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Subterranean Termites of a University Environment in Port Harcourt, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author APU designed the study. Authors CW and APU performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors CW and NE managed the analyses of the study. Authors CW and DDSB managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Termites are diverse, ubiquitous and abundant in tropical ecosystems and are major examples of soil-dwelling ecosystem service providers that influence the ecosystem functioning by physically altering their biotic and abiotic surroundings. With increasing development in the environment, there is a gradual loss of their habitat. This study was carried out to determine the subterranean termite species in Rivers State University campus and relate the species and prevalence to their soil types. The study area was divided into 10 zones and from each zone 3 stations were selected randomly for sampling. Samples were collected in January and February 2018. Samples were taken from available mounds and soil in each station and termites were sorted, identified and counted. The temperature, organic content, pH, soil particle analysis and moisture content were determined for the soil samples. Five termite species from two families were identified;Termitidae: *Amitermes* spp1, *Amitermes* spp2*,* and *Globitermes* spp; Macrotermitidae: *Macrotermes gilvus*and another *Macrotermes* spp*.* The *Amitermes* spp was the most abundant as it was found in all 10 zones, followed by *Macrotermes* spp and then the *Globitermes* spp being the least abundant. Termite abundance, moisture content and soil type were significantly different in the 10 zones ($p < 0.05$).

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Total Organic Content was negatively correlated with *Macrotermes* spp. The *Amitermes* were more abundant in residential areas as they are wood eating termites suggesting that most destructive aspect of termite behaviour on residential areas may be perpetuated by the *Amitermes* species. The *Macrotermes* spp were found only in cultivated areas and from soil with higher percentage of clay, and they are basically soil feeders. *M. gilvus* and *Macrotermes* spp were seen in reddish mounds with fresh soil at the peak (showing termite activity) giving it a cone shape whereas the mound *Globitermes* spp was black, no fresh soil at the peak and had a circular shape. *Amitermes* was found in abandoned reddish *Macrotermes* mounds in residential areas. This study has provided some information on the termites in the University community as their habitat is gradually being destroyed with new buildings resulting in biodiversity loss. Moisture and TOC appeared to affect abundance.

Keywords: Termites; subterranean; Rivers State University; macrotermes; amitermes; globitermes.

1. INTRODUCTION

Termites are eusocial insects that belong to the phylum Arthropoda, the Class Insecta, and Order Isoptera. Their population, species richness and distribution can be used as a tool for determining environmental integrity. The ubiquity, diversity, and abundance of the different termite species in the tropical ecosystems represent about 80% of animal biomass [1]. The termites are prime shapers of their habitat dynamics through their interaction with several aspects of the ecosystem via modification, maintenance, and creation of macro and micro niches [2]. They are ecosystem modifiers and as such termites play significant roles in tropical forest. Termites and ants as decomposers have been implicated in nutrient cycling, soil formation and soil structural modification, and their biophysical and chemical processes aid in regulating soil fertility as well as counteracting with the physical and chemical processes of soil degradation [3]. Mounds built by termites and other species of insect have been found to be highly mineralized and enrichment minerals and exchangeable cations have been reportedly high in biogenic mounds than the surrounding soil [3]. Termite mounds can reveal some changes in the soil properties via change in litter around mounds which could be responsible for appearance, performance and composition of plant community assemblage in agro ecology. Termites and ants are major examples of soil-dwelling ecosystem service providers that influence ecosystem functioning by physically altering their biotic and abiotic surroundings [4]. Their movement in soil helps to increase soil porosity, aeration and soil water permeability which increases soil micropores [5]. Their richness and abundance may be severely affected by land-use practices such as agricultural practices, industrialisation and habitat fragmentation which are leading causes of biodiversity loss [6]. Land degradation is particularly associated with population increase in sub-Saharan Africa where millions of people depend on agriculture for their livelihoods [7]. Termite population is dependent on environmental variables such as rainfall, soil moisture content, availability of food, soil texture and soil temperature. They are known as 'silent destroyer' because of their ability to cause deterioration of building materials, discolouration of houses, destruction of furniture etc. Some species of termite construct nest or mound in soil and are known as subterranean termites while others on dead and growing trees are known as arboreal. Mounds are constructed using body fluids such as saliva to bind soil particles together [8]. They feed on cellulose and therefore harbour bacteria, flagellate and fungi in their digestive tract that aid in the digestion of the cellulose [9].

Out of about 2,600 known termite species, only 300 of these species are known to be destructive pests in agriculture and termite families known to occur in tropical forest and grassland savannah areas worldwide include *Mastotermitidae, Kalotermitidae, Hodotermitidae, Termopsidae, Rhinotermitidae, Seritermitidae* and *Termitidae* [10]. The most economically important termite genera in agricultural and forest areas are *Macrotermes, Allodontermes, Amitermes, Pseudacanthotermes, Odontotermes, Ancistrotermes, Trinervitermes, Hodotermes* and *Microtermes* [11]. Species of termites vary from locality to locality. Iqra [12] on population density of termites in garden trees of Gujranwala Pakistan, recorded six species (*Coptotermes heimi*, *Microcerotermes championi*, *Odontotermes obesus*, *Microtermes obesi*, *Microtermes mycophyagus* and *Odontotermes guptia*. Kemabonta [13] in the study of species richness, diversity and relative abundance of termites in the University of Lagos, Nigeria recorded two families (*Rhinotermitidae* and

Termitidae) and six sub families (*Rhinotermitinae*, *Amitermitinae*, *Macrotermitinae*, *Nasutitermitinae*, *Termitinae* and *Microcerotermitinae* with *Amitermes* spp as the most abundant and widely distributed species. Subterranean termites constitute a major menace to our everyday life as they continually eat up source of livelihood and support. In the Niger delta there is a paucity of information on termites and their prevalence thereby justifying this research work. This research is the first of its kind in Rivers State University and the main aim of this research work was to determine the prevalence of subterranean termites in Rivers State University community (a closed community in the Niger Delta of Nigeria) as a baseline survey considering the rapid habitat degradation that is ongoing as the place is built up.

2. MATERIALS AND METHODS

2.1 Brief Description of Study Area

The research was carried out in the campus of Rivers State University (RSU), Port Harcourt in the Niger Delta region of Nigeria. The study area is located between longitude 6.972 and 6.986 and latitude 4.787 and 4.807 (Fig. 1). Rivers State University has a tropical wet climate with a long and heavy rainy season and short dry season. Port Harcourt's heaviest precipitation occurs during September with an average of 367 mm of rain. The driest month of the year is December, with an average rainfall of 20 mm. Temperatures are relatively constant, showing little variation. Average temperatures are typically between 25°C - 28°C in the study area. The vegetation of RSU campus is sparsely distributed as there are farms and farming activities in the school farm, offices, lecture halls, libraries, residential quarters and small gardens behind these residential quarters.

2.2 Sample Collection and Treatment

The study area was divided into 10 zones (Fig. 1) and each zone into three transects of 50 m by 50 m. Three of the 10 sample zones were within the farm area while the remaining seven were in the built-up area. From each 50 m x 50 m transect, a quadrant of 10 cm x 10 cm was measured. From each of the quadrant top soil was excavated to 10 cm depth (giving a 1000 cm^3 volume of sample) from the mound and around the mound (about 30 cm distance). The excavated soil was taken to the laboratory for sorting in a transparent plastic container.

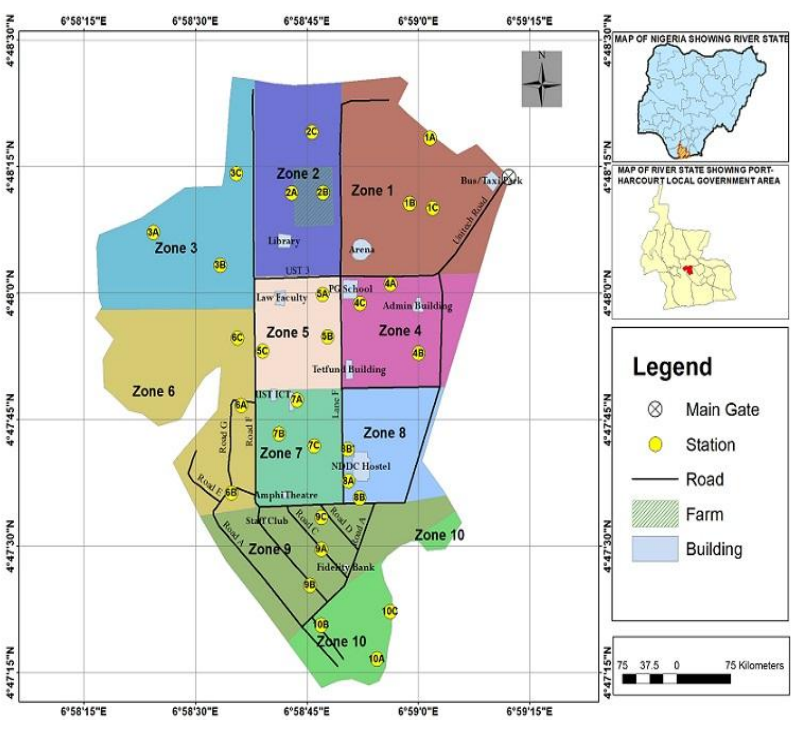

Fig. 1. Map of RSU showing sample collection points

Temperature for mound and soil were measured in-situ. Soil and mound samples were also collected for the analysis of soil texture, moisture content, total organic content (TOC), and pH using standard methods. The shape, colour and texture of mounds were noted in each station. Sampling was in January - February 2018 for 8 weeks.

2.3 Laboratory Analysis

In the laboratory, all the soil samples collected were sorted for termites. The isolated termites were grouped into casts according to their morphology and counted. The termites were identified by observing the mandibles, pronotum, postmentum and number of articles on the antenna under a light microscope with the aid of a key provided by [14]. Identification was to genus level. Filtration method was used to determine the particle size of the soil samples [15]. Moisture content was determined by weighing 100 g of the sample on foil paper with a weighing balance (W1). The weighed samples were placed on the work bench and allowed to air dry for five days and reweighed (W2). The percentage of moisture content was calculated with the equation:

$$\text{Moisture Content \%} = \frac{W_1 - W_2}{W_1} \times 100 \quad [16]$$

TOC determination was by standard methods [17].

2.4 Data Analysis

The statistical tests were done using EXCEL computer package and the JMP statistical software. These packages were used to compute for both inferential and descriptive statistics. Turkey and One-way ANOVA was used for the comparison of abundance across stations. Correlation, PCA (Principal component Analysis) and cluster analysis were used to relate physicochemical parameters to termite abundance. All tests were done at 95% confidence level. GIS mapping using mean abundance was used to provide a colour chart presentation.

3. RESULTS

3.1 Species of Subterranean Termite found in Study Area

The species of subterranean termites belonged to 2 families :Termitidae and Macrotermidae. Two species of *Amitermes* and 1 species of *Globitermes* from the family Termitidae and two species of *Macrotermes* from Macrotermidae (Plate 1). Their distribution (Fig. 2) in study area revealed that *Amitermes was* found in mounds and soil from the 10 zones, *Macrotermes* was in mounds and soil from zones 1 and 2 (Farm area) and *Globitermes* mound was found in zone 9 (built up residential, area).

The *Macrotermes* mounds located in zone 1 and 2, were active (Plate 1c) as they had freshly built extension of the mound at the peak, where as abandoned mounds were overgrown with grasses. The *Amitermes spp 2* was seen in zone 1 and zone 5 in abandoned *Macrotermes* mound (Plate 1b) with weeds growing on every side.

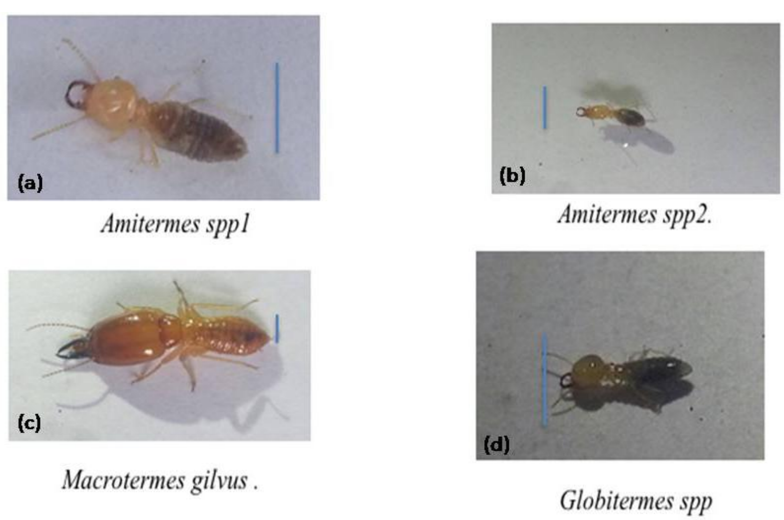

Plate 1 (a-d). Species of termites found in study area

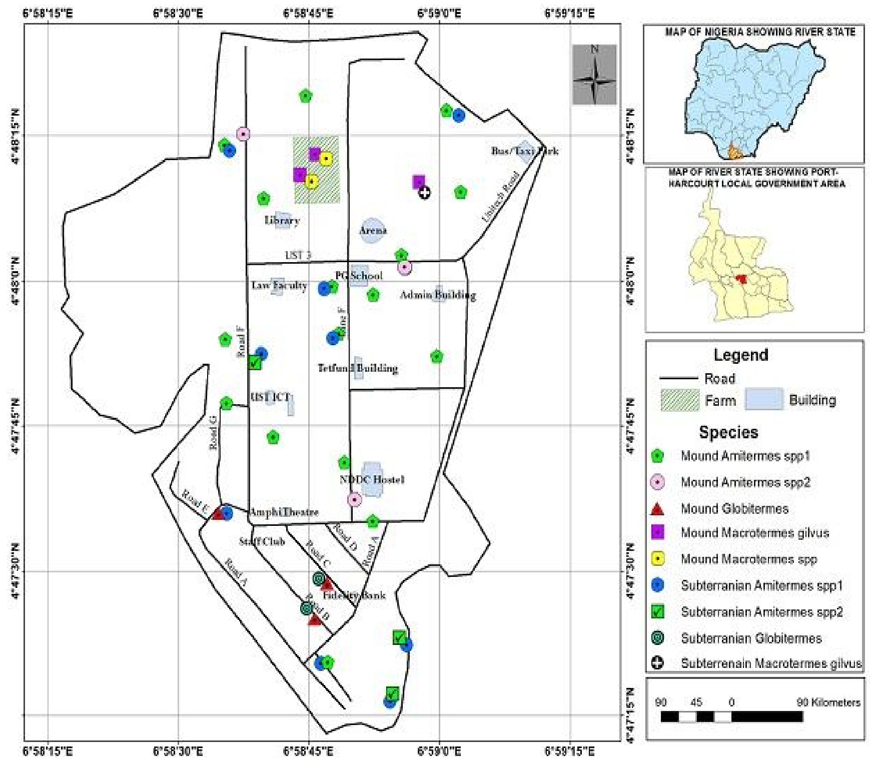

Fig. 2. Distribution of termite species in the study area

- a) Macrotermes mound
- b) Amitermes found in (abandoned Macrotermes mound)
- c) Amitermes mound
- d) Globitermes spp
-

Plates 2(a -d). Mound types observed in study area

The mound of *Amitermes spp1* was found in all the zones, circular and dark coloured (Plate 1a) while *Globitermes spp* mound was found in zone 7 and zone 9 (Plate 1d).

3.2 Abundance of Termites in the Study Area

GIS mapping by colour chart presentation of mean abundance is shown in Fig. 3. The area with the highest colour intensity represents zones with the highest abundance per 1000 cm^3 of soil. Zones 1 - 3 had the highest mean abundance of 138.3 - 191.7 termites per area of sampled soil and zone 5 had the least (41.7 / 1000 cm3) with the lightest color.

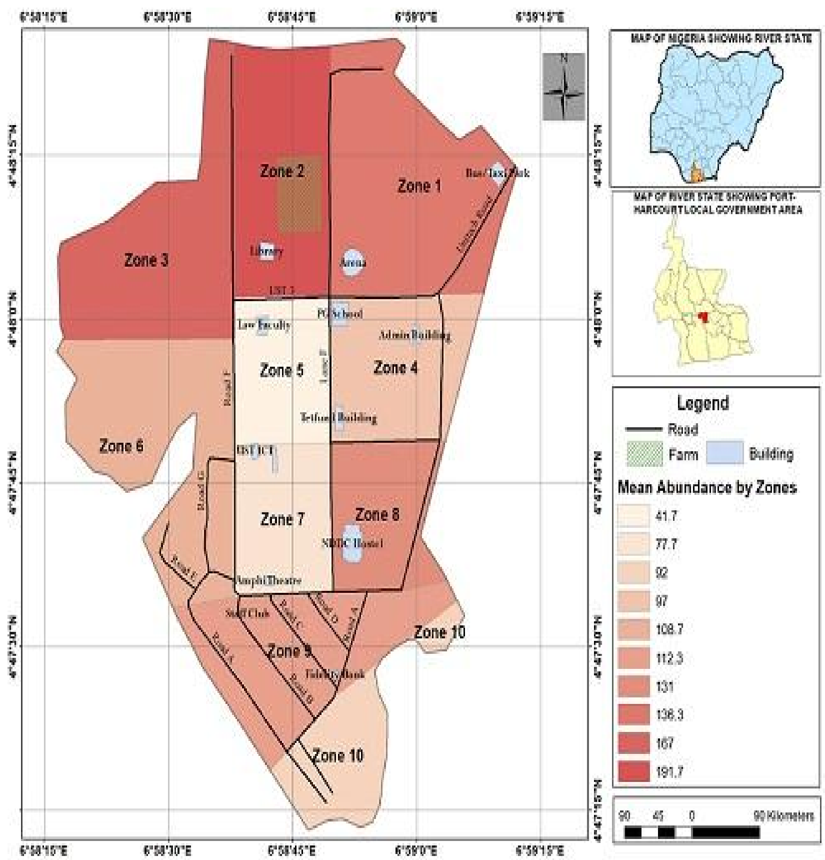

Fig. 3. Map of study area using colour intensity to show zonal mean abundance

Table 1. Environmental properties (mean) of study area

Sample Id	Temp (°C)	pH	Organic content mg/kg	Moisture (%)	PSA % Sand	Silt	Clay	*Texture (USDA)
Zone_ 1	23.85^a	5.8^a	1.70	12.21^{bcd}	24	36	40	SCL
Zone _2	24.85^a	6.0^a	1.41	16.71^{abc}	24	30	46	C
Zone_ 3	24.90^a	5.4^a	1.37	17.75^{ab}	23	32	45	C
Zone _4	24.50^a	5.6^a	1.88	9.71^d	29	25	46	C
Zone 5	20.81^a	5.5^a	1.48	11.51^{bcd}	22	31	47	C
Zone 6	24.83^a	5.3^a	2.16	10.11^d	22	28	50	C
Zone 7	24.36^a	5.5^a	2.19	11.05^{bcd}	24	30	46	C
Zone 8	25.21^a	5.7^a	1.66	12.71^{bcd}	25	30	45	C
Zone 9	24.33^a	5.3^a	1.64	11.25^{bcd}	30	30	40	SCL
Zone 10	24.20^a	5.6^a	1.84	19.46^a	25	30	45	C

Same superscript along column = not significantly different.

**Where: C, clay; CL, clay loam; L, loam; LS, loamy sand; SCL, sandy clay loam; SL, sandy loam*

3.3 Physicochemical Parameters

The mean temperature, pH and organic content of soil ranges were 20.81 - 25.21°C, 5.3 - 6.0 and 1.37 - 2.19 mg/kg respectively. The pH and organic content of soil revealed slight variations that were not statistically significant ($p < 0.05$) in the sampled zones. The moisture content ranged from 9.71 to 19.46% and was significantly different in the study zones @ $p < 0.05$. The particle size analysis showed zones 1 and 9 as sandy clay loam while all other zones were clay (Table 1).

3.4 Principle Component Analysis of Data

The principal component analysis of the environmental parameters and termites abundance (Fig. 4) showed the percentage and cumulative percent accounted for by each principal component. The square and loading plots show that the first two principal components accounted for 51.1% (27.1% for component 1 and 24% for component 2) of the variation in the data. In the loading plot, moisture content, pH, % sand and termite abundance were positively correlated with the first principal component accounting for the 27.1% of the factors influencing abundance; while temperature, % silt, TOC and % clay accounted for the 24% of the factors influencing the abundance negatively.

3.5 Cluster Analysis of Termite Species

The cluster analysis of the samples in the study area (Fig. 5) showed two groups. The first group was the drifters or generalist which were characterised by occurrence in more than one station of the study area; while the second group were the specialist, characterised by a single station occurrence in the study area. The generalist species were *Amitermes* spp1 and spp2 *Macrotermes spp* and *Globitermes* spp, while the specialist was *Macrotermes gilvus*.

4. DISCUSSION

4.1 Species Abundance and Distribution

Five (5) species of termites were found on RSU campus. *Amitermes* spp were more abundant than the other genera. The abundance of *Amitermes* spp according to [17] is because they are polyphagous and able to feed on all substrate available in an area. [13] while studying species diversity and richness of termites observed *Amitermes and Macrotermes* as the dominant species, reporting a population

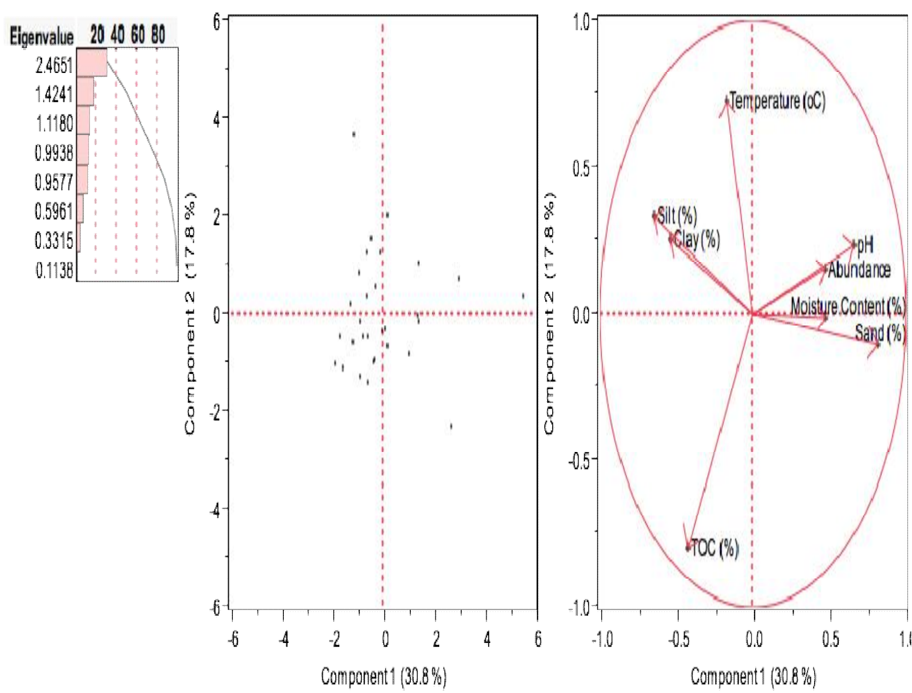

Fig. 4. Principal component analysis of the data set

of 40% for *Macrotermes* and 27% for *Amitermes.* High population of *Macrotermes* spp is common in the tropical climate and favoured by climatic factors and soil nutrient content.The presence of *Amitermes* in all the study zones, indicates their ability to tolerate and exist in different environments with differing physico-chemical parameters. *Amitermes* species were found in both disturbed habitat and secondary or newly cultivated habitat. [13] reported that abundance of *Amitermes and Macrotermes* in most of their studied zones was in connection with the fact that they fed on soil, dead woods, grasses and litters. From this study, *Amitermes* was found in both cultivated and human inhabited areas while *Macrotermes* were dominant in cultivated vegetation and *Globitermes* in more inhabited areas. Habitat and food preference by termite according to [18], showed that *Amitermes* was found to tolerate a range of habitat, preferring wood concentrate high in cellulose content.

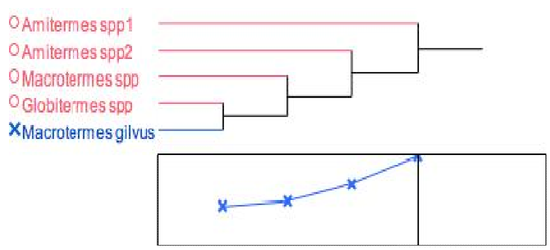

Fig. 5. Cluster analysis of the species

4.2 Physico-chemical Parameters

The pH of study area (mounds and surrounding area) was all acidic (5.3 - 6.0) and appeared not to affect termite distribution. This falls within the range recorded by [19] of 5.4 to 7.6 for pH of external and internal walls of *Macrotermes bellicosus* mounds. [20] also observed the pH in termite colony to be within the range of 5.9-7.6. Depending on the species, pH plays a key role in soil preference for construction of nest, foraging and social behaviour of termites [21].

Temperature of mound and soil of the study zones of 20.8 - 25.2°C, is in agreement with the report of [22], that species composition of termites depend on the temperature regimes to carry out their activities, as high temperatures tend to retard termite foraging and population assemblage. Also high temperatures could lead to insect going into diapause (an arrested state of development) and subsequent death. Temperature also affects food availability, solubility of organic compounds and nutrients. Termites depend mostly on temperature for foraging, creating of feeding tunnels and building of nest. It was further stated that *Anoplotermes pacificus* and *Anoplotermes* group had positive correlation with temperature, saying although tropical termites are tolerable to high temperature, they may be affected by extreme end temperature regime. There was no significant difference in the temperature of the study area, so the distribution of the termites may not be significantly affected.

With respect to soil moisture content, it was noticed that the study zone had a mean moisture content range of 9.71 -19.46 that was not in agreement with the observations of [18] who recorded moisture content range of 16.7 and 62.0% in the external and internal walls of *Macrotermes bellicosus* mounds. While some species such as *Macrotemes* and some species of *Amitermes* prefer high soil moisture content, others such as *Globitermes* and *Amitermes* show less preference to soil and mound with high moisture content. This may affect their behaviour, abundance, diversity and nesting. It could also impede the availability of food, such as dry wood species, which could require less moisture to forage and nest. While dead wood stump and soil feeders could show positive preference to moisture at certain regime. The results showed significant differences in moisture content of the study zones, and this could affect distribution as it positively affected the abundance of termites. [22] has observed that nesting, foraging and other social behaviour of termites were affected by moisture contents of the surrounding environment making termites to build their nest on high elevated soil and at far distance from river source.

Particle-size distribution of the study zone were analyzed and found that, termite abundance varied with soil texture of the surrounding. It could be deduced from this study that, termite in the study area preferred soil with high percentage of clay. The different mean values for sand grain ranged from 18.3 - 33.3%, silt 24.2-35.0%, and clay from 40.83-49.16% across the study area revealing that clay content was more followed by silt and sand. These results were not consistent with [18], who reported that sand content was more (32.60-88.2%) followed by silt (6.70-37.10%) and clay (0.40-48.20%). Soil feeding termites prefer soil with a high percentage of sand because the more clayey the soil, the higher the water logging capacity which may affect the activities of termites. The result in this study is in agreement with [22] who reported that humus feeding species may be affected by factors such as soil grain type which may deprive termites the needed feeding potential. The grain size did not significantly affect the distribution of the termites.

The mean TOC (Total Organic Carbon) ranged between 1.37 and 2.19% in the study area and their correlation to termite abundance varied across the stations and within species. For some species such as *Amitermes* (0.336), *Globitermes* (0.31) and *Macrotermes gilvus* (0.06), an increase in TOC may not significantly effect an increase in species abundance. However, in some aspects there appeared to be a negative (significant or non significant) relationship between the various species and TOC. For example, *Amitermes* (- 0.19) was not significantly affected by TOC while *Macrotermes* (- 0.68) negatively correlated with soil TOC. Foraging activities like construction of tunnels which require feeding on debris and soil may affect the termites and their distribution [23]. Some termite species (*Anoplotermes* spp) are soil-feeders that are found in abandoned termite nest and feed on very rotten wood and substrates rich in organic matter [24].

The Principal Component Analysis (PCA) of the correlation between the physico-chemical parameters and abundance showed pH and moisture content as the principal components affecting the abundance of termites by 27.1% while temperature, silt, clay and TOC negatively influenced termite abundance by 24%. The cluster analysis revealed two groups of termites related by their distribution. The first group which was made up of the *Amitermes* spp1*, Amitermes* spp2, *Macrotermes* spp and *Globitermes* spp were the generalist because they were found in more than one station while the other group was the *M. gilvus* which is the specialist found only in one station. This is as a result of the types of vegetation and landform found in the study area. [25] reported that *Amitermes spp* prefer regions containing herbs and shrubs while *Microtermes spp* prefer areas with large trees and grass and are more abundant in plains.

5. CONCLUSIONS

Termites exist in almost all biomes and are major threat to wood, buildings, crops, and forest. This study was to determine the subterranean termites in a university community where the trees, grasses and soil surface are fast disappearing due to increasing rapid development of infrastructure. The area was divided into 10 zones and soil samples were collected from and around mounds. The results revealed only three genera of termites - *Amitermes, Macrotermes* and *Globitermes*. Amitermes was a generalist found in every zone sampled, but higher counts were recorded around residential areas while *Macrotermes* and *Globitermes* were seen in the cultivated areas. This suggests that, most destructive aspect of termite behaviour on residential areas are perpetuated by the *Amitermes* species. The *Macrotermes* and *Globitermes* spp were basically soil feeders while *Amitermes* species were dry wood and dead stump feeders. Moisture and TOC appeared to affect abundance while pH, particle size and temperature did not affect the distribution and abundance of the species. *Amitermes* appeared to colonise deserted *Macrotermes* mounds in built up areas.. This is a baseline report that will be useful for future studies. This study does not include arboreal termites found on trees and those infesting buildings in the community.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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