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Original Article

DIVERSITY AND ABUNDANCE OF SUBTERRANEAN TERMITES ENGINEERS ISLANDS OF SOIL QUALITY IN DIFFERENT LAND COVER TYPES

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ABSTRACT
Subterranean termites are an important component of below ground biodiversity since they live in the soil and they provide physical niche opportunities for lower level organisms determining their community structure. The distribution and abundance of termite species are used to indicate termite community structure. Soil physical and chemical properties are often affected by termite activity. Therefore, land use systems are suggested to be influenced by termites' density and diversity through the different operations executed by the farmers and the type of vegetation cover. This study was instituted to determine termite diversity and abundance in different land cover types in correlation to soil physical and chemical characteristics. It was carried out over a period of 6 months during a dry period and a wet season. Two transects of 5m x 40m and 200m x 600m were employed based on vegetation cover. Our results using mainly the macrotermitinae termite community structure showed that land cover type and season significantly affected the termites' abundance (P=0.005). That termites created islands of fertility in ecosystems via a type of ecosystem engineering. This also study concluded that the conversion of forest into farmland negatively affects termites' abundance and consequently the soil quality decreases. Therefore, sustainable use of agro- ecosystems is suggested to focus on the use of organic manure to conserve termites which are important in improving soil fertility.

KEYWORDS: termite, ecosystem, fertility, community, land use, agriculture.

INTRODUCTION

Soil is a major reservoir of biodiversity. Biodiversity studies include both the abiotic components of below ground which include the soil physical and chemical properties and biotic factors which include the soil organisms. Swift *et al,* 2004, classified soil organisms into functional groups depending on body size. The functional groups are macro fauna e.g. termites, earthworms; microflora e.g. rhizobia, mycorrhiza; micro fauna e.g. protozoa, nematodes and mesofauna e.g. mites, springtails. Soil invertebrates have also been classified according to their feeding habits and distribution in soil profile (Woomer*et al*., 1994; Swift *et al*., 2004; Giller*et al*., 2005). Endogeic species are soil invertebrates which live in soil and feed on organic matter and dead roots e.g. earthworms and soil feeding termites. Earthworms and termites have been referred to as the keystone species since they provide physical niche opportunities for lower level organisms and determine the community structure of those organisms (Jones 1994).

Termites can form an important component of agro-ecosystems particularly in developing economics, where there are alternative to expensive agro- inputs. Alan *et al,* 2008, argued using data on numerical and biomass densities, geographical distribution and known functional roles, that earthworms and termites are the most important engineers in terrestrial ecosystem. Recent global happenings like climate change, are most likely going to affect termite distribution and abundance especially through the quantity and quality of litter. Furthermore, expected changes in temperature will expand the latitudinal distribution of termites and favor humivorus termites and endogeic earthworm species that feed in the soil. Therefore, this study envisioned to evaluate the current scientific knowledge for termites as ecosystem engineers, in particular their capacity to act as bio indicators and threatening processes which influence their abundance and diversity. Past studies indicated a high termite presence in Africa. For example, Hegh, 1922, commented of the soil of Africa as in reality a vast termite-mound. There are about 2000 different species of termites, with the largest number found in tropical Africa (Wanyonyi, et al 1984).

Termites modify soil structure through bioturbation and the production of biogenic structures (Brussard et al., 1997). The activities of termites in the soil affect nutrient cycling, soil physical and chemical properties and this has impact on other soil organisms (Lavelle, P., Bignell, and Lepage,1997).Termites have been used to recuperate surface sealed soil in Burkina Faso through the application of organic mulch (Mando, 1998). The strategic application of cow manure and straw to crusted soil surfaces, just before the onset of rains and during termite foraging periods, stimulated the burrowing and feeding activities of termites, which in turn increased soil macroporosity and resulted in the restoration of crusted sahelian soils.

The abundance and distribution of termites can involve examination of the dynamics of the formation of castes (Davis et al., 2010) with a queen, king, and soldiers which may pass through theoretical immortality after the death of the queen or king (Bignell, and Higashi, 2000). However, the caste development is governed by hormones, pheromones and nutritional conditions, Studies show that the influence of these differs with the various termite species (Grimaldi, and Engel, 2005).The distribution of species depends upon various ecological factors (Sands, 1973).The biology and activities of termites cannot fully be understood, without knowledge of ecological conditions upon which termites depend (Longhurst, C.1977).Work done by Wielemaker (1984) in Western Kenya showed the importance of termite on soil formation. Few studies have been done in Kenya on the role of termites in the soil. This is because many studies on conservation tend to be confined largely to bird and large mammals that are a major attraction to tourists. Land degradation in natural habitats is reflected by a change of species (Giller, 1996). However, there is increasing attention on the use of biological indicators in assessment of land degradation e.g. earthworm in temperate region (Eggleton, and Bignell, 1995).Loss of biodiversity affects the ecosystem functioning with a rapid decline in soil organic matter due to crop residue removal after conversion of forests into agricultural use (Swift, and Bignell, 2001). Hypothetical pathways of decrease of biodiversity along gradients of increasing intensification of agricultural land use, show that it differs from species and in relation to body size. The macro fauna e.g. termites and earthworms are considered to be the most susceptible (Grimaldi, and Engel, 2005).Biological indicator have the potential to provide early warning because they can capture subtle changes in quality as a result of their integrative nature that simultaneously reflects changes in physical, chemical and biological characteristics of the soil (Stork, *et al* ., 1992).

MATERIALS AND METHODS

This study was carried in Embu County which lies approximately between UTM zone 37 N (02091326, 03387864 E and 9989843, 9986280 N). It has a forest ecosystem as found on the slopes of Mount Kenya. The Mount forms an isolated mountain Island. This isolation, especially on the higher altitudes has produced considerable endemism among the plants with 80% of afro alpine plant species being endemic and presumably also in the invertebrates. The rainfall pattern is bimodal with two rain seasons; long rains in April to June and short rain in November to December.

The average annual rainfall was 1485mm; above 2000m elevation there was adequate rainfall and high efficiency of indigenous forest to store water, thus ensuring that most streams are perennial.

The Taita Taveta is located between UTM zone 37(425687, 426707 E and 962863, 9632053).There are 48 forests which survive on hill tops in the County of which 28 are gazetted and are under government protection and management. It is one of the globally recognized biodiversity "hot spot" (Bytebier et al.2001).The climate in Taita Hills is influenced by Inter-Tropical Convergence Zone (ITCZ). The average annual rainfall in the area is 1500mm in the highlands and 250mm in the low lands. The rainfall pattern is bimodal with two rain seasons, long rains in March- May and short rains in November-December. Mean monthly temperatures range from17.5-35^0 C. The soils in Taita Hills are sandy loam with high infiltration rates, resulting in low water holding capacity, prolific leaching and low Ph. They have high aluminum and low calcium levels coupled with lack of potassium resulting in low cation exchange (TSBF-CIAT BGBD, GEF-UNDP project 2002).

Sampling and data collection

The area which was sampled had been selected by UNDP-GEF project. Sampling was done in different windows within these sites. The guidelines for window selection were adopted from the UNDP-GEF Indonesian global meeting 2001, which required a sampling plot of 6km^2 from every benchmark site. Seven land cover types were studied in the two sites; indigenous and plantations forests, tea, coffee, Napier, pasture, maize/beans intercrop and horticulture. The study used the monolith method along transects at each sampling point, the position of a monolith was established by throwing a wooden quadrat (0.25m ×0.25m) randomly. The monolith was isolated by cutting down with a spade a few centimeters outside the quadrat and then digging 0.25m wide 0.30m deep trench around it. Data on termite abundance was obtained by digging a monolith at each sampling point along transect. The soil from the delimited monolith block was placed on outstretched polythene paper and each layer (0.00m-0.10m, 0.1-m-0.20m, and 0.20m-0.30m) and hand sorted separately. Termites were collected using forceps and placed in vials containing 70% alcohol and labeled as sample 1 (SI). Sampled 2 (S2) and sample 3 (S3) respectively. Additional attribute data related to each sampling point like plot owner, major land cover type and GPS reading were recorded. The termite specimen was stored for later identification in the National Museums of Kenya (NMK).Soil analysis for pH, potassium, nitrogen, carbon and calcium content level were done.

The homogeneity of the variances of the land cover type was tested using the post ANOVA analysis (Turkey test) to determine the variance for the different land cover types. Two-way scatter plot was used to show the correlation between termite abundance and soil variables. The Shannon –Weiner function was applied because of the assumption that it was more sensitive to the presence of rare termite species in sample.

RESULT AND DISCUSSION

Dry season mean abundance of termites

There was a display of termite diversity both in number and in ages (Figure 1). The highest mean abundance of termites of 28:21 was recorded in the indigenous forest and least mean abundance of termites was 4:25 in the horticulture land cover type. The land type significantly affected the termite's abundance (P=0.005). From the post ANOVA analysis (Turkey test), there were three major groups in the land cover type that is, horticulture and inter crop in one group, pines plantation and indigenous forest in another group, then last group was cypress and Napier. The mean abundance of termites was significantly different between indigenous forest and horticulture (P=0.01). No significant difference was found in the mean abundance of termites between horticulture and intercrop, between indigenous forest and pines plantation and, between indigenous and cypress plantation (P=0.005). The mean abundance order increased from horticulture, maize-beans intercrop, cypress plantation, Napier, pines plantation and indigenous forest.

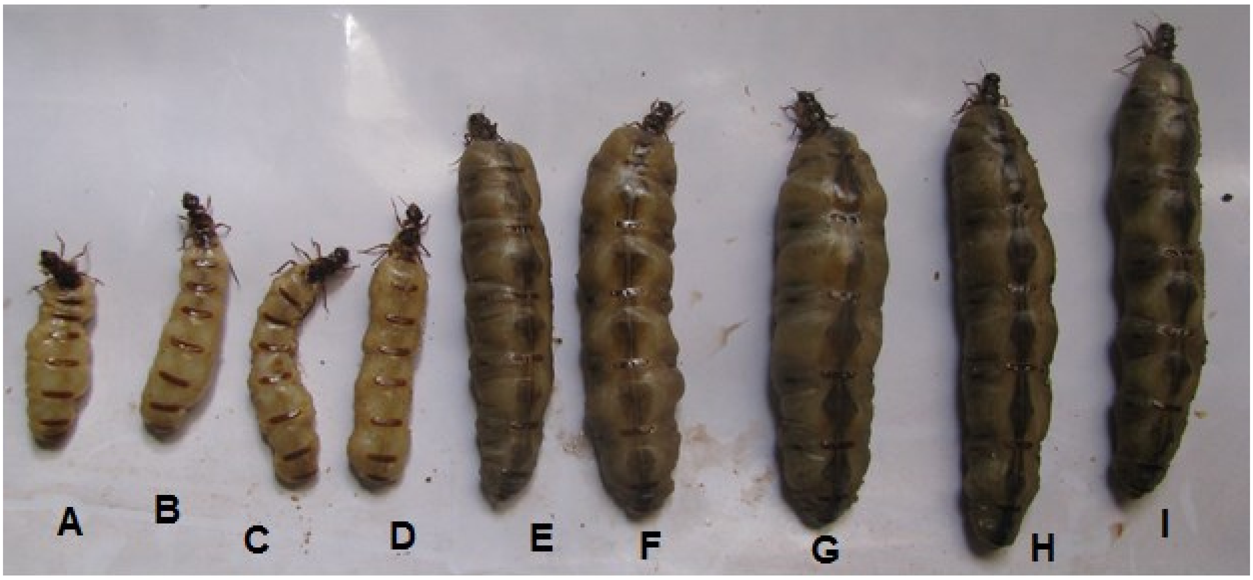

Fig 1. The morphology of the queen termites studied in the south eastern region in Kenya. Notice the correlation of the length, colour, and breath as they age from A to I.

Wet seasons mean abundance of termites

Among the forest land cover type the highest mean abundance of termites of 30.13 was recorded in the indigenous forest, pines forest had a mean abundance of 26.27 and cypress plantation had a mean of 22.33. Horticulture land cover type had the least mean abundance of termites of 5.33. The effect of land cover type and mean abundance of termites was statistically significant (P = 0.040). From the post ANOVA analysis (Turkey test) there were three major groups, that is horticulture in one group, pines plantation and indigenous forest in the other group, with intercrop, cypress plantation and Napier in the other group. There was no significant difference in the abundance of termites between Napier and cypress plantation. There was a significant difference in the mean abundance of termites between indigenous forest and horticulture, between horticulture and pines plantation, between cypress plantation and horticulture, between Napier and horticulture and, between intercrop and horticulture land cover type. The mean abundance order increased from horticulture, Napier, intercrop, cypress plantation, pines plantation and indigenous forest.

Table 1: Mean Abundance and Diversity of subterranean termites under different land covers types at Taita during dry and wet seasons.

LCT	Mean abundance dry season	Mean abundance wet season	Shannon Weiner Diversity index (H')
Indigenous forest	28.21 ± 4.3 c	30.13 ± 5.1 c	3.2 ± 0.3 c
Pinus plantation	25.87 ± 7.5 c	26.27 ± 5.7 c	1.2 ± 0.1 a
Cypress plantation	15.78 ± 7.1 abc	22.33 ± 8.8 bc	1.1 ± 0.3 a
Napier	17.78 ± 6.4 abc	13.56 ± 2.6 bc	2.6 ± 0.2 bc
Intercrop	6.75 ± 2.1a	17.25 ± 8.4 bc	2.4 ± 0.1 b
Intercrop	4.25 ± 1.1a	5.33 ± 1.6 a	1.9 ± 0.0 ab
	$F_{5,75}$=3.70 P=0.005	$F_{5,75}$=2.46 P=0.40	$F_{5,75}$=3.17 P=0.01

*Means with the same letters in the same column are not significantly different at P=0.005 (Fisher test)

Termite diversity

Diversity was higher in indigenous forest, Napier and intercrop land cover types and least in horticulture, pines plantation and cypress plantation. Termites diversity was found to be significantly different between indigenous forest and horticulture (P =0.005).There was no significant difference in the termite diversity between pines plantation and cypress plantation (Table 2). Also no significantly difference was found in termite diversity between Napier and intercrop, and between Napier and horticulture land cover types. The effect of land cover type on diversity of termites was statistically significant (P=0.01) during dry season at Taita.

Table 2: Mean Abundance and Diversity of Subterranean Termites under different land cover types at Embu during dry and wet dry season.

LCT	Mean abundance dry season	Mean abundance wet season	Shannon Weiner Diversity (H')
Indigenous forest	40.25±9.7 d	38.08 ± 9.8 d	3.5 ± 0.9 c
Camphor plantation	46.67± 17.5 d	38.44 ± 11.6 d	2.8 ± 0.8 bc
Eucalyptus plantation	31.44± 10.7 c	28.56 ± 5.9 c	2.0 ± 1.1 ab
Meru oak plantation	19.78± 7.0b	19.33± 6.0b	1.9 ± 0.6b
Napier	17.67± 6.1 b	17.50 ± 6.0 b	2.5± 0.1 bc
Pasture	11.78± 3.7 b	11.56 ± 3.7 b	0.2 ± 0.3 a
Tea	4.08 ± 1.0 a	4.17 ± 0.9 a	2.7 ± 0.9 bc

Coffee	2.75 ± 0.8 a	2.76 ± 0.9 a	1.5 ± 0.7 b
Intercrop	9.58 ± 2.0 a	9.59 ± 2.3 a	1.6 ± 0.74b
	F 8,87=4.334 P= 0.000	F 8,87=5.08 P= 0.000	F8,87=2.30 P= 0.005

Means with the same letters in the same column are not significantly different at (P=0.005) Fishers test.

Soil chemical characteristics at Taita.

The highest percentage of carbon was recorded in the indigenous forest and the least mean percentage of carbon was found in intercrop land cover type (Table 3). There was significant difference between the mean percentage of C with land cover type (P=0.005). Our observations should that the termite mound soils differed from the surrounding soils in physical and chemical compositions. This was depicted from the enhanced herb vegetation growth indicating isolated 'islands of fertility' with some plant species even having hemi-parasitic associations around the mounds.

Table 3: Mean percentage of C, N, Ca and pH in different LCT at Taita.

LCT	Mean % C	Mean % N	Mean% K	Mean % Ca	Mean pH
Indigenous	4.5 ±0.04 d	2.3 ± 0.01 b	1.1 ± 0.01 b	5.3 ± 0.06 b	4.0 ± 0.07 ab
Pinus	2.4± 0.01 c	3.1 ± 0.04 c	0.6 ± 0.01 b	4.4 ± 0.01 a	3.9 ± 0.09 a
Cypress	1.2 ± 0.06 b	2.8 ± 0.05 bc	0.7 ± 0.06 a	4.1 ± 0.03 a	3.7 ± 0.07a
Napier	0.3 ± 0.02 a	4.9 ± 0.03 d	1.4 ± 0.01 ab	4.8 ± 0.07 ab	5.9 ± 0.01 cd
Intercrop	0.2 ± 0.07 a	0.8 ± 0.07 a	0.8 ± 0.07 a	4.3 ± 0.09 a	5.6 ±0.05 cd
Horticulture	0.6 ± 0.01 a	0.3 ± 0.02 a	1.5 ± 0.01 ab	5.6 ± 0.04 bc	5.4 ± 0.03 c
	F 5,27=10.71 P<0.0001	F 5,27=8.74 P<0.0001	F 5,27=13.96 P<0.0001	F 5,27=17.02 P<0.0001	F 5,27=21.67 P<0.0001

DISCUSSION AND CONCLUSION

The results at both Embu and Taita indicate that termites were found in all LCT. In this research, the abundance of termites tended to vary with LCT. These findings are in conformity with what had earlier been observed by Moreira (2000) who studied termite density in response to five land use changes in Brazil.

At Taita, the indigenous forest and Napier recorded the highest abundance with horticulture and intercrop having the least number of termites in the dry season. During the dry season, termite density was higher in the soil samples of 0.1m-0.2m and 0.2m-0.3m depth, whereas during the wet season, termites tended to come to the soil surface to forage and were abundant in the soil sample of 0.00m-0.10m depth.

The indices of abundance showed that termite counts were higher during the wet season than the dry season. The highest variation between dry and wet season in termite abundance was in the intercrop (agroecosystem). This could be attributed to disturbance effect such as mechanical tillage and low food resource factors. The mean abundance of termites in the forest ecosystem had minimal season variation possibly due to low disturbance and expected higher food resource from litter layer and suitable micro-climate (Rodriguez, et al.2006). At Embu, Pasture, coffee, intercrop (agro ecosystem) had lower diversity than camphor plantation. Diversity was least in agro ecosystem and highest in forest ecosystem of camphor and eucalyptus. Similar studies by Wood *et al* (1997) in southern Guinean Savannah of Nigeria supports the above findings. He found out that part of the twenty three species disappeared within one year of clearing and cultivation. Termite abundance and species diversity are greatly reduced by forest clearance (Wood *et al*, 1986 Eagleton *et al,* 1995).

Termites sampled were identified into one family termitinae, 2 sub-family macrotermitinae, amitermitinae and five genera namely: *Macrotermes, Odontotermes, Microtermes, Amitermes* and *Macrotermes*. The sub family macrotermitinae are the fungus growing termites with nest underground. The genus *Odontotermes* was the most abundant in the intercrop and less abundant in the forest and tea.

The genus *Amitermes* and *Cubitermes* were only sampled in forest ecosystem at Taita. *Amitermes* belong to the sub-family amitermitinae and have their nest attached to the trunk of trees. *Cubitermes* are abundant in areas of moderate to high rainfall and trend their numbers become more seasonal (Sands, 1957; 1959). The genera *Macrotermes* and *Microtermes* are pests of maize and bean respectively. Mathews *et al* (1974) believe the *Microtermes* are damage to maize was counterbalanced by benefits. He advocated burial of trash to expose diapusing stalk borer larvae to ant or termites attack, perhaps the first instance of termites being regard as biological control agents.

The community structure of termites sampled were mainly non-soil feeders (Macrotermitinae termites are non-soil feeders). Wood *et al* (1976) observed that there are relatively few species of termites compared with the majority of invertebrates, and their impact on ecosystems arises from their numerical abundance and elaborate behavior patterns rather than through species diversity.

The Nitrogen and carbon percentage was highest in the forest and least in Napier intercrop LCT. Termite mean abundance increased with increasing carbon and Nitrogen levels. Plants materials in whatever form it is consumed (Wood, leaves) by foraging termites is profoundly changed during passage through the termite gut and this increase the C/N ratio (Wood T. G *et al*, 1978). This could be supported by what was observed as islands of fertility which enhanced vegetation growth (Davies *et al*., 2014). When Napier leaves/stems and intercrop (beans and maize) stalks are harvested, termites in the soils are deprived of these nutrients and the soil ends up lacking these nutrients. Mulches provide food for termites which in turn decompose them and incorporate C and N into the soil. Calcium content was highest in the soil with had low pH values, nitrogen and potassium were abundant in soils with pH 5.5. This could be attributed to the use of chemical fertilizer TSP (which is acidic).

This research found that termite population and their mounds actually enrich soils with nutrients and enhance moisture retention through internal tunnels that allow water to sip into deeper levels of the soil. This is one of the explanations why vegetation was found to increase around termite mounds in arid and semi-arid areas. This made the areas greener and habitable for dry land organisms as the vegetation persist longer in hot seasons. The growth of the vegetation correspondingly made the termites themselves to also survive longer, indicating that termites are engineers of their own ecosystem (Figure 2).

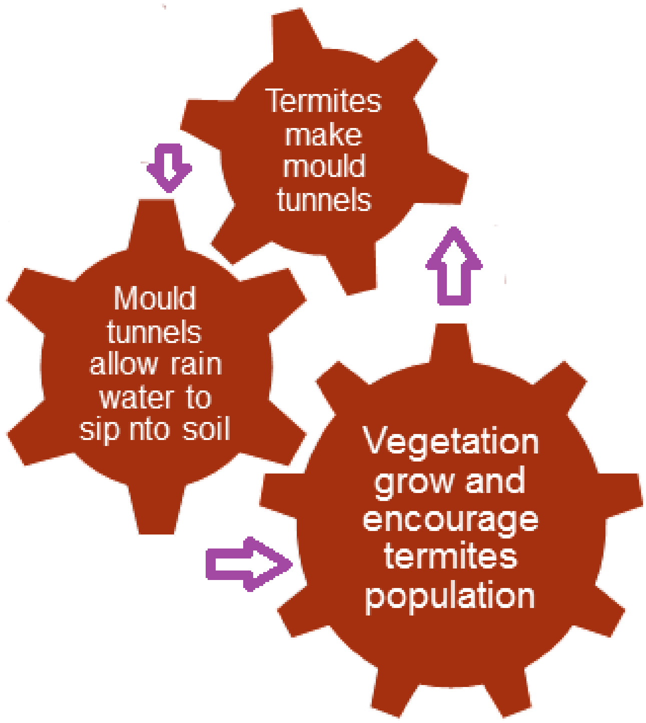

Fig 2: The perceived interactive ecosystem engineering phenomenon which is encouraged by termites in arid and semi-arid areas.

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