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Seasonal Changes on Termite Foraging Behaviour under Different Habitats in Rufiji District Tanzania.

Christopher Materu[1*] & Jacob Yarro,[2] Bruno Nyundo,[2]

1. Christopher L. Materu, P O Box 6226, Mikocheni Agricultural Research Institute Tanzania
2. Bruno A. Nyundo & Jacob G. Yarro P O Box 35064, University of Dar Es Salaam
*chrismateru@yahoo.com, bnyundo@uccmail.co.tz and jgyarro@uccmail.co.tz

Abstract
The effect of wet and dry season on termites foraging was examined in cropland, forest and grassland in Rufiji district for a period of one year. Termites species richness as well as abundance were sampled using standardized transect lines. Sampling was carried out on monthly basis. Termite species abundance was significantly different between the three locations, but species richness was not significantly different. These results reveal that termite abundance was higher in disturbed habitat due to the removal of vegetation which denies termites food and areas for nesting. Furthermore movement of termites from lower horizons during the wet season was higher than in the dry season.
Key words: Termites activity, abundance, species richness, Rufiji district.

1. Introduction

The effect of seasonal changes on termites foraging in different habitats in Rufiji district is poorly studied despite the influence of termites on decomposition of organic matter and nutrient cycling (Park *et al*. 1996). For example, studies carried out in Malaysia observed that termites are more abundant in the forest and grassland sites during the wet season than during the dry season (Lee & Wood 1971). Studies related to effects of humans on tropical rainforest biodiversity have shown that species richness declines due to human activities (Lawton *et al*. 1998). Seasonal weather variation in tropical forest areas have been reported by Eggleton & Bignell, (1995). The direct effect of rainfall arises from the physical effects of large amounts of water falling on litter fauna and forest floor litter (Chiba *et al.* 1975). Termites are regarded as decomposers of wood in tropical forests, (Wood & Sands 1978); and in savannah (Holt, 1987)**.** These functions are dependent on the species assemblage, structure of the termite community (Lawton *et al*. 1996). Reduced ground cover vegetation results in increased colony establishment of some African *Macrotermitinae*. Termites form a component of the ecosystem and hence their foraging activity is seasonal for most termite species. Seasonal food availability influences termite foraging activity hence a higher foraging activity in the wet season than in the dry season. Termites foraging is mainly for food searching during the wet season and highly reduced during dry season. Therefore exposure of termites on the soil surface during dry season may lead to desiccation (Creffield, 1991). The common food storage is faeces and fungal comb in *Microtermitinae* sub-family or as carton in other species. The studied sub-terranean termite species forage and store food that will be consumed the following season. On opening the termites nest you will find out that termites are divided into groups known as castes ie reproductives, workers and soldiers (Creffield, 1991). The role of reproductives is to lay more eggs for the expansion of the colony members, while workers play a role of food searching, nest repair, construction and feeding of the young ones while soldiers characterised with big mandibles responsible for defending the colony members from natural enemies. Currently no comprehensive studies on termite foraging behaviour depending on seasonal changes have been conducted. This study was carried out in three different habitats *i.e*. grassland, cropland and in a primary forest from October, 2010 to November 2011 in Rufiji district.

2. Materials and Methods

The study on termite species richness and abundance was carried out using standardized transect lines (Eggleton, 1996). The transect lines were able to provide quick information on different termite species present in the selected habitats. The district is located 178 km south of Dar es Salaam and covers an area of about 53,000 ha. The prominent feature of the district is the Rufiji River, an eponym for the district. The study area lies between 7° 27′S - 8 ° 27′S and 37° 52′E - 39°28′ E. The district has a bimodal rainfall pattern, the long rains are between March and June and the short between October and December. The district receives an average rainfall of about 1,100 mm/year Temperatures range from 25°C to 35°C and are highly influenced by monsoon winds, which bring rains. The distribution of forest in the district greatly influences the rainfall patterns. There is no weather station at each selected site but the rainfall data was obtained from the Tanzania Meteorological Weather Agency. The key selection criteria of the study sites were size and habitat complexity. Large areas were expected to have more species than small areas and the greater the habitat complexity the higher the diversity. Therefore, different habitat types including grassland, forested land and coconut farms of different ages were selected for termite

sampling.
All selected habitat types were below 500m above sea level. Study locations were randomly selected to cover various habitats in the district. Standard transect line 200 m with 5 m wide were used during data collection (Eggleton *et al*. 1996). Termite abundance and richness were regarded as data, and these were used to compare variation among or between habitats (Whittaker, 1972). Termite sampling was carried out when termite activity was high between 0730 to 1200 noon and 1600 when temperatures were also cool. Insect sampling was carried for a period of one year on monthly basis. Sampling during rainfall was carried out after three days to avoid the effect of rain on termite foraging activity. Termite samples from each quadrat were collected and preserved in labelled vials containing 70% ethanol for later identification.

3. Data Analysis
The species diversity (abundance and species richness) in different sites was calculated by using the Shannon Weaver Index (H′) (Zar, 1999**).** The Shannon-Weaver Index takes into account the number of species in the community (species richness) and the number of individuals per species. The index H′ is calculated as follows: $H' = -\Sigma\, p_i \ln p_i$, where p_i = proportion of total sample belonging to the i^{th} species.
Species diversity has two main important components namely species richness and equitability. Species equitability is related to dominance relationship. The Species evenness or equitability was calculated by $E = H'/\ln S$ or $E = H'/H'_{max}$ (Zar, 1999**).** Where:

- E is evenness or equitability of species
- H′ is the observed species diversity
- The diversity of species in various habitats between seasons and between habitat types was compared by Mann-Whitney test (Zar, 1999). Analysis of variance among the habitat types was computed using Kruskal-Wallis test. The U–test was used to compare termite abundance between habitat types. Chi-square test was used to compare species richness sampled from the selected study areas.
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3.1 Taxonomy
Termites species collected were examined under dissecting microscope using identification keys (Bouilon, & Mathot, 1965; Pearce *et al*. 1992). Termite soldiers were used to identify termite species and estimate their relative abundance. Termites without soldiers were excluded from the analysis.

4. Results
4.1 The termite abundance in the study habitats during wet and dry season
During the entire period of this study a total of 26,149 termites were recorded with their respective mean averages *i.e*. termites from the cropland, grassland and forest habitats, respectively (Table 1). Comparison of termites abundance was done using the Kruskal-Wallis test which showed statistically significant differences in abundance (P = 0.0427) (Table 2).
4.2 Comparison of termite abundance between pairs of habitat types
Termite abundance between cropland and forest habitats was significantly different (U = 55.500 and 162.500, p = 0.0353). Comparison of cropland and grassland habitats also showed significant differences in termite abundance (U = 36.000 and 55.000, p = 0.031). However, there was no significant difference in termite abundance between the forest and the grassland habitats (Table 2). Species diversity as well as evenness during wet and dry season was summarised in Table 3 and Table 4.
4.3 Species richness
The highest number of species was recorded from the forest habitat (16), followed by cropland (13) and the least was grassland (7) (Table 3). However there was no significant difference in species richness ($\chi^2 = 1.68$, $p > 0.05$). Overall, termite species richness was higher during the wet season than during dry season. During the study period termite species richness was higher in the forest habitat than cropland as well as in grassland habitat Table 3 provides an overview of species richness in different habitats during wet and dry season. Termite species richness was 19%, 36% and 44% for grassland, cropland and forest habitats respectively. The species richness was lowest in the grassland possibly because of human activities. In the cropland, for example, the most important genera were the *Microtermes alluaudanus Microcerotermes brachygnathus* and *Macrotermes bellicosus* which were feeding on dead cassava plants, maize straws left in the field from previous harvest, dead tree stumps and dead tree logs. *Pseudacanthotermes militaris Nasutitermes kempae*) and *Odontotermes* sp was found at much lower densities and were feeding on dead tree stumps and dead tree logs. *Fastigitermes jucundus Cubitermes glebae* and *Termers bolivianus* were feeding on damp decomposing wood material and soil. It was found that soil and wood feeding termite species were equally represented in all habitat types.
4.4 The termite abundance in the study habitats during wet and dry season
Termite individuals were more abundant during wet season than during the dry season. The increase in numbers

ranged from about 4,000 in grassland to 16,000 individuals from cropland. Forest and grassland habitat had fewer termites numbers than crop land habitats. Termite abundance in coconut farms and nurseries was high during the wet season compared to the dry season. The cropland habitats were planted with annual and perennial crops *i.e* cassava, maize, pineapples and young coconut seedlings. Intercropping of coconut trees with citrus was practiced by farmers in all crop land habitats. There was high termite abundance in cropland habitat and low species richness. Cropland and grassland habitats had low species richness too. In the grassland habitat *Cubitermes* sp were recorded during both seasons. More soil feeding termite genera were thus encountered during the wet season than during dry season in all the habitat types although the seasonal differences were not significantly different.

Microtermes sp. was recorded during entire period of this study in all the habitat types. Furthermore, *Pseudacanthotermes* sp. was recorded in all habitats during both seasons except in the grassland habitats. Fungus growing termite species were more tolerant to drought and their nests were also located at positions deep enough down the soil out of reach of farm operation activities. In some areas where colonies were disturbed by farm operations like frequent cultivation. Apart from this, there were dead stumps and roots in the cropland which provided plenty of food for fungus growing termites all the year around.

5. Discussions

5.1 The termite abundance in the study habitats during wet and dry season

Alterations in the environment from forest habitat to grassland or agriculture activities have an influence on food availability, presence/absence of natural enemies and nesting habit (Holloway *et al.* 1992). The increase in termites numbers was not uniform from one habitat to another, the numbers were probably influenced by the abundance of food. Most of the food in the forest consists of leaf litter, wood, woody stumps and decaying wood material which change very little. Un-weeded cultivated cropland resembles the forest habitat in terms of food availability. Thus in an ecologically stable ecosystem where food availability is more or less stable, fluctuations in termite abundance are minimal. Termite abundance in coconut farms and nurseries was highly influenced by the weather and various field operations in the farms including nursery husbandry practices. Forest clearing, burning, tillage operation, weed management and the type of crop grown may strongly impact on termite abundance as well as on species richness in Rufiji district. Similar results were reported by Abe & Watanabe (1983), on soil macro fauna in subtropical rain forest and its adjacent cassava plantation in Okinawa- with special reference to the activity of termites. Similar studies carried out in Southern Cameroon showed that there was an increase of termite abundance in relation to forest disturbance although species richness collapsed along with land use (Pinheiro *et al*. 2002; Abensperg-Traun & Smith 1999). Intercropping maximizes land use but from the point of view of termites it increases biomass through accumulation of crop residues and dead trees providing abundant sources of food for different termite species.

Crop diversity influences termite richness and abundance under different land use system. Studies carried out in the Mbalmayo Forest Reserve, southern Cameroon have shown that the diversity, abundance and biomass of termites differ under different levels of anthropogenic disturbance (Eggleton *et al.* 1996).

These findings are in agreement with results reported from the effects of habitat fragmentation on Amazonian termite communities (De Souza & Brown 1994) and Mabira forest in Uganda (Okwakol, 2000). It has also been reported in Indonesia where species richness was negatively correlated with the removal of canopy cover (Jones & Eggleton 2000). Conversion of forest areas to agriculture results in habitat loss and severe changes in water holding capacities (Black *et al.* 1997), thereby putting soil organism at risk. Termite activity is also influenced by changes in the organic matter and its quality (Wood *et al*. 1977). Loss of habitat can also be brought about by setting fires which remove leaf litter materials thus destroying suitable condition for soil inhabiting organisms including soil feeding termites. Indeed presence of leaf litter in grassland, forest or in cropland area is important because leaf litter acts as mulch and retains soil moisture or source of organic matter, creating a favourable environment for termites. Similarly, the effect of free range grazing and overgrazing in grassland habitats leads to reduction in the number of species in the habitat during both seasons. Wood (1975), reported that decline of termite species richness in grassland habitats and croplands is due to various human activities.

5.2 Termite species richness

With regard to the cropland, the areas under cultivation might have been part of a more extensive forest whose canopy was cleared to give way to agriculture which negatively changed the physical and biological complexity of the area resulting in reduced species richness. High temperatures in cropland habitats raise the soil temperature, making sub-terannean termite species to move deeper into the soil, influencing termite foraging activities as well as the number of species observed on the soil surface at the time of sampling. Kumar (1991), observed that termite foraging activity varies seasonally with weather conditions.

Drought is one of the major factors influencing termite foraging because soil moisture is related to termite foraging such that high temperatures on the soil surface and low soil moisture content, will cause a raise in soil

temperature causing termites to shift from the surface area to deeper soil horizons. There were no significantly differences between the seasons in terms of species richness. Studies carried out in northern California showed that there was seasonal foraging behaviour of *Reticulitermes* sp. (Rhinotermitidae) (Haverty *et al*. 1974).

5.3 Termite species diversity and evenness

Species diversity and evenness, a measure of proportional diversity, was determined by employing the Shannon Weaver as a test statistic for a model that is neutral with respect to physical, functional, and biotic interactions. The results from this study indicated that the habitat with high diversity figures also had the highest termite richness as well as evenness. The intercropping system practiced in the cropland habitat studied, could have been mimicking the forest habitat because the species evenness in the two habitats were not significantly different. The termite species were evenly distributed in all habitats, this is probably because the habitats were not located far away from each other.

6. Conclusion

The present study was carried out in grassland, forest and cropland habitats whereby the forest habitat had the highest termite species richness. Due to higher biomass productivity in the forest areas many termite species were able to share available food resources when compared to the grassland and cropland habitats leading to higher species richness, diversity and evenness**.** Termites abundance was observed to be high in the cropland habitat probably alteration of the natural forest reduce competition for ecological resources. The results of this work will assist researchers to plan well on termite sampling when taking into consideration of seasonal effect on termite species richness, abundance and diversity. Further studies are needed to cover more diverse agro-ecological regions to identify termite species richness and diversity and how they interact with the environment**.**

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Table 1: Termites abundance (total number of individuals) in the three habitat types (n = number of quadrates) during wet and dry season

Habitat type	Termites abundance wet season (mean)	Termites abundance dry season (mean)
Cropland (n=160)	16,820 ± 105	5,307 ±.33.1
Forest (n=40)	4,622 ± 115.5	1,308 ± 32.7
Grassland (n=40)	4,707 ±117.7	694 ± 17.35

Table 2: Comparison of termite abundance between habitat types (cropland, grassland and forest) in Rufiji district

Habitat pairs	U-Statistic	U'	P	Significance
Crop vs forest	55.500	162.500	0.0353	*
Crop vs grass	36.000	55.000	0.031	*
Forest vs grass	36.000	76.000	0.1977	ns

Table 3: Pair wise comparison of species diversity (H′) during wet and dry season

Habitat	Species richness	Wet season species diversity (H′)	Dry season species diversity (H′)
Cropland	13	2.0485	1.7432
Forest	16	2.2836	1.8724
Grassland	7	1.4854	1.2669

The pair wise comparison showed that there was no significant difference between the seasons (U= 10.500 and U' = 25.500, P>0.05).

Table 4: Species evenness during wet and dry season

Habitat	Species richness	Wet season Species Evenness (J)	Dry season Species Evenness (J)
Cropland	9	0.73885	0.62872
Forest	9	0.82362	0.67534
Grassland	5	0.53573	0.0458