SECTION 8: TERRESTRIAL INSECTS: TERMITES

SPECIES RICHNESS, FUNCTIONAL DIVERSITY AND RELATIVE ABUNDANCE OF TERMITES UNDER DIFFERENT LAND USE REGIMES

D.T. Jones[1], F.X. Susilo, D.E. Bignell & H. Suryo

8.1 Introduction:

Indonesia contains more rain forest than any other country in the Asia-Pacific region, and is currently experiencing rapid changes in land use, although exact figures are difficult to obtain. It has been estimated that Indonesia lost between 0.5% to 0.8% of its total closed forest cover per year during the first half of the 1980s (Groombridge, 1992). The equatorial island of Sumatra is the third largest island in the Indonesian archipelago. The island's lowland forests have been heavily logged and large areas are seriously degraded (Riswan & Hartanti, 1995). Sumatra has a relatively high and rising population density and, under growing socioeconomic pressure, large areas of forest have been lost to commercial logging, permanent or shifting subsistence agriculture, or cleared for plantations and transmigration schemes (Whitten *et al.*, 1984). By 1991, Collins *et al.* estimated about 49% of Sumatra's original forest cover remained, although very little was pristine. In Jambi Province, Central Sumatra, during a six-year period up to 1992, about 8% of primary forest was converted to secondary forest, another 5% was converted to agricultural land, while about 0.3% became grassland (Murdiyarso & Wasrin, 1995).

Much of Sumatra is now a mosaic of different land-use types. Fragments of primary forest remain within large areas of impoverished logged-over and secondary forest, while various silvicultural systems, including vast industrial plantations of oil palm, rubber and fast-growing soft wood tree species, dominate the landscape. Indigenous agroforestry systems vary from cash-crop monocultures to complex multispecies and multi-storey gardens (Aumeeruddy & Sansonnens, 1994). The 'jungle rubber' system is a man-made diverse agroforestry system with a high concentration of rubber trees, which has a forest-like structure when in its mature phase and provides fruits, fuelwood and timber, as well as an income from latex (Gouyon *et al.*, 1993). Intensively farmed and burnt land can be exhausted of nutrients and often reduced to alang-alang (*Imperata cylindrica*) grassland. Some transmigration farming systems set up on former forested lands have been shown to be unsustainable with the current level of resourcing (Holden *et al.*, 1995).

Within the context of sustainable agricultural production under conditions of rapid land-use change, declining forest cover, loss of biodiversity and an increasing human population, research should be focused on those groups of organisms that contribute directly to plant productivity and their response to changes in land use. The importance of invertebrate macrofauna to the promotion of tropical soil fertility has been stressed in recent reviews

[1] Address for correspondence;
David T. Jones
Biodiversity Division, Entomology Department
The Natural History Museum
Cromwell Road
London, SW7 5BD, UK

(Fragoso *et al.*, 1993; Lavelle *et al.*, 1994; Garnier-Sillam & Harry, 1995; Nash & Whitford, 1995; Brussaard & Jumas, 1996; Wood, 1996). The distribution, protection and stabilization of organic matter, the genesis of soil structure, humification, the release of immobilized N and P, the improvement of drainage and aeration, and the increase in exchangeable cations have all been demonstrated in soils modified by termites and earthworms (Lavelle *et al*., 1997). In African systems, forest clearance depletes termite abundance and diversity (Wood *et al.* 1982; Eggleton *et al.*,1995; 1996) but similar studies are not yet available from Asia.

Termites are a key functional group of animals in the tropics and can achieve very high populations. For example, in the forests of southern Cameroon, termites are the most numerous of all insect groups (Watt *et al.*, 1997) with abundances of up to 10,000 m^{-2}, and live biomasses of 100 g m^{-2} (Eggleton *et al.*, 1996). As the dominant arthropod detritivores, termites are important in decomposition processes (Wood & Sands, 1978; Collins, 1983) and thereby play a central role as mediators of nutrient and carbon fluxes (Jones, 1990; Abbadie *et al.*, 1992; Lawton *et al.*, 1996; Bignell *et al.*, 1997). However, being social insects, termites tend to concentrate around colony centres. These centres are often scattered unevenly through the habitat (for example, see Baroni-Urbani *et al.*, 1978; Gontijo & Domingos, 1991), leading to extreme heterogeneity of individuals and populations.

Given the ecological importance of termites, there is a need to characterize termite assemblage structure within and between sites. As a consequence of their highly patchy spatial distribution, combined with the many and varied field sampling regimes adopted by previous researchers, it has not been possible to use the existing data to make reliable direct comparisons of termite diversity and abundance between sites (see Eggleton & Bignell, 1995). As Sutton & Collins (1991) emphasised, it is necessary to develop and test standardised sampling methods that can be applied easily throughout the tropics. To this end, a standardised transect sampling method designed to measure termite species richness and functional diversity in tropical forests has been developed. The protocol has been used in Cameroon (Eggleton et al, 1995), Thailand (Davies, 1997), Peninsular Malaysia (Jones & Brendell, in press) and two sites in Sabah; Maliau Basin (Jones *et al.*, in press) and Danum Valley (Eggleton *et al.*, in press).

8.2 Aims:

- To assess the termite assemblage under different land uses. The first aim is to measure species richness, functional diversity and the relative abundance of termites under seven different land-use regimes in Jambi Province, central Sumatra. The seven land uses are listed in Section 8.4. By using a standardised sampling protocol, the results from each site can be directly compared, both within this study and with other locations where the transect method has been employed.

- The responses of termites to land-use changes. If the history of exploitation at each of the Jambi study sites is known, it may be possible to arrange the sites along a 'land-use intensification gradient' or into one or more 'land-use sequences'. By assuming that all the Jambi sites were originally forested and had similar termite assemblages, it will be possible to hypothesise about the response of termites to changes in land use. This assumes the primary assumption is correct.

- The search for correlates between termites and other organisms. The multidisciplinary approach adopted in this project is rare in ecological field studies. In all, seven groups of organisms have been studied in the same sites in Jambi Province. These groups are:

vascular plants, mammals, birds, termites, butterflies, soil macrofauna (including ants and earthworms), and selected canopy arthropod groups. The third aim is, therefore, to investigate and identify possible correlates between termites and the other target taxa studied in this project.

8.3 Personnel:

Principal Investigator:
Dr D.T. Jones (termite ecologist and taxonomist) - Biodiversity Division Entomology Department
The Natural History Museum.

Assisted by:

Dr David Bignell (termite physiologist), Tropical Biology & Conservation Unit, University Malaysia Sabah.
Dr F.X. Susilo (entomologist) - Jurusan Proteksi Tanaman, Fakultas Pertanian, Universitas Lampung
Dr Suryo Hardiwibowo (biologist) - Gadjah Mada Universitas, Yogyakarta, Indonesia

8.4 Methods:

Seven sites in Jambi Province were studied during November 1997, each site representing a distinct land-use type. The seven land-use types and the dates sampled are listed below. One transect was run in each land-use type as follows:

Land use type	**Site code**	**Date sampled**
1. *Paraserianthes* plantation	BS 6	19 + 20 Nov. 1997
2. Primary forest	BS 1	21 + 22 Nov. 1997
3. Logged-over forest	BS 3	22 + 23 Nov. 1997
4. *Imperata* grassland	BS 12	24 Nov. 1997
5. Cassava garden	BS 14	24 + 25 Nov. 1997
6. Jungle rubber	BS 10	26 + 27 Nov. 1997
7. Rubber plantation	BS 8	27 + 28 Nov. 1997

8.4.1 The standardized transect sampling method:

All transects were co-located with a 40x5m strip transect used to sample vegetation and for other multidisciplinary studies. Each termite transect was 100 m long and 2 m wide, divided into 20 contiguous sections (each 5 m x 2 m), and numbered sequentially. Each section was sampled by two people for 30 minutes (a total of one hour of collecting per section). In order to standardise sampling effort, the trained collectors worked steadily and continuously during the 30 minute collecting period. In each section the collectors searched the following microhabitats which are common sites for termites: surface soil to 5 cm depth; accumulations of litter and humus at the base of trees; the inside of dead logs, tree stumps, branches and twigs;

the soil within and beneath very rotten logs; all subterranean nests, mounds, carton sheeting and runways on vegetation, and arboreal nests up to a height of 2 m above-ground level.

The protocol was designed to offer a flexible approach to the sampling, whereby the collectors used their experience and judgement to search for, locate and sample as many species of termite in each section as time allowed. Specimens from each termite population encountered were sampled. All castes were collected if present, but priority was given to finding soldiers and workers. Termites were placed in vials labelled with the section number and filled with 80%ethanol.

In structurally complex habitats, i.e. with a relatively large above-ground biomass (such as forests and plantation systems), the collectors spend approximately half their collecting time searching the above-ground microhabitats described above. The remaining 15 minutes were used searching for termites in the soil. However, in the case of the *Imperata* grassland (BS 12) and the Cassava garden (BS 14) there was relatively little above-ground biomass. Within the transects in both systems there were no trees and virtually no dead wood or leaf litter. Therefore, in these land-use types (*Imperata* grassland and the Cassava garden) the collectors sampled only for 15 minutes (total collecting effort = 30 minutes) in each section. This procedure ensured that equal effort was given to searching for termites in the soil in each transect.

The transect sampling method provides a semi-quantitative measure of the relative abundance of termites based on the number of encounters or 'hits' with each species in a transect. A hit is defined as the recorded presence of a species in one section. Therefore, if a species is present in every section of a transect it will have a relative abundance score of 20. The number of hits per transect can then be used as an indicator of the relative abundance of termites occurring within a transect, as well as between transects. It gives no measure of the absolute abundance per unit area.

8.4.2 *Identification of material:*

During the field trip, great effort was taken to examine as much of the material as time allowed. This was made possible due to the microscope and light source provided by David Bignell. In the evenings, many hours were spent making provisional identifications. All samples with soldiers were identified to genus, and then morphospecies numbers were allocated. A working reference collection was maintained so that material from all transects could be cross-referenced and the morphospecies designations applied consistently. Many vials contained two or more species, and some of these were separated where time and accuracy allowed. Two groups of samples were not identified. The first were samples with workers (i.e. no soldier specimens collected). Workers are difficult and time consuming to identify as the mandibles must be dissected, and the structure of the gut must be examined, sometimes necessitating the removal and mounting of the enteric valve. The second group were genera in the Subulitermes complex. These are small termites whose taxonomy is ill-defined and that are difficult to identify.

It must be stressed that the results given in this report are based solely on the provisional identifications made during the field trip. At the Natural History Museum every sample will be examined again, and accurate species-level identifications will be made. By comparison with the museum's extensive reference collection (which contains approximately 16000 vials of identified material, plus about 1000 vials of type material), it will be possible to put specific names on alarge proportion of the Jambi collection. It is estimated that the identification work at the museum should take about 4 to 5 weeks [*note*: completed July 1998. eds. See Annex III, Table 11)

Functional groups:
Genera were assigned to one of five functional groups based on known feeding habits (see Collins, 1984; Eggleton *et al.*, 1996; Jones *et al.*, in press; Eggleton *et al.*, submitted), the shape of the molar plates of the worker mandibles (Deligne, 1966), and worker gut content analyses (Sleaford *et al.*, 1996). The functional groups are;

- Soil-feeding: termites that feed on humus and mineral soil.
- Wood-feeding: termites that feed on dead wood.
- Soil/wood interface-feeding: termites that feed on extremely decayed wood that has lost its structure and become soil-like.
- Litter-feeding: termites that feed exclusively on leaf-litter and small items of woody trash.
- Epiphyte-feeding: Hospitalitermes is known to feed on lichens and other free living non-vascular plants which they graze from the surface of tree trunks (Collins, 1979; Jones & Gathorne-Hardy, 1995).

8.5 Preliminary results:

8.5.1 *Species richness:*

The preliminary sorting carried out during the Jambi field work produced a conservative total of 23 genera and 48 morphospecies for all seven land-use types (Annex III, Table 11). However, in addition to these taxa, the Subulitermes complex and many vials of workers await examination. The senior author speculates that these vials will possibly contain several genera plus between 3 to 10 species which can be added to the checklist. Members of the Apicotermitinae subfamily are rare inSoutheast Asia but have been collected in transects run in Sabah (Eggleton *et al.*, in press) and Peninsular Malaysia (Jones & Brendell, in press). Within this subfamily the soldiers are absent or rare, however, specimens may be present in the vials of workers from Jambi.

Table 8.1 gives the list of morphospecies currently recorded from each transect. The preliminary identifications clearly show that the primary forest site is the most species rich, while the *Imperata* grassland and the Cassava garden sites are the most depauperate. The logged-over forest site and the agroforestry systems all have intermediate levels of species richness. Figure 8.1 displays the taxonomic composition of each transect sample. The Termitinae are the dominant subfamily in sites except the *Paraserianthes* plantation site and the Cassava garden system.

8.5.2 *Relative abundance:*

The number of hits (the presence of a species in a section) is recorded in Table 8.1. Termites are most abundant in the primary forest site and least abundant in the Cassava garden. The termites collected in this study fall into four feeding groups. Wood-feeding and soil-feeding species are relatively abundant in most transects, while epiphyte-feeders are rare and interface-feeders (those species that feed on extremely decayed soil-like wood) vary considerably in abundance among transects. Figure 8.2 displays the relative abundance of termites in each functional group. Of notable interest is the high relative abundance of soil-feeders in the jungle rubber system, and their absence from the *Paraserianthes* plantation. Grass-harvesting species and taxa that feed exclusively on leaf-litter appear to be absent from the study sites.

8.6 Discussion:

It must be stressed that the results given in the table and figures are based on provisional identifications. Table 8.1 also lists the number of vials containing specimens of the Subulitermes complex and workers which still await examination, and suggest the possible extent of extra species and hits that may be added to each transect. While we are certain that the final results for most of the transects will vary in species richness and relative abundance from those presented here, the senior author is confident that the overall patterns are likely to be similar to those already evident in the preliminary results.

Our knowledge of the termite fauna of Sumatra is very limited and based on casual sampling (Holmgren, 1913-14; Oshima, 1923, John, 1925; Amir, 1975). Tho (1992) lists a total of 89 species from Sumatra, but this is certainly an underestimate. The development of comprehensive and rigorous sampling techniques produces much higher local species richness estimates than those given by casual collecting methods. For example, after extensive and widespread collecting, Thapa (1981) lists 103 species from Sabah. However, recent research in one area (Danum Valley, South-east Sabah) using transects and labour-intensive sampling regimes produced a checklist of 93 species (Eggleton *et al.*, in press; Homathevi *et al.*, in prep.). Therefore, it is highly likely our studies at Jambi will increase the Sumatran species list.

The transect method has been tested against known local termite faunas and shown to produce representative samples that are not significantly different in taxonomic or functional composition from their local assemblage (Jones & Eggleton, in prep.). The highest species richness found in Southeast Asian forests using the transect method is 33 species at Danum Valley (Eggleton *et al.*, in press). There is a reasonable possibility that the Jambi primary forest transect will exceed the Danum Valley species richness. Changes in the taxonomic and functional composition of the termite assemblages across the seven land-use types will be discussed in detail when the final data set is produced.

The preliminary results show a decline in termites species richness (Fig. 8.1) and relative abundance (Fig. 8.2) across the seven land-use types. Casual observations of the botanical features at each site by the authors suggested a positive relationship between termite species richness and physical complexity. It has been speculated that the degree of canopy closure appears to have a strong influence on termite diversity (Eggleton *et al.*, 1995, 1996). Preliminary results from Jambi show a very high correlation between termite relative abundance and the recorded basal area of woody plants ($r^2 = 0.95$; Gillison, pers. comm.; see also Annex II, Figure 1c). We await the dissemination of the vascular plant data to investigate whether there are significant correlates between the termite assemblages and the plant communities.

The efficiency of the transect method, based on the number of species collected per unit effort (number of days for one trained person to collect and identify samples) has already been calculated (Jones & Eggleton, in prep.). One transect takes one trained collector four days to complete. The material from one primary forest transect at Danum Valley takes one taxonomist about 10 days to sort and identify to species. Given the known levels of species richness and taxonomic difficulty associated with the termite fauna of primary forest in

Southeast Asia, we can estimate that 14 days' effort is required for one trained person to run one transect and identify the material. If we make the assumption that the Jambi primary forest transect will have a final richness of 33 species, this equates to an approximate cost of 2.4 identified species per person per day.

8.7 Conclusions:

With the completion of seven termite transects and the preliminary sorting, the field-based phase of the Jambi project can be considered a great success. When all the museum-based identification work is complete, the top set of material will be deposited at the Bogor Museum. A smaller reference collection will be retained by the Natural History Museum. The results of the termite transect study in Jambi will be written-up for publication in an international peer-reviewed journal. This paper will address the first two aims stated in this report, and it will also address partially the third aim (correlates between the termite assemblage and the vascular plant community). This latter line of research is perhaps the most exciting and important theme to be investigated in the Jambi termite project. For the first time it will be possible to relate termite diversity to measured plant parameters. The full set of final results will be sent to Dr Andy Gillison and CIFOR, and it is hoped that at least one joint paper will be produced which investigates correlates between all the groups of organisms studied at Jambi, and the potential usefulness of these groups as target taxa in rapid biodiversity assessment.

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Table 8.1 Species checklist of termites collected from the seven land-use types in Jambi Province, central Sumatra, in November 1997.
Termites were collected using the standardised transect sampling protocol. One transect was run in each land-use type. Figures are the relative abundance of each species, based on the number of 'hits' of each species in a transect (the presence of a species in one section represents one hit). Functional group are: W = wood-feeders, I = soil/wood interface-feeders, S = soil-feeders, E = epiphyte-feeders

Species	**Functional group**	**Primary forest (BS 1)**	**Logged forest (BS 3)**	**Jungle rubber (BS 10)**	**Rubber pltn. (BS 8)**	***Parase-ianthes* (BS 6)**	***Imperata* grassland (BS 12)**	**Cassava garden (BS 14)**
KALOTERMITIDAE								
Glyptotermes sp.	W	-	-	-	1	-	-	-
RHINOTERMITIDAE								
Coptotermes curvignathus	W	1	1	1	3	1	-	-
Coptotermes sepangensis	W	-	-	-	-	4	-	-
Coptotermes borneensis	W	-	-	-	-	1	-	-
Heterotermes tenuior	W	1	-	-	-	-	-	-
Parrhinotermes near *minor*	W	-	-	1	-	-	-	-
Parrhinotermes near sp. C	W	-	1	-	-	-	-	-
Schedorhinotermes javanicus	W	1	-	7	-	7	-	-
Schedorhinotermes sarawakensis	W	1	-	-	-	9	-	-
Schedorhinotermes tarakanensis	W	6	7	4	1	-	-	-
Schedorhinotermes sp.	W	-	-	-	2	-	-	-

Species	**Functional group**	**Primary forest (BS 1)**	**Logged forest (BS 3)**	**Jungle rubber (BS 10)**	**Rubber pltn. (BS 8)**	***Parase-ianthes* (BS 6)**	***Imperata* grassland (BS 12)**	**Cassava garden (BS 14)**
TERMITIDAE								
Macrotermitinae								
Macrotermes gilvus	W	-	-	-	-	-	-	1
Macrotermes sp. 1	W	1	-	-	-	-	-	-
Odontotermes denticulatus	W	-	-	5	-	-	-	-
Odontotermes sarawakensis	W	10	9	-	-	-	-	-
Ancistrotermes pakistanicus	W	-	-	3	-	-	-	-
Termitinae								
Prohamitermes mirabilis	I	3	7	-	6	4	-	-
Labritermes buttelreepeni	S	-	-	1	2	-	-	-
Globitermes globosus	W	8	4	1	-	-	4	-
Microcerotermes serrula	W	3	7	-	1	-	-	-
Microcerotermes near *havilandi*	W	-	1	-	-	-	-	-
Termes comis	I	4	1	-	-	1	-	-
Termes propinquus	I	3	-	-	12	1	-	
Homallotermes eleanorae	I	1	-	-	3	-	-	-
Homallotermes foraminifer	I	1	4	-	-	-	-	-
Mirocapritermes connectens	S	-	2	10	-	-	-	-
Malaysiocapritermes prosetiger	S	3	2	10	-	-	-	-
Procapritermes neosetiger	S	-	-	-	6	-	-	-

Table 8.1 Species checklist of termites collected from the seven land-use types in Jambi Province, central Sumatra, in November 1997.

Species	Functional group	Primary forest (BS 1)	Logged forest (BS 3)	Jungle rubber (BS 10)	Rubber pltn. (BS 8)	*Parase-ianthes* (BS 6)	*Imperata* grassland (BS 12)	Cassava garden (BS 14)
Procapritermes sandakanensis	S	-	-	3	-	-	-	-
Procapritermes setiger	S	8	6	2	-	-	-	-
Procapritermes near *minutus*	S	4	-	1	-	-	-	-
Procapritermes sp. A	S	-	-	5	-	-	-	-
Coxocapritermes sp. A	S	6	1	-	-	-	-	-
Coxocapritermes sp. C	S	2	3	-	-	-	-	-
Coxocapritermes sp. D	S	1	3	2	-	-	-	-
Kemneritermes sp. A	S	4	1	-	-	-	-	-
Pericapritermes dolichocephalus	S	-	-	6	-	-	-	-
Pericapritermes nitobei	S	1	-	2	-	-	-	-
Pericapritermes semarangi	S	2	-	-	-	-	5	-
Dicuspiditermes nemorosus	S	11	18	12	12	-	-	-
Dicuspiditermes santschii	S	6	5	1	2	2	-	-
Nasutitermitinae								
Havilanditermes proatripennis	W	-	-	-	6	-	-	-
Nasutitermes havilandi	W	1	-	2	-	3	-	-
Nasutitermes matangensiformis	W	-	-	2	-	-	-	-
Nasutitermes neoparvus	W	-	-	-	1	-	-	-
Nasutitermes sp. C	W	-	-	-	2	-	-	-
Nasutitermes sp. D	W	1	-	-	-	2	-	-

Species	Functional group	Primary forest (BS 1)	Logged forest (BS 3)	Jungle rubber (BS 10)	Rubber pltn. (BS 8)	*Parase-ianthes* (BS 6)	*Imperata* grassland (BS 12)	Cassava garden (BS 14)
Bulbitermes germanus	W	2	-	-	-	-	-	-
Bulbitermes prabhae	W	1	-	-	-	-	-	-
Bulbitermes sp. A	W	3	1	-	-	-	-	-
Hospitalitermes hospitalis	E	4	-	-	2	-	-	-
Hospitalitermes sp. G	E	-	-	-	-	-	-	-
Proaciculitermes ?*malayanus*	S	1	3	-	-	-	-	-
Proaciculitermes sp. B	S	2	3	-	-	-	-	-
Aciculioiditermes sp. C	S	1	-	-	-	-	-	-
Oriensubulitermes inanis	S	2	4	2	-	-	-	-
Number of species	35	23	22	16	11	2	1	
Relative abundance (total hits)	110	94	83	62	35	9	1	

Figure 8.1. Species richness of termites collected from transects in seven land-use types in Jambi Province, Central Sumatra

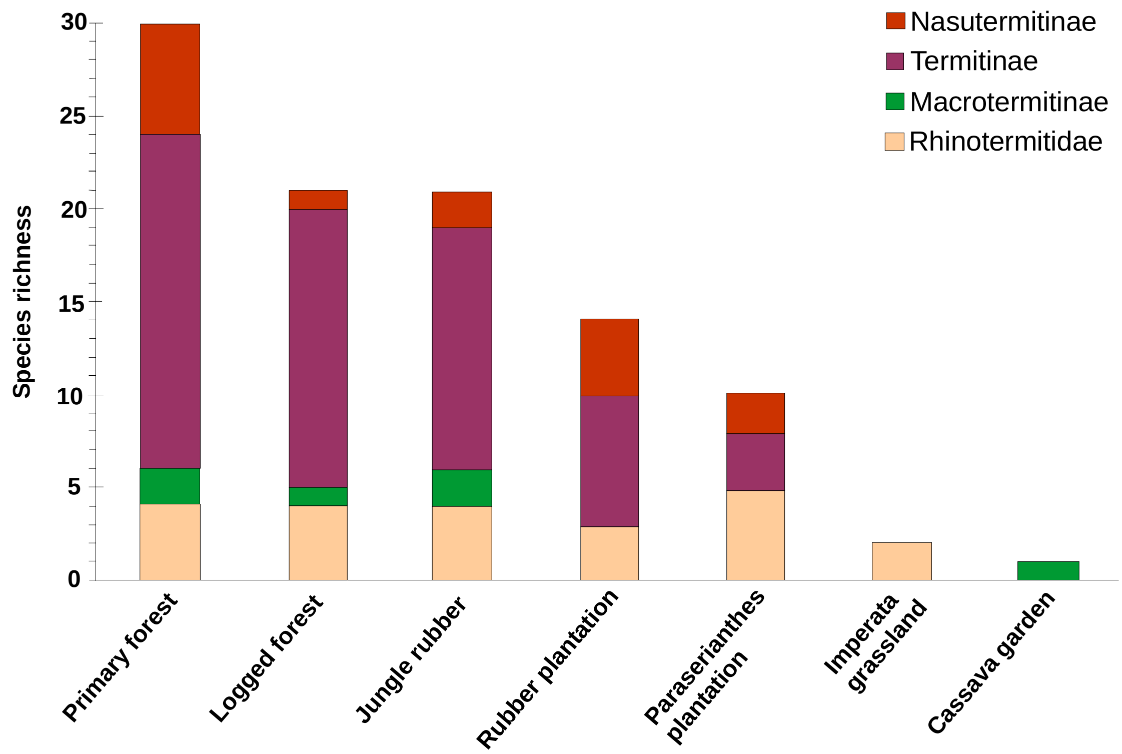

Figure 8.2. Relative abundance of termites collected from transects in seven land-use types in Jambi Province, Central Sumatra