwa ditemukan 30 jenis rayap pada 6 tipe penggunaan lahan tersebut, dengan keragaman jenis dan kelimpahan individu rayap tertinggi pada lahan hutan. Kekayaan jenis dan kelimpahan relatif rayap menurun secara nyata apabila ekosistem hutan dikonversi menjadi tanaman karet dan kelapa sawit. Penurunan kekayaan jenis menjadi jauh lebih besar ketika hutan dikonversi menjadi kebun ketela pohon dan padang alang-alang. Kelimpahan individu rayap akan sangat menurun apabila terjadi perubahan ekosistem hutan menjadi padang alang-alang. Jenis-jenis rayap yang mempunyai kelimpahan tinggi pada ekosistem hutan adalah ***Dicuspiditermes nemorosus, Schedorhinotermes medioobscurus, Nasutitermes longinasus*** *dan* ***Procapritermes setiger.***

Kata kunci: hutan tropika basah, konversi lahan, rayap, keragaman jenis, kelimpahan

INTRODUCTION

The nature is comprised of the biological diversity; although not apparent to the naked eye, the soil is one of the most diverse habitats on earth and contains one of the most diverse living organisms (Giller *et al.*, 1997). Activity of soil fauna may contribute to soil profile differentiation by modifying the physico-chemical soil properties (turn-over and displacement of soil, aeration, porosity, drainage etc.). According to Luxton (1982), the soil fauna function by fragmenting organic matter and increasing the surface area available for microorganisms. The soil fauna activities can disseminate spores, mycelia of fungi and bacteria partaking in the decomposition process of the litter. Soil fauna convert litter into smaller fragments and feces, increasing the surface area and modifying the substrate for further microbial colonization and use. The soil fauna takes important roles in the soil ecosystem in decomposition process, carbon cycling, nutrient cycling, and soil aggregation.

Termites are major decomposers in tropical regions and play important role in soil processes (Jones *et al.*, 2003). They are major dominant macro-arthropod detritivores in many tropical soils, and are particularly diverse and abundant in lowland equatorial forests (Wood and Sands 1978; Collins 1983; Eggleton *et al.* 1999; Eggleton 2000; Jones *et al.*, 2003). Termite and earthworm have been shown to affect the physical structure of the soil and influence nutrient dynamics through their effect on immobilization and humification (Lavelle *et al.*, 1993). Termites are major agents of decomposition, and play an important part in nutrient and carbon fluxes (Bignell *et al.*, 1997; Jones *et al.*, 2003). Termite activities such as soil feeding, subterranean tunneling, mound building, maintains macro-pore structure, redistributes organic matter and improves soil stability and quality (Holt and Lepage 2000; Donovan *et al.*, 2001; Jones *et al.*, 2003).

Lowland tropical forests are the species-rich terrestrial habitats and have a high diversity of soil organisms. Over recent decades natural tropical forest has been converted to agricultural and silvicultural systems (Noble and Dirzo 1997; Tilman *et al.*, 2001). Soil faunal communities show a variety of reactions to changes induced by land management. Their abundance and diversity are indicators of the quality of soils and influence soil organic matter dynamics, nutrient contents and physical parameters such as bulk density, porosity and water availability (Lavelle *et al.*, 1994). Soil fauna and soil organism can be used as a bio indicator on the effect of environmental changes (Paoletti *et al.*, 1992). Most of Jambi Province in the central part of Sumatera, in 1932 was covered by natural rain forest vegetation, but since 1994 the natural forest has been changed and converted into other land-uses (Van Nordwijk *et al.*, 1995).

Conversion of tropical rain forest to other land-uses might exert impacts on forest fragmentation and degradation, cause loss of diversity and affect the function and stability of the ecosystems. Slash and burn agriculture system and timber exploitation have changed the natural tropical rain forest. It was reported by Susilo and Aini (2005) that the termite diversity and density decreases along increasing gradient of land-use intensification in the Rigis Hill Area-Sumberjaya, Lampung. In recent decades most of tropical rain forest in Jambi Province, Sumatera have been converted to other land-use systems i.e.: secondary logged over forest, industrial timber plantation, rubber plantation, *Imperata* grassland and other agricultural system especially for oil palm plantation. It is important to understand that the conversion of natural tropical rain forest may affect termites which are important in tropical soil ecosystem. The objective of this study was to clarify the impacts of tropical rain forests conversion into other land-uses over the diversity and abundance of termites in Jambi Province.

STUDY SITES AND METHODS

Study sites

The research was done in Sub-Districts of Kuamang Kuning and Rantau Pandan, Bungo and Tebo Districts, Jambi Province. Kuamang Kuning was located at coordinat of 1°30′0″ - 1°37′33″ LS and 102°15′49″- 102°17′42,3″ BT with an elevation of less than 100 m a.s.l.; while Rantau Pandan was located at coordinat of 1°39′3″ - 1°40′8″ LS and 101°53′14″ - 101°56′7″ BT, with a range elevation on 100-500 m a.s.l. In general, the area has annual rainfall about 3,000 mm, with a wetter season of about 6 months and a drier season of about 6 months. Six land-use types namely primary forest, secondary logged over forest, rubber plantation, oil palm plantation, cassava cultivation and *Imperata* grassland were used in this study. Brief condition of the six sites can be illustrated as follows:

Site 1. Primary Forest was a mixed of dipterocarp forest with dense canopy and closed canopy. The forest consisted of the trees of 20-40 m height.

Site 2. Secondary Forest was second rotation of logged over area. The canopy is less dense than primary forest due to logging activities by using Indonesian Selective Cutting System

Site 3. Rubber plantation (Tree based rubber intensive /TBRI). This plantation consisted of a high density of mature rubber trees growing among regenerating forest. The trees were estimated to be 25-30 years old.

Site 4. Oil palm plantation (Tree Based Oil Palm Intensive/TBOPI). It consisted of young trees and old trees of oil palm which is still productive.

Site 5. Cassava (Crop less intensive). The area was close to imperata grassland, and it was comprised a line cassava plantation (CP)

Site 6. *Imperata* grassland (IG) consisted of a dense and uniform of *Imperata cylindrica* with about 1 m in height.

The overall six sites were further classified into 3 land use types, i.e.: 1) primary forest and secondary forest are referred as forested areas because the areas are dominated by trees naturally, 2) rubber and oil palm plantation are still dominated by trees but the areas have been intensively managed by people; and 3) cassava and grassland types are supposed to be representative sites which were intensively managed, dominated by small vegetation and grass, and the absence of trees.

Method

Five rectangular transects with size of 20m x 2 m was set up in each study site, following the sampling protocol formerly described by Jones *et al.* (2003) then modified by Susilo and Aini (2005). The transect of 20m x 2m was divided into 4 contagious sections of 5m x 2 m, and each section was divided into two subsections of 5m x 1m. Termites were collected inside the transect during 1.5 person-hour per section. In each subsection, termites were sampled by an experienced collector for 30 minutes (one person-hour per section). Six soil samples (small monolith with size of 12 cm x 12 cm x 10 cm) of soil surface in each sub-section were taken using a small shovel. Inside the transects the collector searched for termites in the soil, litter and humus at the base of trees, subterranean nests, and mounds. An additional half-person hour (2 persons both in 15 minutes per section) was spent by the collector to search for termites from some macro niches such as stumps, dead wood, buttresses, mounds and arboreal nest up to a height of 2 m above ground level surrounding the transect until radius of 200 m. Macro niche collection surrounding the transects were conducted as soon as the micro niche collection has been finished.

The soil sample was placed into plastic tray and sorted for termite *in situ* using sharp pointed forceps. Termite specimens (soldier caste as priority and some worker caste) were collected into glass vials containing 70% alcohol solution for preservation and identification. Specimens encountered in the same samples were placed in the same vial. A pencil-written paper was used for label and placed inside the vial. The information in the label included date, transect section, origin of specimen, name of sample point and land use, and name of the collector. The allocated 1.5 person-hour time was used for the whole process, i.e. taking soil samples, putting taken samples into the tray, sorting, putting the termites into vial, and labeling. The termite pecimens were stored in the form of wet collection (in 70 % alcohol) in the laboratory, and they were cleaned (from dirt) and relabeled prior to storage and identification. Termite identification up to the species level was done under a dissecting microscope using several references (Thapa, 1981; Tho, 1992; Rahman, 2003) at the Laboratory of Animal Taxonomy Faculty of Biology and Laboratory of Forest Protection, Faculty of Forestry Gadjah Mada University and Laboratory of Arthropod Pests Faculty of Agriculture, Lampung University.

The collected data were analyzed to compare the species diversity and abundance of termites across the six land-use systems. The diversity was the total number of species found in the transects of each land-use system; and it was analyzed using the diversity index (a sample point). The abundance of termites in each land-use type was analyzed using Relative Density and Relative Dominance measures while the diversity was expressed as the Shannon – Wienner diversity index (H'), as follow (Ludwig and Reynolds, 1988).

RESULTS AND DISCUSSION

Species diversity

Species number and diversity index of termites in each land-use type is shown in Table 1. A total of 30 termite species were found in the six land use types. Highest diversity of termites was found in forested areas, i.e. 19 species in secondary logged over forest and 15 species in primary forest, with diversity index of 2.94 and 2.71, respectively. Lower species numbers were found in rubber plantation (12 species) and oil-palm plantation (9 species), with diversity index of 2.48 in rubber plantation and 2.20 in oil-palm plantation.

$$H' = \sum_{i=1}^{S} (p_i \ \mathrm{h} \ p_i)$$

where S = species number and p_i = proportion of the ith spesies (relative abundance)

$$\text{Relative Density} = \frac{\Sigma \text{ density of a species}}{\Sigma \text{ density of all species}} \times 100\%$$

where the density of a species was number individual per sample point (transect) of a land-use type.

$$\text{Relative Dominance} = \frac{\Sigma \text{ biomass of a species}}{\Sigma \text{ biomass of all species}} \times 100\%$$

where the dominance of a species was biomass of the species per sample point (transect) of a land use type.

Table 1. Species and diversity index of termites in each land-use type

No	Species	Land-use Type					
		PF	SF	RP	OP	CC	IG
1	*Bulbitermes constrictus*		√				
2	*Bulbitermes sp A*	√					
3	*Bulbitermes sp C*		√				
4	*Coptotermes curvignathus*		√				
5	*Coptotermes havilandi*	√	√		√		
6	*Coptotermes sepangensis*		√	√	√		
7	*Dicuspiditermes nemorosus*	√	√	√			√
8	*Heterotermes tenuior*	√	√				√
9	*Hypotermes xenotermis*		√				
10	*Longipeditermes longipes*		√				
11	*Nasutitermes havilandi*		√		√	√	√
12	*Nasutitermes longinasus*	√	√	√		√	
13	*Nasutitermes sp B*		√				
14	*Parrhinotermes equalis*			√			
15	*Pericapritermes buitenzorgi*	√					
16	*Pericapritermes dolichepalus*	√		√			
17	*Pericapritermes smarangi*				√		
18	*Pericapritermes sp A*	√					
19	*Pericapritermes sp C*	√	√		√		
20	*Pericapritermes sp D*		√	√	√	√	√
21	*Procapritermes setiger*	√	√	√			
22	*Procapritermes sp C*		√				
23	*Procapritermes sp E*	√					
24	*Procapritermes sp G*			√			
25	*Prorhinotermes flavus*	√					
26	*Schedorhinotermes javanicus*			√	√		√
27	*Schedorhinotermes malacanensis*		√			√	
28	*Schedorhinotermes medioobscurus*	√	√	√	√	√	√
29	*Termes comis*	√	√	√		√	
30	*Termes rostratus*	√		√	√	√	√
	Number of Species	15	19	12	9	7	7
	Shannon-Wiener Diversity Index	2.71	2.94	2.48	2.20	1.95	1.95

Note: PF = Primary Forest, SP = Secondary Forest, RP = Rubber Plantation, OP = Oilpalm Plantation, CC = Cassava Cultivation, IG = *Imperata* Grassland

Lowest number of termite species was found in cassava cultivation and *Imperata* grassland, each 7 species and diversity index of 1.95.

The species found in the study sites belonged to six sub families of termites are as follows:

1. Sub family Coptotermitinae consisted of three species, i.e. *Coptotermes curvignathus*, *Coptotermes havilandi* and *Coptotermes sepangensis*. 2. Sub family Heterotermitinae was only one species: *Heterotermes* sp., 3. Sub family Rhinotermitinae consisted of three species, i.e. *Parrrhinotermes* sp., *Prorhinotermes* sp. and *Schedorhinotermes* sp., 4. Sub family Macroterminae consisted of one species: *Hypotermes* sp. , 5. Sub family Nasutitermitinae consisted of three species, i.e. *Nasutitermes sp*, *Bulbitermes* sp. *dan Longipeditermes* sp., 6. Sub family Termitinae consisted of four species, i.e. *Dicuspiditermes* sp., *Pericapritermes* sp., *Procapritermes* sp. and *Termes* sp.

Table 2. Relative Density (%) of each termite species in each land-use type

No	Species	Land-use Type (LuT)						Total
		PF	SF	RP	OP	CC	IG	
1	*Bulbitermes constrictus*	-	0.60	-	-	-	-	0.10
2	*Bulbitermes sp A*	1.49	-	-	-	-	-	0.25
3	*Bulbitermes sp C*	-	0.63	-	-	-	-	0.11
4	*Coptotermes curvignathus*	-	7.90	-	-	-	-	1.32
5	*Coptotermes havilandi*	1.21	2.82	-	1.76	-	-	0.97
6	*Coptotermes sepangensis*	-	2.46	0.08	2.23	-	-	0.79
7	*Dicuspiditermes nemorosus*	33.98	33.57	23.38	-	-	2.91	15.64
8	*Heterotermes tenuior*	4.25	7.46	-	-	-	4.66	2.73
9	*Hypotermes xenotermis*	-	1.67	-	-	-	-	2.28
10	*Longipeditermes longipes*	-	1.11	-	-	-	-	0.19
11	*Nasutitermes havilandi*	-	9.05	-	4.46	1.54	37.28	8.72
12	*Nasutitermes longinasus*	2.81	11.47	6.10	-	1.83	-	3.70
13	*Nasutitermes sp B*	-	0.60	-	-	-	-	0.10
14	*Parrhinotermes equalis*	-	-	1.47	-	-	-	0.24
15	*Pericapritermes buitenzorgi*	3.59	-	-	-	-	-	0.60
16	*Pericapritermes dolichepalus*	8.16	-	2.16	-	-	-	1.72
17	*Pericapritermes smarangi*	-	-	-	51.12	-	-	8.52
18	*Pericapritermes sp A*	0.39	-	-	-	-	-	0.06
19	*Pericapritermes sp C*	1.21	0.52	-	5.47	-	-	1.20
20	*Pericapritermes sp D*	-	0.40	14.04	8.26	0.19	16.12	6.50
21	*Procapritermes setiger*	13.73	3.57	2.39	-	-	-	3.28
22	*Procapritermes sp C*	-	1.55	-	-	-	-	0.26
23	*Procapritermes sp E*	5.79	-	-	-	-	-	0.97
24	*Procapritermes sp G*	-	-	0.08	-	-	-	0.01
25	*Prorhinotermes flavus*	0.88	-	-	-	-	-	0.15
26	*Schedorhinotermes javanicus*	-	-	1.62	3.13	-	0.97	0.95
27	*S. malacanensis*	-	0.32	-	-	1.06	-	0.23
28	*S. medioobscurus*	11.69	0.91	27.24	20.42	7.31	11.07	13.11
29	*Termes comis*	9.87	13.41	12.89	-	64.58	-	16.79
30	*Termes rostratus*	0.94	-	8.56	3.13	23.48	26.99	10.52
	Total R.Den in each LuT	100	100	100	100	100	100	100
	% R.Den in each LuT	22.44	31.19	16.04	11.09	12.86	6.37	100

Note: PF = Primary Forest, SP = Secondary Forest, RP = Rubber Plantation, OP = Oilpalm Plantation, CC= Cassava Cultivation, IG = *Imperata* Grassland

Abundance of Termites

The termites abundance was measured using the parameters of Relative Density and Relative Dominance, and the average of the two parameters was taken as the Relative Abundance. Relative Density of each termite species in each land-use type is shown in Table 2. The table showed that high Relative Densities of termites were found in the land-use types of forest, i.e.: 31.19 % in secondary forest and 22.44 % in primary forest. The Relative Density became significantly lower when the forests were converted into rubber plantation and oil-palm plantation with Relative Density 16.04 % and 11.09 %, respectively. In comparison with forest land-use types, the densities of termites were much lower in cassava cultivation (12.86 %) and the lowest Relative Density occurred when the forested areas were changed into the *Imperata* grassland with the density only 6.37%.

Termites species which had high relative densities in the forests were *Dicuspiditermes nemorosus* (33.98 %), *Procapritermes setiger* (13.73 %), *Schedorhinotermes medioobscurus* (11.69 %), *Termes comis* (9.87 %) in Primary Forest; and *Dicuspiditermes nemorosus* (33.57 %), *Termes comis* (13.41 %) and *Nasutitermes longinasus* (11.41 %). High Relative Densities of termite species in rubber plantation were *Schedorhinotermes medioobscurus* (27.24 %), *Dicuspiditermes nemorosus* (23.38 %), *Pericapritermes sp D* (14.04 %), *Termes comis* (12.89 %). Highest Relative Density of termite species in oil-palm plantation was *Pericapritermes smarangi* (51.12 %), followed

Table 2. Relative Density (%) of each termite species in each land-use type

No	Species	Land-use Type (LuT)						Total
		PF	SF	RP	OP	CC	IG	
1	*Bulbitermes constrictus*	-	0.60	-	-	-	-	0.10
2	*Bulbitermes sp A*	1.49	-	-	-	-	-	0.25
3	*Bulbitermes sp C*	-	0.63	-	-	-	-	0.11
4	*Coptotermes curvignathus*	-	7.90	-	-	-	-	1.32
5	*Coptotermes havilandi*	1.21	2.82	-	1.76	-	-	0.97
6	*Coptotermes sepangensis*	-	2.46	0.08	2.23	-	-	0.79
7	*Dicuspiditermes nemorosus*	33.98	33.57	23.38	-	-	2.91	15.64
8	*Heterotermes tenuior*	4.25	7.46	-	-	-	4.66	2.73
9	*Hypotermes xenotermis*	-	1.67	-	-	-	-	2.28
10	*Longipeditermes longipes*	-	1.11	-	-	-	-	0.19
11	*Nasutitermes havilandi*	-	9.05	-	4.46	1.54	37.28	8.72
12	*Nasutitermes longinasus*	2.81	11.47	6.10	-	1.83	-	3.70
13	*Nasutitermes sp B*	-	0.60	-	-	-	-	0.10
14	*Parrhinotermes equalis*	-	-	1.47	-	-	-	0.24
15	*Pericapritermes buitenzorgi*	3.59	-	-	-	-	-	0.60
16	*Pericapritermes dolichepalus*	8.16	-	2.16	-	-	-	1.72
17	*Pericapritermes smarangi*	-	-	-	51.12	-	-	8.52
18	*Pericapritermes sp A*	0.39	-	-	-	-	-	0.06
19	*Pericapritermes sp C*	1.21	0.52	-	5.47	-	-	1.20
20	*Pericapritermes sp D*	-	0.40	14.04	8.26	0.19	16.12	6.50
21	*Procapritermes setiger*	13.73	3.57	2.39	-	-	-	3.28
22	*Procapritermes sp C*	-	1.55	-	-	-	-	0.26
23	*Procapritermes sp E*	5.79	-	-	-	-	-	0.97
24	*Procapritermes sp G*	-	-	0.08	-	-	-	0.01
25	*Prorhinotermes flavus*	0.88	-	-	-	-	-	0.15
26	*Schedorhinotermes javanicus*	-	-	1.62	3.13	-	0.97	0.95
27	*S. malacanensis*	-	0.32	-	-	1.06	-	0.23
28	*S. medioobscurus*	11.69	0.91	27.24	20.42	7.31	11.07	13.11
29	*Termes comis*	9.87	13.41	12.89	-	64.58	-	16.79
30	*Termes rostratus*	0.94	-	8.56	3.13	23.48	26.99	10.52
	Total R.Den in each LuT	100	100	100	100	100	100	100
	% R.Den in each LuT	22.44	31.19	16.04	11.09	12.86	6.37	100

Note: PF = Primary Forest, SP = Secondary Forest, RP = Rubber Plantation, OP = Oilpalm Plantation, CC= Cassava Cultivation, IG = *Imperata* Grassland

Abundance of Termites

The termites abundance was measured using the parameters of Relative Density and Relative Dominance, and the average of the two parameters was taken as the Relative Abundance. Relative Density of each termite species in each land-use type is shown in Table 2. The table showed that high Relative Densities of termites were found in the land-use types of forest, i.e.: 31.19 % in secondary forest and 22.44 % in primary forest. The Relative Density became significantly lower when the forests were converted into rubber plantation and oil-palm plantation with Relative Density 16.04 % and 11.09 %, respectively. In comparison with forest land-use types, the densities of termites were much lower in cassava cultivation (12.86 %) and the lowest Relative Density occurred when the forested areas were changed into the *Imperata* grassland with the density only 6.37%.

Termites species which had high relative densities in the forests were *Dicuspiditermes nemorosus* (33.98 %), *Procapritermes setiger* (13.73 %), *Schedorhinotermes medioobscurus* (11.69 %), *Termes comis* (9.87 %) in Primary Forest; and *Dicuspiditermes nemorosus* (33.57 %), *Termes comis* (13.41 %) and *Nasutitermes longinasus* (11.41 %). High Relative Densities of termite species in rubber plantation were *Schedorhinotermes medioobscurus* (27.24 %), *Dicuspiditermes nemorosus* (23.38 %), *Pericapritermes sp D* (14.04 %), *Termes comis* (12.89 %). Highest Relative Density of termite species in oil-palm plantation was *Pericapritermes smarangi* (51.12 %), followed by *Schedorhinotermes medioobscurus* (20.42 %) and *Pericapritermes sp D* (8.26 %). In cassava cultivation, the highest Relative Density was *Termes comis* (64.58 %), followed by *Termes rostratus* (23.48 %) and *Schedorhinotermes medioobscurus* (7.31 %). *Nasutitermes havilandi* had the highest Relative Density of 37.28 % in imperrata Grassland, followed by *Termes comis* (26.99 %), *Pericapritermes sp D* (16.12 %) and *Schedorhinotermes medioobscurus* (11.07 %).

Relative Dominance of each termite species in each land-use type is shown in Table 3. The Table showed that high Relative Dominances of termites were found in the land-use types of forest, i.e.: 40.73 % in secondary forest and 19.30 % in primary forest. The Relative Dominance became significantly lower when the forests were converted into rubber plantation and oil-palm plantation with Relative Dominance 13.68 % and 11.96 %, respectively. In comparison with forest land-use types, the dominances of termites were much lower in cassava cultivation (9.25 %) and the lowest Relative Density occurred when the forested areas were changed into the *Imperata* grassland with the dominance only 5.09%.

Similar to the densities, species which had high relative dominances in the land-use type of forests were *Dicuspiditermes nemorosus* (32.31 %), *Procapritermes setiger* (15.21 %), *Schedorhinotermes medioobscurus* (14.30 %) in Primary Forest; and *Dicuspiditermes nemorosus* (29.55 %), *Nasutitermes longinasus* (21.58 %), and *Coptotermes curvignathus* (14.65 %) in secondary forest. High Relative Dominances of termite species in rubber plantation were *Dicuspiditermes nemorosus* (41.94 %), *Schedorhinotermes medioobscurus* (25.71 %) and *Nasutitermes longinasus* (14.30 %). Highest Relative Dominance of termite species in oil-palm plantation was *Pericapritermes smarangi* (41.48 %), followed by *Schedorhinotermes medioobscurus* (27.29 %) and *Coptotermes sepangensis* (13.17 %). In cassava cultivation, the highest Relative Dominance was *Termes comis* (47.49 %), followed by *Termes rostratus* (34.22 %) and *Schedorhinotermes medioobscurus* (10.20 %). *Nasutitermes havilandi* had the highest Relative Dominance of 43.34 % in imperrata Grassland, followed by *Schedorhinotermes medioobscurus* (18.07 %) *Termes comis* (17.58 %), and *Pericapritermes sp D* (10.34 %).

Tropical rain forests in the study site were in the lowland areas, as terrestrial habitats with high species-richness and abundance. Data from this study showed that the highest diversity and abundance of termite species was in the forested areas, i.e. primary and secondary forests. The species diversity and abundance of termites decreased significantly when the forests were converted into rubber plantation, oil-palm plantation, cassava cultivation and *Imperata* grassland. It was clear from this study that the impact of tropical rain forest conversion and degradation was the local disappearance of some termite species and their abundance.

Tropical rain forests in the Rigis Hill Area-Sumberjaya, Lampung had also highest diversity and density of termites in comparison with other land-use types; in this area the reduction of termite diversity and density was in general associated with the increasing land-use intensity (Susilo and Aini, 2005). The impacts of diversity loss and the decreases of termite relative abundance seemed to be a general trend in the tropical areas as it was reported in previous studies in South-east Asia, Africa and South America (Collins, 1980; Eggleton *et al.*, 1995; Eggleton *et al.*, 1996; Okwakol, 2000; Dangerfield, 1990; Wood *et al.*, 1977; Wood *et al.*, 1982; Bandeira and Vasconcellos, 2002; Jones *et al.*, 2003; Susilo and Aini, 2005).

Susilo and Aini (2005) reported that termite diversity in the Rigis Hill Area-Sumberjaya, Lampung was highest in forest land-use type with the highest altitude in comparison with other land-use types which had lower altitude. There was a question whether land use intensity or altitude or combination of both actually influenced the termite diversity and density. The study conducted in a very large forested area

Table 3. Relative Dominance (%) of each termite species in each land-use type

No	Species	Land-use Type (LuT)						Total
		PF	SF	RP	OP	CC	IG	
1	Bulbitermes constrictus	-	0.58	-	-	-	-	0.10
2	Bulbitermes sp A	1.45	-	-	-	-	-	0.24
3	Bulbitermes sp C	-	0.50	-	-	-	-	0.08
4	Coptotermes curvignathus	-	14.65	-	-	-	-	2.44
5	Coptotermes havilandi	3.46	0.73	-	0.84	-	-	0.84
6	Coptotermes sepangensis	-	2.26	0.26	13.17	-	-	2.62
7	Dicuspiditermes nemorosus	32.31	29.55	41.94	-	-	3.27	17.85
8	Heterotermes tenuior	3.35	3.36	-	-	-	6.56	2.21
9	Hypotermes xenotermis	-	2.39	-	-	-	-	0.40
10	Longipeditermes longipes	-	1.24	-	-	-	-	0.21
11	Nasutitermes havilandi	-	10.06	-	4.06	1.29	43.34	9.79
12	Nasutitermes longinasus	7.76	21.58	14.30	-	4.98	-	8.10
13	Nasutitermes sp B	-	0.30	-	-	-	-	0.05
14	Parrhinotermes equalis	-	-	0.58	-	-	-	0.10
15	Pericapritermes buitenzorgi	4.37	-	-	-	-	-	0.73
16	Pericapritermes dolichepalus	4.97	-	3.57	-	-	-	1.42
17	Pericapritermes smarangi	-	-	-	41.48	-	-	6.91
18	Pericapritermes sp A	1.90	-	-	-	-	-	0.32
19	Pericapritermes sp C	0.82	0.23	-	2.82	-	-	0.65
20	Pericapritermes sp D	-	0.31	2.40	5.79	0.27	10.37	3.19
21	Procapritermes setiger	15.21	2.20	2.12	-	-	-	3.26
22	Procapritermes sp C	-	0.78	-	-	-	-	0.13
23	Procapritermes sp E	4.21	-	-	-	-	-	0.70
24	Procapritermes sp G	-	-	0.05	-	-	-	0.01
25	Prorhinotermes flavus	0.71	-	-	-	-	-	0.12
26	Schedorhinotermes javanicus	-	-	1.01	3.01	-	0.81	0.81
27	S. malacanensis	-	0.23	-	-	1.55	-	0.30
28	S. medioobscurus	14.30	4.90	25.71	27.29	10.20	18.07	16.75
29	Termes comis	4.74	4.15	4.12	-	47.49	-	10.08
30	Termes rostratus	0.43	-	3.92	1.53	34.22	17.58	9.61
	Total R.Dom. in each LuT	100	100	100	100	100	100	100
	% R.Dom in each LuT	19.30	40.73	13.68	11.96	9.25	5.09	100

Note: PF = Primary Forest, SP = Secondary Forest, RP = Rubber Plantation, OP = Oilpalm Plantation, CC = Cassava Cultivation, IG = *Imperata* Grassland

of Leuser Ecosystem – Aceh (Gathorne-Hardy *et al.*, 2001) showed that termite diversity declined with the increase in altitude. The termite diversity in forests of this study was higher in comparison with those obtained in higher altitude by Susilo and Aini, (2005). It was suggested that the loss of termite diversity was more influenced by the conversion and degradation of tropical rain forests than that of altitudinal gradient factors.

Jones *et al.* (2003) showed that woody plant basal area was strongly correlated with abundance of termite. Termite species richness and relative abundance declined as follow: primary forest > selectively logged forest > mature jungle rubber> mature rubber plantation> young *Paraserienthes* plantation> *Imperata* grassland > cassava cultivation. Woody plants in primary and secondary forest provide the huge food source for termites which mainly consume cellulose. In cassava cultivation, *Imperata* grassland, and oil palm plantation, the woody plants were scarce. That explained why the number of termite was very low. Besides, simplification of physical structure of habitat, resulting in the reduction of canopy cover, alteration of micro climate, and loss of feeding and nesting sites may decrease the abundance of termites. Woody plant basal area was strongly correlated with termite species richness and relative abundance. This reflects the response of forest-adapted termites to progressive simplification of the physical structure of the habitat, resulting in the reduction of canopy cover and alteration in microclimate, and the loss of feeding and nesting sites (Jones *et al.*, 2003).

CONCLUSIONS

Tropical rain forests in the Central part of Sumatera were very rich in diversity, i.e.: 19 species in secondary logged over forest and 15 species in primary forest, with diversity index of 2.94 and 2.71, respectively. The species richness of termites decreased significantly when the forests were converted to rubber plantation (12 species) and oil-palm plantation (9 species), with diversity index of 2.48 in rubber plantation and 2.20 in oil-palm plantation. The loss of species richness was much greater when the forests were changed to cassava cultivation and *Imperata* grassland, each with 7 species and diversity index of 1.95.

Tropical lowland forests in the Central part of Sumatra were the most abundance of termites, with Relative Abundances of 35.96 % in secondary forest and 20.87 % in primary forest. The Relative Abundances became significantly lower when the forests were converted into rubber plantation, oil-palm plantation and cassava cultivation, with Relative Abundances of 14.86 %, 11.52 % and 11.05 %, respectively. The abundance greatly decreased when the forests were degraded to *Imperata* grassland, with the Relative Abundance only 5.73 %.

Termite species which had high relative abundances in primary forests, secondary forest and rubber plantation were *Dicuspiditermes nemorosus*, *Schedorhinotermes medioobscurus*, *Nasutitermes longinasus* and *Procapritermes setiger*. High Relative Abundances of termite species in oil-palm plantation was *Pericapritermes smarangi*, *Schedorhinotermes medioobscurus* and *Coptotermes sepangensis*. In cassava cultivation, species with high Relative Abundance were *Termes comis*, *Termes rostratus* and *Schedorhinotermes medioobscurus*; and those in *Imperata* grassland were *Nasutitermes havilandi*, *Schedorhinotermes medioobscurus* and *Termes rostratus*.

ACKNOWLEDGEMENTS

This publication presents part of the findings of the international project "Conservation and Sustainable Management of Below-Ground Biodiversity (CSM-BGBD)" implemented in seven tropical countries – Brazil, Mexico, Cote d'Ivoire, Kenya, Uganda, India, and Indonesia. The project is coordinated by Tropical Soil Biology and Fertility Institute of CIAT (TSBF-CIAT) with co-financing from the Global Environment Facility (GEF) and implementation support from the United Nations Environment Programme (UNEP).

REFERENCES

Bandeira, A.G. and Vasconcellos, A. 2002. A quantitative survey of termites in a gradient of disturbed highland forest in northeastern Brazil (Isoptera). *Sociobiology* 39: 429-439.

Bignell, D.E., Eggleton, P., Nunes, L. and Thomas, K.L. 1997. Termites as mediators of carbon fluxes in tropical forest: budgets for carbon dioxide and methane emissions. *Forests and Insects* (Eds A.D. Watt, N.E. Stork and M.D. Hunter), pp. 109-134. Chapman & Hall, London U.K.

Collins N.M. 1983. Termite populations and their role in litter removal in Malaysian rain forests. *Tropical Rain Forest: Ecology and Management* (Eds S.L. Sutton, T.C. Whitmore and A.C. Chadwick), pp. 311-325. Blackwell Scientific Publications, Oxford, UK.

Collins, N.M. 1980. The effect of logging on termite (Isoptera) diversity and decomposition processes in lowland dipterocarp forests. Pp. 113-121. *Tropical ecology and development*. Ed., J.I. Furtado. International Society of Tropical Ecology, Kuala Lumpur.

Dangerfield, J.M. 1990. Abundance, biomass, and diversity of soil macrofauna in savanna woodland and associated managed habitats. *Pedobiologia* 34: 141-150.

Donovan, S.E., Eggleton, P., Dubbin, W., Batchelder, M. and Dibog, L. 2001. The effect of a soil-feeding termite *Cubitermes fungifiber* (Isoptera: termitidae) on soil properties: termite may be an important source of soil microhabitat heterogeneity in tropical forests *Pedobiologia*, 45, 1-11.

Edward, C.A., and Lofty, J.R. 1977. Biology of Earthworms. Chapman and Hall New York. 333pp.

Eggleton, P., Bignell, D.E., Sands, W.A., Waite, B., Wood, T.G., and Lawton, J.H. 1995. The species richness of termites (Isoptera) under differing levels of disturbance in the Mbalmayo Forest Reserve, southern Cameroon. *J. Trop. Ecol.* 11: 85-98.

Eggleton, P., Bignell, D.E., Sands, W.A., Mawdsley, N.A., Lawton, J.H., Wood, T.G., and Bignell, N.C. 1996. The diversity, abundance, and biomass of termites under differing levels of disturbance in the Mbalmayo Forest Reserve, southern Cameroon. *Phil. Trans. Royal Soc. London, Ser. B* 351: 51-68.

Eggleton, P., Homathevi, R., Jones, D.T., MacDonald, J., Jeeva, D., Bignell, D.E., Davies, R.G. and Maryati, M. 1999. Termite assemblages, forest disturbance and greenhouse gas fluxes in Sabah, east Malaysia. *Philosophical Transactions of the Royal Society of London, Series B*, 354, 1791-1802.

Eggleton, P. 2000. Global patterns of termite diversity. *Termites: Evolution, Sociality, Symbiosis, Ecology* (Eds T. Abe, D.E. Bignell and M. Higashi), pp. 25-51. Kluwer Academic Publications, Dordrecht, the Netherlands.

Gathorne-Hardy, F., Syaukani, and Eggleton, P. 2001. The effects of altitude and rainfall on the composition of the termites (Isoptera) of the Leuser Ecosystem (Sumatera, Indonesia). *J. Tropical Ecol.* 17: 379-393.

Giller, K.E., Beare, M.H., Lavelle, P., Izac, A.M.N., and Swift, M.J. 1997. Agricultural Intensification, Soil Biodiversity and Agroecosystem Function. *App. Soil Ecol.* 6:3-5

Holt, J.A. and Lepage, M. 2000. Termites and soil properties. *Termites: Evolution, Sociality, Symbiosis, Ecology* (Eds T. Abe, D.E. Bignell and M. Higashi), pp. 389-407. Kluwer Academic Publications, Dordrecht, the Netherlands.

Jones D. T., Susilo F. X., Bignell, D. E, Hardiwinoto S., Gillison A. N., Eggleton P. 2003. Termite assemblage collapse along a land use intensification gradient in low land central Sumatera, Indonesia. *Journal of Applied Ecology* 40: 380-391.

Lavelle, P., Blanchart, E., Martin, S., Barois I., Toutain, F., Spain, A. and Schaefer, R. 1993. A hierarchical model for decomposition in terrestrial eco-systems, application to soils in the humid tropics. *Biotropica* 35:130-150.

Lavelle, P., Dangerfield, M., Fragoso, C., Eschenbrenner, V., Lopez-Hernandez, D., Pashanasi, B. and Brussaard, L. 1994. The relationship between soil macrofauna and tropical soil fertility. *Biological Management of Tropical Soil Fertility* (Eds. Woomer, P.L. and Swift, M.J.). John Wiley & Sons.

Ludwig, J.A. and Reynolds, J.F. 1988. Statistical ecology: A primer on methods and computing. John Wiley and Sons, Inc., Canada

Luxton, M. 1982. General ecological influence of the soil fauna on decomposition and nutrient circulation. *Oikos* 39 (3): 355-357

Makeschin, F. 1997. Earthworm (Lumbricidae: Oligochaeta): Important promotors of soil development and soil fertility. *Fauna in Soil Ecosystem, Recycling Process, Nutrient Fluxes, and Agricultural Production* (Ed. Benchiser, G.). Marcel Dekker. Inc. New York.

Noble, I.R. and Dirzo, R. 1997. Forests as human-dominated ecosystems. *Science* 277, 504-509.

Okwakol, M. J.N. 2000. Changes in termite (Isoptera) communities due to the clearance and cultivation of tropical forest in Uganda. *African J. Ecol.* 38: 1-7.

Paoletti, M.G., Pimentel, D., Stinner, B.R. and Stinner, D. 1992. Agroecosystem Biodiversity: Matching production and conservation biology. *Agric. Ecosyst Environ.* 40:3-23.

Rachman, H. 2003. Manual for Bornean termites (Isoptera). Jointly organized by Forest Research Centre Forestry Department Sandakan Sabah Malaysia, Entomology Dept. The natural History Museum Cromwell Road London, UK, University Sabah Malaysia, Kota Kinabalu Sabah, Malaysia

Susilo, F.X. & Aini, F.K. 2005. Diversity and density of termites in a range of land use types in the Rigis Hill area, Sumberjaya – Lampung. *J. Sains Tek.* 11 (3): 129 – 136.

Thapa, R.S. 1981 Termites of Sabah (East Malaysia). Entomology Branch, Forest Research Institute and College Dehra Daun, India.

Tho, Y.P. 1992. Termites of Peninsular Malaysia. Forest Research Institute of Malaysia Kepong, Kuala Lumpur.

Tilman, D., Fergione, J., Wolff, B., D'Antonio, C., Dodson, A., Howarth, R., Schindler, D., Schlesinger, W.H., Simberloff, D., and Swackhamer, D. 2001. Forecasting agriculturally driven global environmental change. *Science* 292, 281-284.

van Noordwijk, M., Tomich, T.P., Winahyu, R., Murdiyarso, D., Suyanto, Partoharjono, S., dan Fagi, M. (Eds.) 1995. Alternatives to Slash-and-Burn in Indonesia. Summary Report Phase 1. ASB-Indonesia Report No. 4, Bogor.

Wood, T.G., Johnson, R.A., and Ohiagu, C.E. 1977. Populations of termites (Isoptera) in natural and agricultural ecosystems in Southern Guinea savanna near Mokwa, Nigeria. *Geo Eco Trop* 1: 139-148.

Wood, T.G. and Sands, W.A. 1978. The roles of termites in ecosystems. *Production Ecology of Ants and Termites* (ed. M.V. Brian), pp. 245-292. Cambridge University Press, Cambridge, UK.

Wood, T.G., Johnson, R.A., Bacchus, S., Shittu, M.O., and Anderson, J.M. 1982. Abundance and distribution of termites (Isoptera) in a riparian forest in the Southern Guinea savanna zone of Nigeria. *Biotropica* 14: 25-39.