

# Seasonal Distribution and Diversity of Termite Taxa in Different Habitats in the Middle Montane Ecozone of Northwestern Ethiopia

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## Research article

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# Abstract

Background: Knowledge of the diversity and occurrence of termites is important for environmental management, but this is unknown in the Bahir Dar Zuria area of northwestern Ethiopia, which represents tepid to cool sub-moist mid-highlands or also known as the middle montane ecozone. The objective of this study was to identify termite taxa and determine the diversity and distribution of termites in different habitats in the middle montane ecozone. Data were collected for eight months starting from December 2016 to July 2017. Termites were collected from different habitats using maize stalks as baits. Results: A total of over 16,000 termite individuals representing one family (Termitidae), two subfamilies, i.e., Macrotermitinae and Termitinae, and five genera (Macrotermes, Odontotermes, Microtermes, Amitermes and Microcerotermes) were found. More Microtermes and Macrotermes termite individuals were found than on other genera. Microtermes and Macrotermes were more abundant. Shannon's diversity index and Simpson's index of diversity values appeared to be higher in the protected vegetation. The distribution of termites in the different habitats showed that protected vegetation had more genera (five genera), followed by grass and cultivated lands (four genera each). Termite populations were significantly higher during the rainy season. The genus *Odontotermes* occurred more during the dry season than the wet season, indicating its foraging behaviour on dry ground. Season, habitat and weather variables were the main factors dictating the type of taxa, distribution and abundance of termites in the study area. Generally, number of individuals increased in the wet and declined in the dry season. *Microcerotermes* was not found in grasslands and *Amitermes* in cultivated fields, indicating distinct difference in habitat preference. Conclusions: Some taxa could be used as indicators of different habitats and seasons because they specialize in these attributes. They also show the degree of environmental degradation and the need for remedial action. Keywords: Biodiversity, Isoptera, Termites, Abundance, *Microtermes*, *Macrotermes*, *Odontotermes*, Habitat, northwestern Ethiopia

## Background

In Africa, human population is increasing rapidly, so does the rate of conversion of natural habitat and land degradation. Approximately 22% of vegetated land in Africa has been classified as degraded, and 66% of this is classified as moderately to severely degraded. Most of these areas experience periodic and recurrent droughts, and climate change has made them even more prone to frequent dry spells [1]. With minimal vegetation cover in degraded areas, it takes long time to recover after drought. Termites contribute for the restoration of degraded habitats to their original state [2].

Invertebrates are integral part of healthy soils because of their critical role in ecosystem services such as decomposition and nutrient cycling [3]. Organisms that live part of their life in the soil, leaf litter and dead wood are ubiquitous, numerous and diverse. However, their specific contribution to ecosystem processes is poorly understood [4]. Generally, it is known that soil organisms are critical to decomposition, nutrient cycling, soil formation and moderating many physical and chemical processes in the soil [5,6]. Despite their role in the ecosystem, which is critical to the overall performance of the ecosystem, conservation organizations rarely consider the functions performed by these organisms. For instance, some soil

animal species, i.e., earthworms, ants and termites are capable of significant ecosystem engineering, modifying both magnitude and direction of resource flow in both natural and managed ecosystems [7].

Termites are primarily wood-feeders, but also feed on a variety of other organic substrates, such as living trees, leaf litter, soil, lichens and animal faeces [8]. Because of their wood-eating habits, termites sometimes greatly damage buildings and other wooden structures, having therefore an important place in economic entomology [9]. Termites occur throughout the tropics and subtropics, as well as in many temperate areas of the world. In natural ecosystems, they perform a beneficial role in nutrient cycles by accelerating decomposition with the highest species richness and in large numbers [7]. Thus, because of their abundance and impact on a large number of ecosystem functions, termites in most tropical and subtropical ecosystems are considered to be similar or even more important than that of earthworms [10]. For the same reason, they are known as “soil engineers”. Ecosystem engineers are organisms that directly or indirectly modulate the availability of resources to other species by causing physical state of change in biotic or abiotic materials [10].

Termites are often separated into two groups, “higher termites” and “lower termites”. The “higher termites” (Termitidae), which makes up 75% of all termite species, has only bacteria present in the gut [11]. In the “lower termites” protozoan symbiosis can be found in the gut in addition to bacteria [12]. These symbionts help digest cellulose. The lower termites are generally evolutionarily more primitive, having simple galleries but not well-formed nests (with the exception of a few Australian *Coptotermes* (Rhinotermitidae) which have mounds for nests) [12]. Some have colonies without true workers, and generally eat only wood. Higher termites (Termitidae) are much more diverse ecologically [7]. While some still consume wood, others have evolved different diets of herbage, grass, dung, humus, fungus, lichens, or organic materials in the soil [5]. The higher termites often build large nests or mounds, and are common in tropical areas, but are rare or absent in temperate climates [13]. There have been no comparative studies on termite fauna and occurrence in Bahir Dar Zuria area, a typical zone for the tepid to cool sub-moist mid highlands or the middle montane ecozone. In an effort to lay the foundation for conservation, the current study was carried out at three habitats of the middle montane ecozone, Bahir Dar Zuria area, Ethiopia, from December 2016 to July 2017. The objective of the study was to determine termite species diversity, distribution and abundance in different habitats (with different degrees of disturbance) and seasons.

## Methods

### Description of the study area

The field survey was conducted at seven locations, i.e., Bezawit, Debanke, Diaspora, Dudu, Gaja Mesk, Gordema and Sebatamit) (Figure 5). At each location, three habitats were selected for the study, i.e., protected, grassland, cultivated. Protected vegetation is a forest where grazing and felling of trees are prohibited, the grassland is free grazing area dominated by grasses and cultivated land is the area where

crops are grown. This area is characterized as middle montane ecozone or tepid to cool sub-moist mid highlands. Bahir Dar is located at 11°36'N 37°23'E at an elevation of about 1,800 m above sea level.

**Rainfall pattern in the study area.** In this study area, the wet season runs from June to September and the dry season from October to May. Amhara State, situated in north eastern to northwestern Ethiopia, is one of the nine states in Ethiopia. The State is divided into wet western Amhara and semi-arid eastern Amhara. In terms of climate and vegetation, Bahir Dar area is typical of western Amhara. This region is relatively more temperate and wetter than eastern Amhara. The region is characterized by a monomodal rainfall pattern of the long rains during the summer season. The main rainy season aka the summer season runs from June to September. The mean rainfall duration of Bahir Dar area is 149 days [14]. The annual total rainfall of western Amhara, where the study site is situated, varies temporally and spatially, ranging from 878 mm to 2100 mm, with an average of 1370 mm per year (1979-2011). The summer season lasts for about three and a half months as a result of convergence in low-pressure systems, and the Inter Tropical Convergence Zone (ITCZ). This season contributes 77% (1054 mm) of the mean annual rainfall of western Amhara [15]. In Bahir Dar, summer season rains contribute 85% of the annual total [14]. The small rains, on the other hand, run from March to May; it does not significantly contribute to the annual total precipitation. The remaining months, i.e., October, November, December, January and February are considered dry season. The small rains and the dry season contribute less than 15% of the annual total rainfall. Between 1978 and 2008, in Bahir Dar, an annual mean rainfall of 1353 mm, a summer mean of 1147 mm, a small rains mean of 105 mm and a dry season mean of 101 mm were recorded [14].

**Temperature.** Between 1978 and 2008, the mean annual temperature of western Amhara was between 17°C and 26°C [14]. In Bahir Dar, for the same period, average minimum temperature was 11.5°C and the maximum was 26.9°C. The maximum temperature reaches its highest peak during March, April and May and declines in July, August and September. Annual averages between 1979 and 2008 showed increasing trend.

### **Characterization of the catchment area of Bahir Dar area and/or Lake Tana area**

The classification of the landscape is done in accordance with the Agroecological Belts of Ethiopia [17]. A chain of mountains and an extensive upland plateau better known as Mount Guna, 3700 m above sea level, is found at aerial distance of 74 km northeast of the study area. Mount Guna belongs to the so-called Afro Alpine zone. Tussock grass dominates the plateau. Next is the Subalpine Zone situated between 3200-3700 m altitudes. The natural vegetation there consists of *Erica arborea* and *Hypericum revolutum*. The Upper Montane Zone is situated at an altitude of 2300 – 3200 m consisting primarily of *Hagenia* woodland, with a tree height of less than 15 m.

The Middle Montane, representing the current study area, Bahir Dar, lies between 1500 and 2300 m altitude. This zone enjoys the most pleasant weather and it is preferred settlement area of the Amhara people of Ethiopia (pers. obs.). Its optimal temperate and humid climate is the most suitable for

agriculture. Within this zone natural forests are still found in lower slopes, for example the Alem Saga State Forest and Tara Gedam forest. Tree species like *Acacia abyssinica*, *Cordia africana*, *Celtis africana*, *Ficus sycomorus*, *Ficus vasta*, *Olea capensis hochstetteri* and *Cussonia holstii* occur naturally within these forests. It is naturally a zone of dry evergreen mountain forest and grassland-complex or evergreen scrub vegetation. Riverine forests along rivers and streams are common site including *Sesbania sesban*, *Mimusops kummel*, and Combretum-Terminalia-Woodland restricted to special locations such as lava streams. Main species in those remnant vegetation patches are *Combretum molle*, *Terminalia brownie*, *Ficus sycomorus*, *Euphorbia abyssinica*, and *Cussonia holstii*. Bahir Dar lies at the southern shore of Lake Tana, the largest lake in Ethiopia (85 km by 66 km area). The Lake suffers from sediments transported from the catchment area described above and its dominant agriculture (siltation process). Some 8.96-14.84 million tons of soil gets into the lake annually [18]. Because of the apparent eutrophication, visibility is less than 30 cm and underwater vegetation is low. Floating mats of *Ceratophyllum demersum*, *Eichhornia crassipes* and *Nymphaea* species are found [18]. The most widely growing wetland plant, *Cyperus papyrus*, is by far the most productive one, with high potential for carbon sequestration. The study area is one of the few major food grain sources of the country. Cereals, pulses, oil crops, fruits and vegetables are widely grown (Pers. obs.).

## Study design

A longitudinal survey, i.e., twice per month, was conducted to assess the diversity, abundance and distribution of termites at different habitats in the study area from December 2016 to July 2017. Sampling was carried out in cultivated land, protected vegetation, and grass land areas. Different research reports indicated that most termites feed on wood and wood products, grasses and food crops [5]. These substrates are found in protected vegetation, cultivated land and grass lands. Soil type of each plot was recorded once. Data were collected using maize stalk as bait. Six plots measuring 30 m × 30 m were randomly established at each habitat making the total 18 plots. The seven sites were Diaspora, Bezawit, Dibanke, Dudu, Gaja Mesk, Gordema and Sebatamit areas. At each plot, five maize stalks of 20 cm long were buried in the ground 15 meters apart from each other. Some were placed directly on the ground or on mounds when available [19]. The maize stalk was left on site for two days. After two days, termites from the maize stalk were collected, counted and recorded. For each termite population encountered, a random sample of soldiers were collected and preserved in 98% ethanol in vials [20] and transported to Bahir Dar University, Zoology laboratory for identification. Each vial containing specimens was labeled (location, date, and habitat type). This was done fortnightly from December 2016 to July 2017. Collections were done early in the morning and late afternoon when termites were active.

The collected termites were identified by using dissecting microscopes. Soldier termite keys up to genus level were used. Identification to the species level was difficult because of the lack of available regional identification keys and laboratory equipment. Using systematic keys [21,22], external morphological characteristics of soldier specimens were observed and classified into subfamily and genera. The major

morphological features used to distinguish termite families, subfamilies and genera were the shape and size of the head capsule (cephalon), mandible, pronotum and labrum. Teeth on mandibles and antennae were also used. Mandibles could be toothed or not; left with prominent and right with smaller or indistinct tooth (*Odontotermes*) or with crenulations (*Macrotermes*) and mandibles with serrations (*Microcerotermes*) [21].

Weather variables were obtained from the nearest meteorology station (Bahir Dar Station, northwest Ethiopia). The time span covered the period of the research.

## Data analysis

**Descriptive statistics.** Abundance of termites of each subfamily and genera were calculated and presented with respect to factors such as habitat, season (time), and taxa.

**Diversity indices:** Shannon's and Simpson's diversity indices were used to determine termite diversity within habitats. The Shannon's diversity index ( $H'$ ) is given below.

Due to technical limitations, Equation 1 has been placed in the Supplementary Files section.

Simpson's diversity index ( $S$ ) was also used to determine the evenness of different taxa in different habitats. The evenness measure changes between 0 and 1, with maximum value when all species are equally abundant, and is independent of richness.

Due to technical limitations, Equation 2 has been placed in the Supplementary Files section.

Where,  $n_i$  = the number of genera in the  $i$ th subfamily,

$S$  = number of different subfamilies in the sample,  $N$  = total number of subfamilies,

The value of ' $S$ ' ranges between 0 and 1; 0 represents no diversity and 1 represents infinite diversity.

**Regression analysis:** After conducting a multivariate correlation analysis, a multiple linear regression analysis was performed to determine the relationship between termite abundance and some quantitative and qualitative explanatory variables including weather variables (minimum and maximum temperatures, rainfall), soil type (Vertisols, Nitosols), and types of habitats.

Correspondence analysis was also carried out to determine relationships between abundance of genera in relation to the different habitats.

## Results

### Occurrence of different taxa in different habitats

Overall, termites belonging to five genera representing one family (Termitidae) and two subfamilies (Macrotermitinae and Termitinae) were identified. A total of five genera (*Macrotermes*, *Odontotermes*, *Microtermes*, *Amitermes* and *Microcerotermes*) were recorded. All of the five genera occurred at the protected vegetation (Table 1). In contrast, in the grass land area *Microcerotermes* and in the cultivated land *Amitermes* were not found. Habitat preference varied with taxa.

Three genera, i.e., *Macrotermes*, *Odontotermes* and *Microtermes*, were recorded from subfamily Macrotermitinae and another two genera, *Amitermes* and *Mirocerotermes*, from subfamily Termitinae.

### Relative abundance of different taxa in different habitats

A total of over 16,000 termite individuals were collected from the three habitats of Bahir Dar Zuria area from December 2016 to July 2017. Subfamily Macrotermitinae was the most abundant (14,000 individuals), followed by Termitinae (2,255). Subfamily Termitinae was generally rare while Macrotermitinae was found everywhere.

Abundance of individuals per genus favoured *Microtermes*, *Macrotermes* and *Odontotermes*. Under genus *Microtermes*, 2679 individuals were collected from the cultivated land, 2438 from the protected vegetation and 1490 from the grassland (Table 2). The soldiers of *Microtermes* are smaller than the workers. They were the smallest in body size of the genera collected during the present study. This termite appears to tolerate a wide range of ecological fluctuations, as it was not only widely distributed in all habitats studied but also the most abundant.

### Monthly termite population fluctuation in different habitats

Termite population steadily increased between December and March, declined in April, then a population explosion followed until July especially in the protected area (Figure 1). After April, cultivated and grassland habitats did not show as much population increase as the protected one. Numbers tended to increase with increasing moisture. April was the driest month and the lowest in termite population. July was the wettest (the rainy season runs from June to mid September).

## Diversity indices

According to Shannon's diversity indices, protected areas appeared to have higher H' values, indicating better diversity in protected vegetation than other habitats. Simpson's index of diversity values was also found to be higher on protected vegetation and grassland/grazing land (0.73) indicating higher evenness. In this study, in general, no taxa appeared to be particularly and decisively dominant (Table 3). High diversity and high evenness mean no one taxon is predominant.

## Abundance of termite taxa during the wet and dry seasons

Significantly more *Macrotermitinae* were recorded between March and July than other months (Figure 2). Number of *Termitinae* did not significantly vary between months. Significantly more individuals of *Macrotermitinae* were found than *Termitinae* in the period between May and July. Generally, termite numbers peaked in the wet or in the rainy season (May, June, July) and declined in the dry season (December, January and February).

Abundance of individuals did not significantly vary among the genera in the dry season. Termite population of the two subfamily *Termitinae* genera, i.e., *Amitermes* and *Microcerotermes* was independent of seasonal influence. On the other hand, season had a profound influence on the number of individuals of the genera of *Macrotermes*, *Odontotermes* and *Microtermes* (subfamily Macrotermitinae). That means the two subfamilies respond to season differently.

As to the seasonal variations of the different genera, *Macrotermes* and *Microtermes* were more persistent, which were available throughout the study period (Figure 3). In contrast, genus *Odontotermes* was more abundant between December and April than between June and July. It was also observed more in March than in January. Therefore, *Odontotermes* prefers the dry season than the wet season. *Macrotermes* and *Microtermes* gradually increased with increasing moisture. The abundance of *Microcerotermes* was low throughout the study period.

**Multiple linear regression:** The linear regression analysis exploring the relationship between termite abundance and a range of explanatory variables was significant ( $F_{10, 931}=4.74, P<0.0001, r^2=0.03$ ). According to the parameter estimates table, termite abundance was significantly negatively influenced by maximum temperature and positively by minimum temperature and Nitosols soil type (Table 4). Coefficients of other variables were not significant.

**Correspondence analysis:** According to the correspondence analysis, Dimension 1 explained 87.4% of the total variation and Dimension 2 explained just 12.6% (Figure 4). *Microcerotermes* was not doing well in all three habitats. The further away a genus from the three habitats in the plot, the most uncorrelated it is. *Microtermes* did well in cultivated and *Macrotermes* in protected habitats. *Amitermes* and *Microcerotermes* behave opposite to each other. *Amitermes* performed well on protected and poorly on cultivated habitats; *Odontotermes* performed in all three habitats almost equally.

## Discussion

In the current study, one family (Termitidae), two subfamilies (Termitinae, Macrotermitinae) and five genera (*Macrotermes*, *Odontotermes*, *Microtermes*, *Amitermes*, and *Microcerotermes*) were identified. According to previous reports, four families, i.e., Hodotermitidae, Kalotermitidae, Rhinotermitidae, and Termitidae, are known in Ethiopia [23]. Yet, Termitidae remains the most frequently recorded family in Ethiopia [19]. Termitidae is represented by four main subfamilies (Apicotermitinae, Termitinae, Macrotermitinae, and Nasutitermitinae) [7]. In Africa, five termite families (Kalotermitidae, Termopsida, Rhinotermitidae, Hodotermitidae, and Termitidae [7], and seven in the world are reported [24]. Therefore, our findings represent a relatively small proportion of the regional taxa.

In the present study, Macrotermitinae was more abundant and more widely distributed than Termitinae. Wood (25) also noted that the dominant species in natural ecosystems belong to the subfamily Macrotermitinae, and include various species of the genera *Macrotermes*, *Odontotermes*, *Pseudacanthotermes*, *Ancistrotermes* and *Microtermes*. Most of these termites are found throughout the savannas and wooded steppes of tropical Africa at altitudes lower than 2000 m. Several authors [e.g.,11] have described that the termite assemblages in African ecosystems are dominated by subterranean species from the family Termitidae and subfamilies Macrotermitinae and Termitinae – the taxa found in the current study. The present findings corroborate previous reports [e.g., 19], which recorded subfamilies Macrotermitinae, Termitinae and Nasutitermitinae. However, Nasutitermitinae was not found in the current study. By increasing the geographical coverage of a similar study, other taxa that were not captured in the current study, could be revealed.

The results have shown that more genera were recorded in protected vegetation than in grazing and cultivated land. The three habitat types were not equally managed by man; protected land being the least managed (and least disturbed), followed by grasslands and cultivated lands (the most disturbed). Habitat

disturbance seems to be a key factor for the differences in species diversity and abundance of termites among the different habitats, as more termite individuals were collected in protected vegetation than in grassland and cultivated lands. The difference implies that cultivation and grazing by livestock appear to eliminate some termite genera [6]. The exclusion of some genera may decrease total number of individuals (Pers. obs.). But in the present study, more *Microtermes* individuals were recorded in cultivated land. *Microtermes* species tend to increase in abundance with increasing intensity of cultivation. This could be attributed to their deep subterranean nests and thus they are less affected by cultivation, unlike *Macrotermes* which have shallow nests [19]. Species with deep subterranean nests and with the ability to survive on living crops and crop residues remain and increase in number; the most important of these being *Microtermes* [25]. The subterranean *Microtermes* moves down into the soil to avoid the effects of surface disturbance [26]. Throughout tropical Africa, grass litter constitutes a significant part of the diet of several species of Macrotermitinae, and in Ethiopia, the most common of these belong to the genera *Macrotermes*, *Odontotermes*, *Microtermes* and *Pseudacanthotermes* [25].

The diversity and relative abundances of termites have been demonstrated to decrease in response to habitat conversion along a disturbance gradient [4,6]. Deforestation, followed by cultivation and overstocking, increases climatic instability and decreases habitat heterogeneity. This disturbance eliminates the most susceptible termite species and causes an increase of other species that are tolerant of disturbance, leading to low biodiversity, i.e., a few dominant species remain [2]. Intensive land use destroys termite microhabitats, their nesting and feeding sites, and ultimately reduces termite diversity and density [27].

In the current study, termite population varied with season. It was low during the dry season and high in the wet season. However, according to the regression analysis, the contribution of weather variables was not consistent. Because some taxa responded to habitat differently – some preferring grassland and others cultivated, these differences in behavior of taxa may serve as indicators of a habitat. Seasonal changes of temperature and relative humidity play an important role in termite biology and behaviour. Temperature has strong influence on termite foraging and seasonal activities [28], even if termites can, to some extent, regulate temperature and moisture of nests. Subterranean termite foraging behaviour is seasonal [29]. They do not forage in areas where soil surface temperatures are either too hot or too cold [28]. Dry climate is one reason for the low number of species in northern Africa [30]. In the current study, during the dry season, mound-inhabiting termites were found very deep inside their nests. That condition made sampling operations difficult. In contrast, under protective vegetation and during wet seasons, termites were found near the soil surface. Some were found in mud tubes or earthen sheets. Protective vegetation (tree canopies) conserves moisture underneath and encourages termites to stay near the surface. The underside of trees is cool and moist. Termite swarms are observable after the second rainfall of the season, creating a suitable combination of temperature and relative humidity [31] Although not included in the current study, it is known that the breeding generation of termites is produced at the onset of the first rains.

*Microtermes*, *Odontotermes* and *Macrotermes* having conspicuous earthen mounds are the major fungus-growing termite genera [32]. This group of termites cultivate fungus gardens. Fungi are important in the diet of the termites, enabling them to live on food of low quality not utilized by mammals. Fungus gardens are also important media for maintaining a constant microclimate in termite nests and serving as a nutritional buffer so that colonies can survive harsh conditions, such as drought or extended periods of heavy, seasonal rains.

## Conclusions

The current study on the occurrence of termites in different habitats and seasons in the Bahir Dar Zuria area showed that one family (Termitidae), two subfamilies (Macrotermitinae and Termitinae) and five genera (*Macrotermes*, *Odontotermes*, *Microtermes*, *Amitermes* and *Microcerotermes*) were recorded from their habitats, i.e., protected vegetation, cultivated land and grassland/grazing land. Seasons, habitats and weather variables were the main factors dictating the distribution and abundance of termites in the study area. Numbers were more during the wet than the dry season and on the cultivated than other habitats. Regression analysis results elucidating the relationship between termite abundance and explanatory variables was not consistent. However, according to the graphical representation of the abundance data, it was possible to see distinct relationship between season and abundance. Shannon's diversity index and Simpson's index of diversity values appeared to be higher in protected vegetation. Overall, no taxa appeared to be particularly dominant. This study is a pioneer study of termites in Bahir Dar area of Ethiopia. It contributes for the national, or regional, effort in determining termite biology and ecology.

## Declarations

Ethics approval

Not applicable.

Consent for publication

Not applicable.

Availability of data and material

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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No external funding was required.

## Authors' contributions

MW initiated the research idea, helped draft a research proposal, supervised the study, analyzed the data, and helped write the report. DN wrote the proposal, defended it, conducted the field and laboratory study and wrote the report.

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The co-author received scholarship award for an MSc degree from Bahir Dar University, Ethiopia.

## Authors' information

MW is an associate professor of entomology (PhD), Director of Research of Bahir Dar University, Ethiopia, published dozens of peer-reviewed journal articles, supervised and graduated over 30 post-graduate students including PhDs, reviewed dozens of articles of internationally reputable journals, at many occasions lectured research methods and data analysis. DN is a Preparatory School teacher and MSc graduate.

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## Tables

Table 1.

Family	Subfamily	Genera found in		
		Protected vegetation	Grassland/grazing land	Cultivated land
Termitidae	Macrotermitinae	<i>Macrotermes</i>	<i>Macrotermes</i>	<i>Macrotermes</i>
		<i>Microtermes</i>	<i>Microtermes</i>	<i>Microtermes</i>
		<i>Odontotermes</i>	<i>Odontotermes</i>	<i>Odontotermes</i>
	Termitinae	<i>Amitermes</i>	<i>Amitermes</i>	<i>Microcerotermes</i>
		<i>Microcerotermes</i>		

Table 2.

Termite genera	Termite generic abundance			
	Protected land	Grassland	Cultivated land	Total abundance
<i>Macrotermes</i>	2093	1348	1287	4728
<i>Microtermes</i>	2438	1490	2679	6607
<i>Odontotermes</i>	921	932	911	2764
<i>Microcerotermes</i>	197	0	289	486
<i>Amitermes</i>	1140	629	0	1769
Total	6789	4399	5166	16354

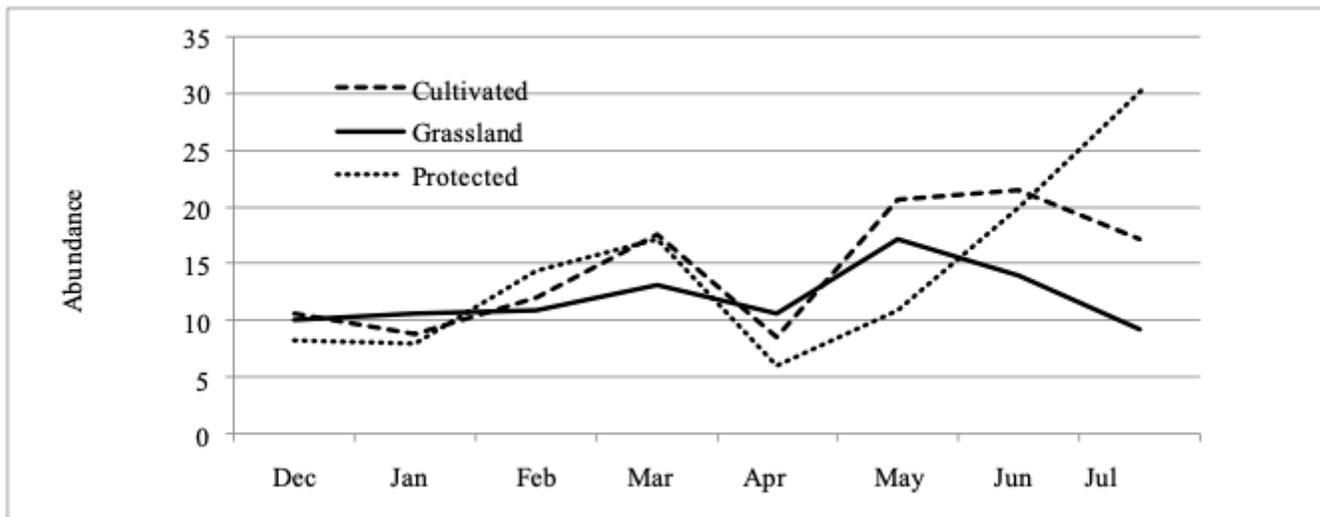
Table 3.

Habitats	Number of subfamilies	Number of genera	Total number of individuals	H'	S
Grass/grazing land	2	4	4399	1.34	0.73
Cultivated land	2	4	5163	1.15	0.63
Protected vegetation	2	5	6789	1.40	0.73

Table 4.

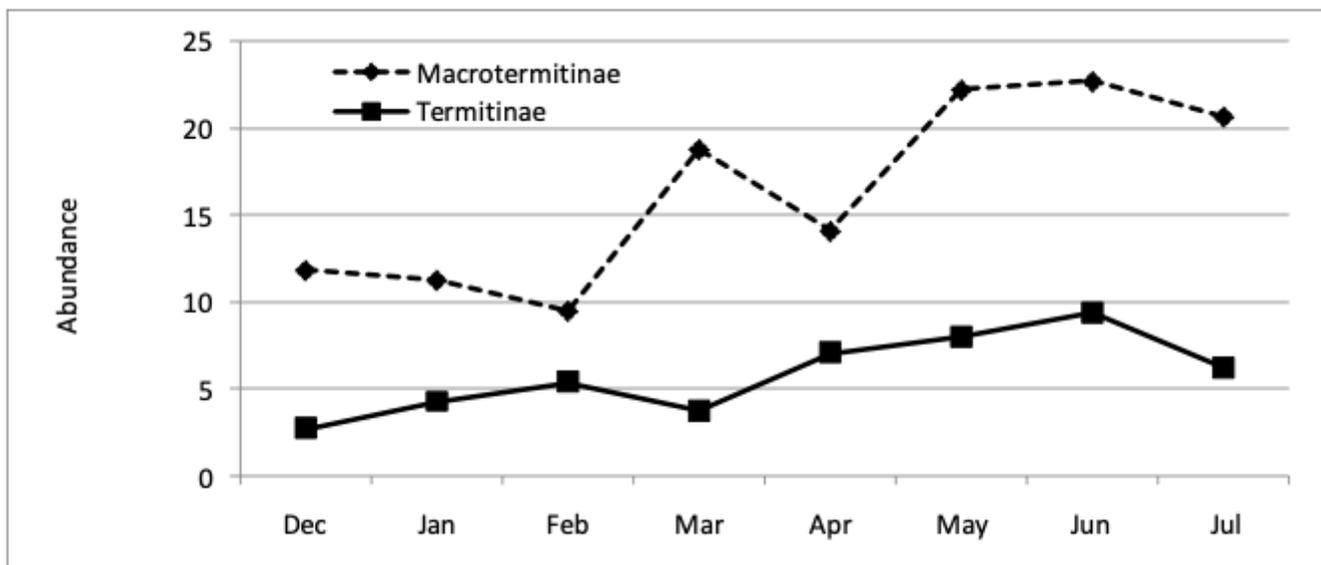
Term	Estimate	Std Error	t Ratio	Prob> t
	(regression coefficient)			
Intercept	54.5308	15.5890	3.50	0.0005
Maximum temperature	-1.4452	0.6640	-2.18	0.0297
Minimum temperature	0.9875	0.4729	2.09	0.0370
Average temperature	-0.7699	0.8650	-0.89	0.3736
Rainfall (mm)	-0.2147	0.1521	-1.41	0.1584
Soil type [Vertisols]	-1.2368	0.9432	-1.31	0.1900
Soil type [Nitosols]	2.5987	1.0069	2.58	0.0100
Type of habitat	1.6908	1.0128	1.67	0.0953

## Figures



**Figure 1**

Termite abundance across the season in each habitat for the period December 2016 to July 2017



**Figure 2**

Seasonal abundance of different termite subfamilies in Bahir Dar Zuria area

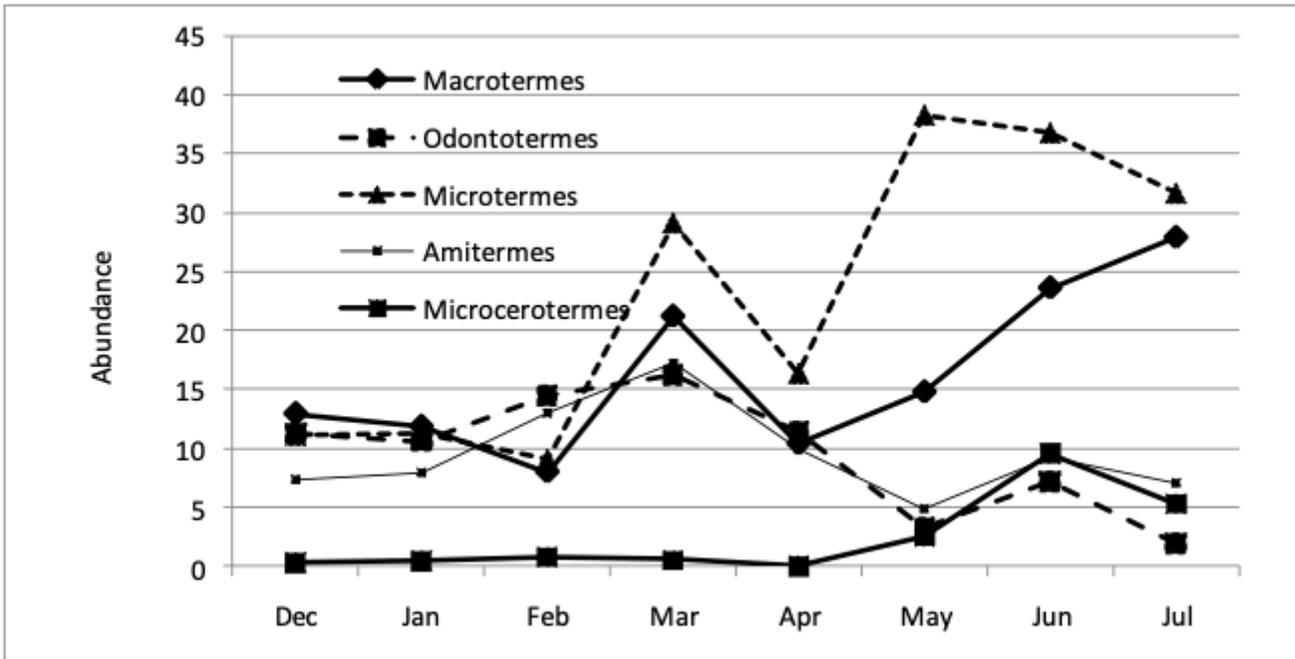


Figure 3

Seasonal abundance of different termite genera in Bahir Dar Zuria area

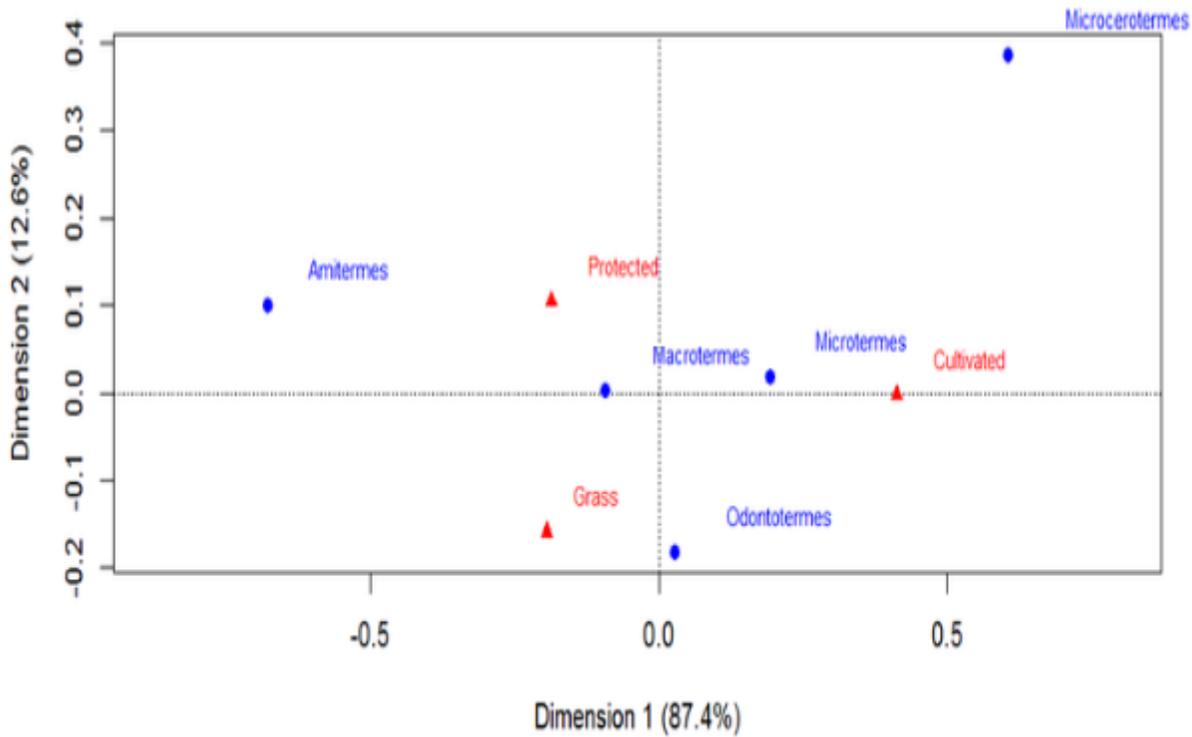


Figure 4

Correspondence analysis of the relationship between abundance of termite genera and habitat type (red text stands for habitats, blue for genera).

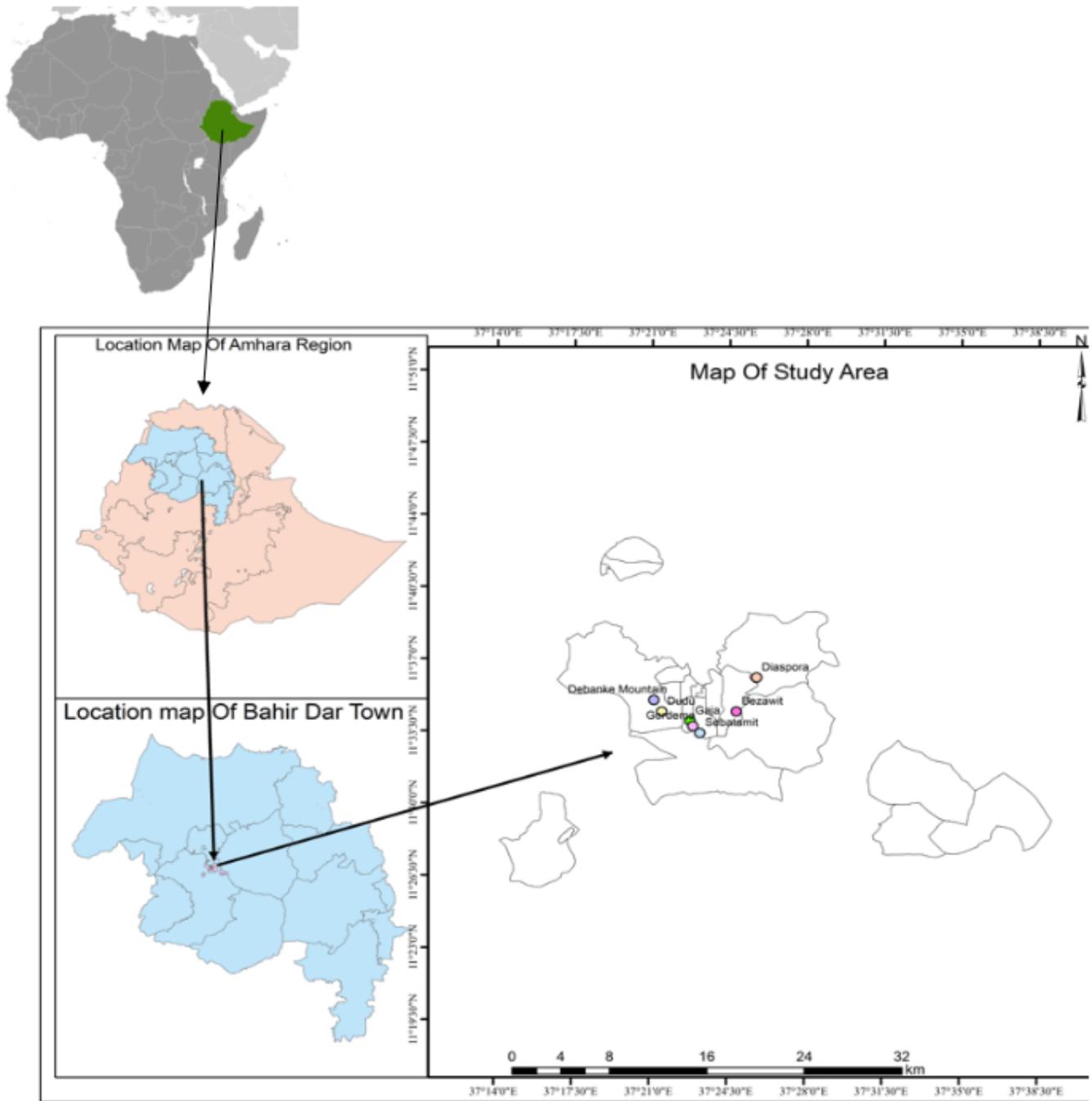


Figure 5

Map showing study sites in three habitats of Bahir Dar Zuria area [3]

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Equation1.png](#)

- [Equation2.png](#)