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A Comparison on Termite Assemblages in Coffee & Teak Plantations and Semi-Evergreen Forest - A case study in North Wayanad, Kerala, India

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ABSTRACT. *In tropical ecosystems, termites as organic decomposers, play a key role in modifying the biotic and abiotic environment. The present study aimed to investigate how the termite diversity and assemblages differed among habitats. Three sites in North Wayanad, Kerala, India,- a teak plantation, a coffee plantation and a semi-evergreen forest, that were structurally different and with varying land use histories- were chosen for this study. Belt transect method was used to sample the termites. The study recorded a total of 10 species in 7 genera belonging to 4 subfamilies under one family. Termite assemblages and feeding group structure differed significantly among habitats. Two functional groups were recorded- Type II (fungus growing wood feeders/litter feeders, micro epiphytes) and Type III (organic rich soil feeders/ humus feeders). Fungus growing wood/litter feeders were dominant in plantations whereas organic rich soil/humus feeders were dominant in forest region. Plantations seem to host more, species like Odontotermes obesus Rambur, Odontotermes anamallensis Holmgren and Holmgren and Odontotermes yadevi Thakur, the species being good colonizers, favoured by disturbance and also those with the potential of becoming pests.* The species diversity, richness, evenness as well as beta diversity were computed for the three habitats. Assemblages of species from the teak and coffee plantations yielded the highest similarity index (42%). *Overall, the termite assemblages and structural attributes of coffee & teak plantations and semi-evergreen forest advocated termites as good biological indicators of habitat quality.*

Keywords*: Biological indicator, functional group, coffee and teak plantation, termites, semi-evergreen forest, diversity.*

INTRODUCTION

The termites are the most dominant arthropod decomposers in the tropical forests (Wood and Sands, 1978; Matsumoto and Abe, 1979; Collins, 1983) and they show high diversity and abundance (Bignell and Eggleton, 2000). Within tropical ecosystems, termites play a key role in modifying the biotic and abiotic environment. They become economic pests when their appetite for wood and wood products extends to human homes, building materials, forests, and other commercial products (Meyr, 2009). Approximately 2,700 described

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species of termites are known globally, but only 10% of known species has been reported as pests (Wood, 1996).

The diversity and distribution of termites are greatly influenced by factors such as vegetation type (Jones, 2000), habitat disturbance (Jones *et al*., 2003, DeBlauwe *et al*., 2008) and habitat fragmentation (DeSouza & Brown, 1994, Davies *et al*., 2003). Hence termites have been used as indicator species to study the effect of land use conversion on biodiversity in several areas (Eggleton *et al*., 1996, Dibog *et al*., 1999).

The present study by comparing the termite assemblages of a semi-evergreen forest with those of two plantations namely coffee and teak, aimed to investigate how the termite diversity and assemblages differed among habitats. The results advocate the potential of termites as efficient ecological indicators.

METHODOLOGY

Study area

The present study was carried out at three selected representative sites in Wayanad district (Table 1), situated in the southernmost Indian state of Kerala, a place well known for its high degree of endemism and richness of flora and fauna (Fig.1). Set high on the Western Ghats with north latitude 11^0 26' 28" and 11^0 58' 22", east longitude 75^0 46' 38" and 76^0 26' 11", the altitude ranges from 700 to 2100 m. The average rainfall is 2322 mm per year. The description of the sample site is given in Table 1.

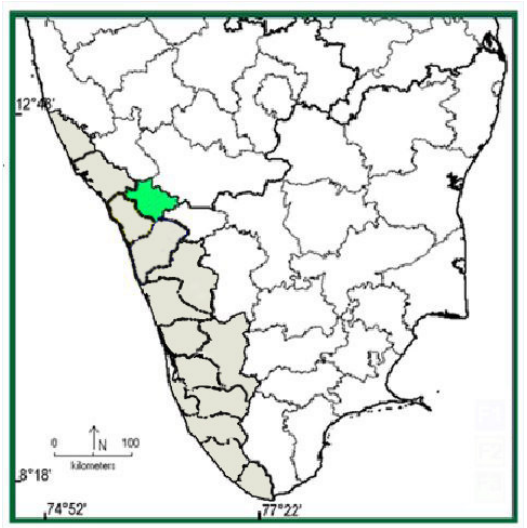

Fig.1. The study area, Wayanad (Kerala)

Study sites in Wayanad

Site 1: Coffee plantation at Kartikulam

The coffee plantation selected for this investigation was situated at Kartikulam of Mananthavady taluk (Fig.2-A), about 9.5 km away from Mananthavady town (11^0 84773" N and 76^0 09661" E, altitude 776 to 793 msl). In the plantation, other trees like *Dalbergia* sp., *Erythrina* sp., *Atrocarpus* sp., *Grevillea* sp. and many other varieties of plants were fond as shade plants. The surface soil was highly enriched with leaf litter and decaying wood particles.

Site 2: Teak plantation at Tholpetty

Wayanad hosts extensive areas of reserve forests, of which the major components are the teak plantations. The study area was a part of Tholpetty division (11^0 53' 13.64 N and 76^0 04' 35.63" E, 747.37 msl) of Wayanad Wildlife Sanctuary, an integral part of the Nilgiri Biosphere Reserve (Fig. 2-B).

Site 3: Semi- evergreen forest at Thirunelli

The area under investigation was situated in the semi-evergreen forest region of Thirunelli (11^0 54'51.45''N, $75^0$59'39.55''E, 900 msl) (Fig.2-C). This forest type was an intermediate between the tropical evergreen and deciduous forms and included both evergreen and deciduous trees. The area sampled was situated on either sides of Papanasini river. Major flora included *Atrocarpus integrifolia*, *Dalbergia latifolia, Lagerstroemia latifolia, Pterocarpus marsupium, Macaranga peltata* and shrubs like *Strobilanthes kuthianus* and *Mesua ferrea* etc. The soil surface had a dense covering of leaf litter and decaying wood particles.

Table 1. Description of sample sites to study termite assemblage

Site	Vegetation type	Location	Latitude	Longitude	Figure
1	Coffee Plantation	Kartikulam	11^0 84773"N	76^0 09661" E	A
2	Teak Plantation	Tholpetti	11^0 53' 13.64 N	76^0 04' 35.63" E	B
3	Semi- evergreen forest	Thirunelli	11^0 54'51.45''N	$75^0$59'39.55''E	C

Collection of samples

Termite samples from the selected areas were collected for a period of 3 months from September to November 2013 at weekly intervals. Standardized transect method of Jones and Eggleton (2000) was used for sampling. A belt transect, measuring 100 x 2 m was laid in each site, which was in turn divided into 20 contiguous sections of 5 x 2 m. Each site had two representative plots separated by a distance of 50 m. Termites were collected simultaneously at weakly intervals. A total of 5 hours were taken to search for termites in the total transect area. Microhabitats like surface soil, leaf litter and humus on the surface; at the base of trees, between roots, inside and beneath the dead woods, in mounds and on vegetations and trees up to a height of a man (about 2 m) and the soil up to a depth of 5 cm were searched. Preferentially soldier and worker castes were collected and were stored in 70% alcohol.

Identification of termites at species level was performed following Chhotani (1997). Major generic diagnostic characters of soldiers and workers are given in Table 2. All specimens are deposited in the National Zoological Collections of the Zoological Survey of India (ZSI), at Calicut (Kozhikode), Kerala, India.

Table 2. Major diagnostic characters of soldiers and workers of different termite genera

Termite genera	Major diagnostic characters	
	Soldier	**Worker**
Odontotermes Holmgren	Monomorphic, medium to fairly large species, head sparsely hairy. Left mandible with a small to prominent tooth.	Monomorphic or dimorphic. Head capsule subsquarish. Fontanelle plate round and oval. Antennae with 17-19 segments.
Microtermes Wasmann	Monomorphic, small and delicate species, head oval, densely hairy. Mandible thin, delicate and weakly incurved distally.	Dimorphic. Head capsule subsquarish. Fontanelle indistinct. Antennae with 13-16 segments.
Speculitermes Wasmann	Head subrectangular, large, prominent and highly chitinised. Mandible strongly built and long; comparatively thinner basally and fairly well curved apically; each with a prominent triangular tooth. Antennae 14-segmented.	Head capsule subcircular. Mid-dorsal spot small to fairly large; either flush with head surface or swollen and raised. Antennae 14 segmented.
Nasutitermes Dudley	Monomorphic. Head not constricted behind antennae. Head pyriform or round. Rostrum long, narrow, cylindrical to conical. Mandible with short or without spine-like process	Generally monomorphic sometime dimorphic. Head capsule subsquarish to broad and oval. Antennae with 13-15 segments.
Grallatotermes Holmgren	Monomorphic. Head not constricted behind antennae. Head greatly produced behind and strongly depressed at base of rostrum in profile. Rostrum short, thick and conical. Mandible with well developed, long spine-like process.	Head brown to black; broad and oval. Antennae with 12-15 segments.
Dicuspiditermes Krishna	Mandibles strongly asymmetrical, left mandible strongly twisted at middle. Antero-lateral corners of head produced into tubercle-like projection. Antennae 14 segmented.	Head capsule subcircular. Fontanelle plate translucent and oval. Antennae 14 segmented.
Pseudocapritermes Kemner	Mandibles strongly asymmetrical, left mandible strongly twisted at middle, distal tip of left mandible bent like a beak. Antero-lateral corners of head not produced into tubercle-like projection. Antennae 14 segmented	Head capsule subcircular. Fontanelle plate translucent, large and circular. Antennae 13-14 segmented.

Fig. 2 (A-C): Different study sites in Wayanad
A. Coffee Plantation at Kartikulam
B. Teak Plantation at Tholpetti
C. Semi-evergreen forest at Thirunelli

RESULTS AND DISCUSSION

Termite species identified

A total of 92 termite colonies were collected from the sites during the study. Termites collected from the two plantations were identified upto species level. They belonged to the family Termitidae under 4 subfamilies (Macrotermitinae, Nasutitermitinae, Termitinae and Apicotermitinae), in 7 genera (*Odontotermes* Holmgren, *Nasutitermes* Dudley, *Dicuspiditermes* Krishna, *Grallatotermes* Holmgren, *Microtermes* Wasmann, *Pseudocapritermes* Kemner and *Speculitermes* (Wasmann). A total of 10 species identified were *Odontotermes obesus* Rambur, *O. anamallensis* Holmgren and Holmgren, *O. yadevi* Thakur, *Nasutitermes matangensis matangensis* Haviland, *N. indicola, Grallatotermes niger* Chatterjee and Thapa *Dicuspiditermes incola* Wasmann, *Microtermes unicolor* Snyder (Amina *et al. in press*), *P.nr fletcheri* and *S. chadaensis* Chatterjee and Thapa .

Termite diversity

The Termite diversity at generic in the three study areas are presented in Table 4. In coffee plantation 3 genera belonging to 3 subfamilies were recorded and from teak plantation 2 subfamilies represented by 3 genera were obtained, whereas from the forest region site, 5 genera belonging to 4 subfamilies were recorded. In all the three study sites, genus *Odontotermes* was the most common and dominating genus. Two genera *Nasutitermes* and *Dicuspiditermes* were common to both the coffee plantation and the semi evergreen forest, whereas *Grallatotermes* and *Microtermes* were present only in the teak plantation. *Speculitermes* and *Pseudocapritermes* were confined to forest area.

Table 3. Diversity indices for the three habitats

Diversity index	Semi-evergreen forest	Coffee plantation	Teak plantation
Simpson's Index	0.80	0.63	0.52
Shannon-Wiener index (*H'*)	1.66	1.10	0.97
Margalef index (á)	1.73	1.14	1.21
Pielou's index (*E1*)	0.24	0.22	0.19

From Table 3, the Simpson's index of diversity values was found to be highest for the semi-evergreen forest (0.80), followed by the coffee (0.63) and teak plantations (0.52). A similar trend was observed for the *H'* values, indicating that species diversity for the forest ecosystem, rich in humus was higher compared to the plantations. The á values for the forest ecosystem was clearly higher (1.73) than that of the plantations, with a more or less similar á value for the teak (1.21) and coffee plantation (1.14). The *E1* values for the three habitats revealed that species distribution was most even in the forest ecosystem (0.24) followd by the coffee (0.22) and teak (0.19) plantations.

The overall Jaccard index (*JI*) between the three habitats was found to be 21%. When the *JI* values for the habitats taken in pairs was computed, it was found that the highest similarity in species was for the plantation crops- coffee and teak (42%). The similarity in the habitat and community structure of the plantations, clearly reflected the correlation in the species assemblages.

The *JI* for the forest *Vs* coffee plantation as well as forest *Vs* teak plantation generated same value of 33%.

Species abundance

Of the identified termite species in coffee and teak plantation and semi-evergreen forest, their abundance showed a huge variations as shown in Table 4. A total of 5 species were obtained from coffee and teak plantations and 7 species from the forest area. Genus *Odontotermes* had the largest representation in all the study sites. Three *Odontotermes* species *O. yadevi, O. anamallensis and O. obesus* were recorded from coffee & teak plantation plantations and the semi ever green forest. *O. obesus* was the dominating species in teak, whereas in coffee and forest sites *O. anamallensis* was found. *N. matangensis matangensis* was recorded only from coffee plantation whereas, *G. niger* and *M. `unicolor* were recorded only from the teak plantation. *D. incola* was recorded in forest and coffee, while, *S. chadaensis* and *P. near fletcheri* were represented only the forest (Table 4).

Among the 33 termite colonies collected from the coffee plantation, 15 belonged to *O. anamallensis* followed by *O. obesus* (14 colonies), *N. matangensis matangensis* (2 colonies), *D. incola* and *O. yadevi* (1 colony each). From the teak plantation, the total collection of 27 termite colonies included 18 colonies of *O. obesus*, 6 colonies of *O. yadevi* and 1 colony of *O. anamallensis*, *G. niger* and *M. unicolor* each. The 32 collections of the semi evergreen forest region, *O. anamallensis* (11 colonies), followed by *N. indicola* (7 colonies), *P. near fletcheri* (6 colonies), *O. obesus* (4 colonies), *D. incola* (2 colonies) *S.chadaensis* and *O. yadevi* (1 colony) were collected.

Termite feeding groups

The termite species collected from the study sites belonged to two feeding groups according to the classification of Donovan *et al*. (2001) they included Type II (wood /litter feeders, micro epiphytes feeders) and type III (organic rich soil/humus feeders) feeders. Type I (lower termites; wood feeders) and Type IV (true soil feeders) were absent in all the study sites (Fig. 3-5 and Table 4).

Out of the total of 10 species recorded, 4 species were fungus growing wood/litter feeders *(O. obesus, O. anamallensis, O. yadevi and M. unicolor),* 3 were organic rich soil/humus feeders *(D. incola, S. chadaensis and P. near fletcheri)* (Bignell *et al*., 2010), *N. matangensis matangensis* was a wood feeder (Jones and Brendell, 1994) and *N. indicola* belonged to non fungus growing wood/litter feeders, based on the mandible structure of the worker castes. In coffee and teak plantations, wood/litter feeders were dominant and while in the semi evergreen forest, organic rich soil/humus feeders were dominant. The organic rich soil/humus feeder *D. incola* was found in the coffee and in the forest. The lichen feeders or micro epiphytic feeder *Grallatotermes* were confined to the teak plantations. The organic rich soil/humus feeders, *S. chadaensis* and *P. near fletcheri* were recorded only from the semi evergreen forest.

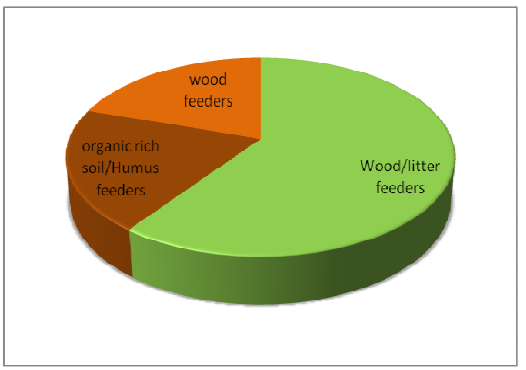

Fig.3. Feeding groups - Coffee plantation

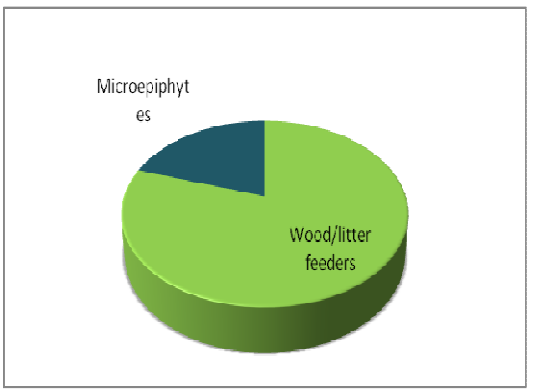

Fig.4. Feeding groups - Teak plantation

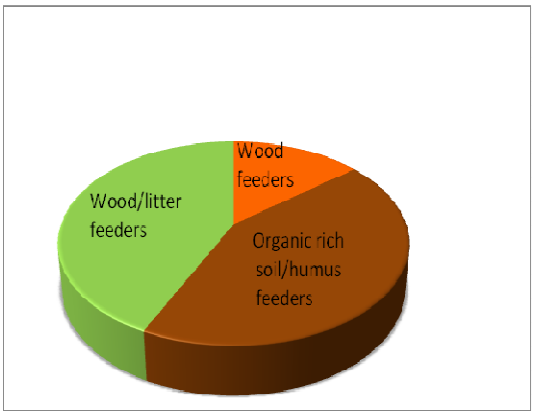

Fig.5. Feeding groups - Semievergreen forest

Table 4. Termite fauna of coffee & teak plantations and semi-evergreen forest studied in Kerala, India

Subfamily	Termite species	Habitat			Food			
		No. of colonies						
		SEF	CP	TP	W	W/L	ME	H
		11	15	1		*		
Macrotermitinae	1.*Odontotermes anamallensis* Holmgren							
	2 *Odontotermes obesus* Rambur	4	14	18		*		
	3 *Odontotermes yadevi* Thakur	1	1	6		*		
	4 *Microtermes unicolor* Snyder			1		*		
Apicotermitinae	5 *Speculitermes chadaensis* Chatterjee and Thapa	1						*
Nasutitermitinae	6.*Nasutitermes matangensis matangensis* Haviland		2		*			
	7 *Nasutitermes indicola*	7			*			
	8 *Grallatotermes niger* Chatterjee and Thapa			1			*	
Termitinae	9 *Dicuspiditermes incola* Wasmann	2	1					*
	10 *Pseudocapritermes nr fletcheri*	6						*

Foot note:
SEF: Semi-evergreen forest
CP: Coffee Plantation
TP: Teak plantation
Feeding Group II: W= Wood, W/L=Wood/Litter, ME= Microepiphytes
Feeding Group III: H= Humus

Several studies have shown that species diversity and richness of termites decrease with increase in altitude and temperature (Gathorne- Hardy *et al*., 2001; Donovan *et al*., 2002). In this study, a total of 10 species belonging to 7 genera 4 subfamilies and one family were recorded. Hence, the low diversity and richness noticed may be attributed to the high elevation of the study sites (Gathorne- Hardy *et al*., 2001).

Termite assemblage and feeding group structure differed significantly among habitats. As per the results of the study, subfamily Macrotermitinae was the most dominant group in plantations. The results of this study corroborated with results of Attignon *et al.* (2005), which recorded Macrotermitinae as the most dominating groups in termite assemblages in West – African semi deciduous forest and teak plantations.

Varma and Swaran (2007) in Eucalyptus plantations and Gowda *et al.* (1995) in coffee plantation reported that *Odontotermes*, feeding on the bark and living tissues, as the most dominant termite group in plantations. The present study confirmed the dominance of *Odontotermes* in plantations. Species of *Odontotermes* ie. *O.obesus*, *O.anamallensis* and *O.yadevi* are categorised as pest species (Sundararaj and Shanbhag, 2013, Amina *et al.*, in press). They are favoured by disturbance and are hence good colonizers. As per Sundararaj and Shanbhag (2013) and Varma and Swaran (2007), O. *obesus* was the dominant species in plantations. In the present study too, coffee and teak plantations were very rich in *O. obesus.*

According to Susilo and Aini (2005), the termite diversity and density decreased with increasing land use intensification, which destroyed the termite microhabitats and their nesting and feeding sites. The lower level of species diversity and richness of termites observed in plantations than those in the natural semi evergreen forest in this study truly authenticates the findings of Susilo and Aini (2005).

As of Attingnon *et al.,* 2005, plantations were dominated with fungal feeders, while the organic/humus feeders frequented most, in the forest area. As the termites are indicators of soil fertility, the presence of organic rich feeders/ humus feeders like *D. incola, S. chadaensis and P. near fletcheri* reflected upon the higher soil fertility in the forest region than that of the plantations. The studies conducted by Eggleton *et al.* (1997), Eggleton *et al.* (2002), and DeSouza and Brown (1994) proved that the soil feeders were more vulnerable to human interference than wood feeders and this justifies the absence of soil feeders, the Apicotermitinae in plantations in the present study.

CONCLUSIONS

Of the three sites compared for termite assemblages, the semi evergreen forest site topped in species diversity, richness, evenness and in the occurrence of maximum number of functional groups. For the same reason, this forest area can be interpreted to be ecologically healthier and more stable than plantations. On the other hand, the presence of pest species in semi evergreen forests, though in lesser numbers, may be an early indication of the increasing disturbances on the habitat. Habitat homogeneity of plantations was reflected in their species similarity.

The vivid agreement between the sampled termite assemblages and structural attributes of different habitats advocates termites as good biological indicators of habitat quality.

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