Assessment of Severity of Termites Attack in Adekunle Ajasin University Akungba Akoko Campus, Ondo State, Nigeria

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Received:- 13 May 2022/ Revised:- 05 June 2022/ Accepted:- 11 June 2022/ Published: 30-06-2022

Abstract— *Termites' attack has been a major problem for wooden structures and buildings. The severity of termites' attack on the AAUA campus area using Triplochiton scleroxylon wood as bait was examined. Identification of prevalent termite species as well as the soil's physical properties were studied in twenty sampled locations. Defect-free wood samples of Triplochiton scleroxylon dimensioned 35 × 35 × 450mm according to ASTM D3345-17 (2017) were buried halfway in the soil and exposed to termite attacks for 12 weeks (3 months) in an established timber graveyard at the locations. A weekly visual assessment of the stakes was done in accordance with the ASTM D 3345 rating scale and a gravimetric weight loss assessment was carried out after the period of exposure. Data obtained were used to produce termites severity probability map of the campus area was prepared using ArcGIS software and following the USDA standard color codes. Six termites species identified were: Ancistrotermes cavithorax (Isoptera: Macrotermitidae; termite), Odontotermes pauperan (Isoptera: Macrotermitidae; fungus-growing termite), Microtermes species (Isoptera: Termitidae; termite), Trinervitermes species (Isoptera: Termitidae; Trinervitermes), Macrotermes subhyalinus (Isoptera: Termitidae; Rambur), and Amitermes evuncifer (Isoptera: Termitidae; amitermes). The result showed that soil properties ranged from 7.19±0.02 to 19.78±0.03% for the moisture content, 28.82±0.02 to 51.72±0.02% for water holding capacity, 1.08±0.01 to 1.76±0.01 for the bulk density, while the soil organic matter values across the locations ranged from 6.08±0.02 to 21.29±0.04, however, only the water holding capacity has a moderate positive correlation with the severity of termite activities. The termite infestation probability map revealed that almost every part of the AAUA campus showed termite activities ongoing with a varying degree.*

Keywords— Subterranean termites, Termites severity probability map, GIS technology, Wood protection.

I. INTRODUCTION

Wood is a traditional building material used for a variety of applications, such as fencing, decking, cladding, and construction of domestic dwellings, it has found applications in the construction of heavy load-bearing structures like jetties, bridges and industrial buildings, etc. (Ritter 1990). However, whenever wood is exposed directly or indirectly to environmental factors, it requires protective measures against weathering and bio deteriorating agents, like fungi, insects (termites), and bacteria.

Termites are an important factor in the forest and its associated ecosystems including micro-human-modified environments; contributing immensely to soil formation, and fertility through cellulosic biomass degradation processes (Ssemaganda*et al*, 2011). They are social insects of the order of *Isopteran* with about 3,000 known species of which 75% are classified as soil-feeding termites (Grimalkin and Engle, 2005). They live in colonies consisting of workers, soldiers, a queen, and a king which collectively form well-organized social formations.

Termites play important contrasting ecological roles in reworking the soil profile and the destruction of material meant for building construction, agriculture, and forestry (Lee and Wood, 1971; Milked and Mike, 1982; Joni; Gummier and Nyanganji, 2005). As polymorphic social insects, they live in self-constructed mounds called termitaria, whose destructive activities are usually higher during the dry season or drought compared to the rainy season, lowland rather than highlands, and in plants cultivated under stress and such are referred to as predictable 'ecosystem engineers' (Rajeev and Sajeev., 1998).

It has been discovered that builders, developers, site buildings without the initial assessment of the prevalence of termites which is a major wood pest. This has led to frequent construction failures of the roof, ceiling, and other wood structures. This study, therefore, was carried out to determine the prevalence of termites using AAUA campus as a case study to advise developers on what needs to be done before putting up a structure.

II. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in Adekunle Ajasin University Akungba Akoko (AAUA which is between latitudes 7^0 28' 9.15' to 7^0 29'' 15.18' North of the equator and longitude 5^0 44'' 15.96' to 5^0 46'' 14.78' East of the Greenwich Meridian (Fig.1). It is situated in Akoko South West Local Government Area of Ondo State. Akungba Akoko town. (Allen, 2012)

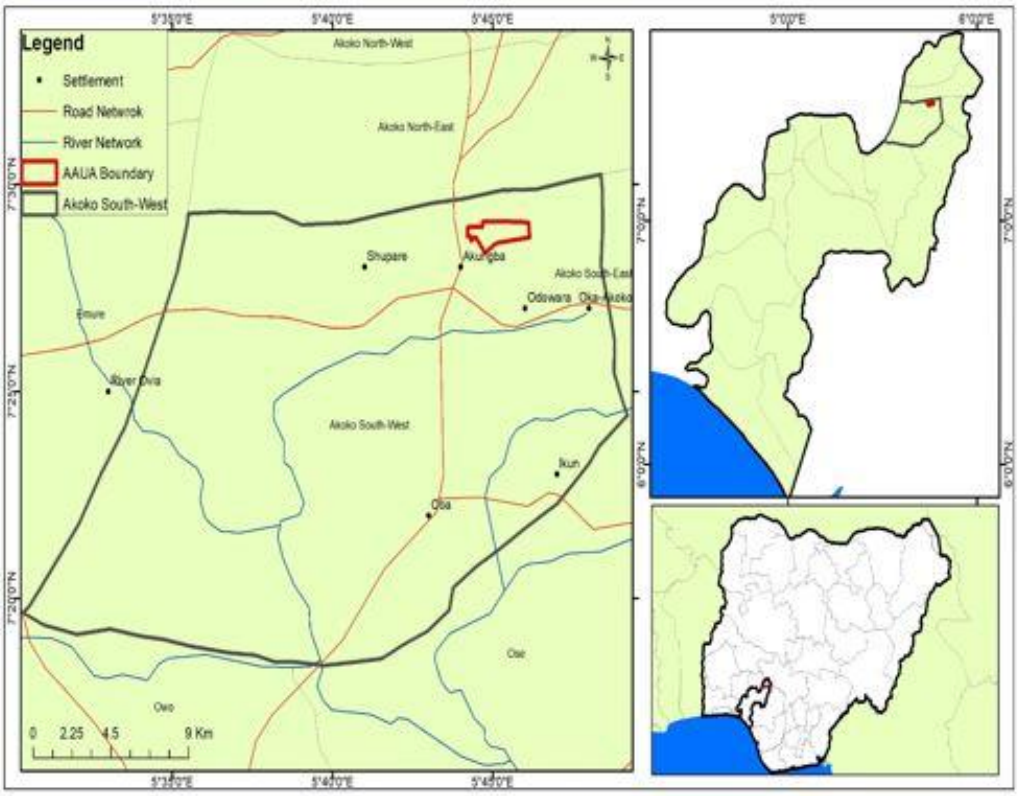

FIGURE 1: Map of the study area

FIGURE 2: Sample Field Plots (Timber graveyard)

The ecological zone which used to be a rainforest is gradually becoming derived savannah due to erratic rainfall patterns resulting from climate change. The zone has a mean annual rainfall of 1250mm and the average temperature is between 18^0C and 35^0C. The area is characterized by Precambrian Basement rocks such as grey gneiss, quartzo-feldspathic gneiss, charnockite; granite gneiss; and porphyritic gneiss (Okpoli, 2015).

2.2 Materials

The site sampling and plot selection were carried out with the use of a georeferenced AAUA Map obtained from the Center for Space Research and Application (CESRA) FUTA using ArcGIS software. The sample stakes used as bait for this study were obtained from *Triplochiton scleroxylon* (Obeche) wood known for its moderate susceptibility to termite attack. The wood species were purchased from a local timber market in Akungba-Akoko, Ondo State, and taken to the wood workshop of the Department of Forestry and Wood Technology Federal University of Technology Akure, where it was converted into standard sample sizes. The other materials that were used include moisture meter, microscope, oven-dryer, core sampler, digger among others.

2.3 Methods

2.3.1 Sites Selection

A hard copy of the AAUA campus map was obtained from the Physical Planning Department of the university. The map was scanned, digitized, and geo-referenced at the Center for Space Research and Application (CESRA) FUTA using ArcGIS software. The map was divided into grids of regular points which were numbered serially after which, the coordinates (Table 1) of twenty randomly selected points were obtained and exported to the geo-referenced map to ascertain their exact locations on the school campus.

TABLE 1
COORDINATES OF THE SELECTED LOCATIONS WITH THEIR SITE NAMES

Location	Latitude(°)	Longitude(°)
1	7.4797	5.7375
2	7.4808	5.7377
3	7.4791	5.7394
4	7.4813	5.7411
5	7.4822	5.7425
6	7.4783	5.7444
7	7.4811	5.7389
8	7.4813	5.7502
9	7.4761	5.745
10	7.4786	5.7486
11	7.4775	5.7542
12	7.4733	5.7436
13	7.4794	5.7597
14	7.483	5.7533
15	7.4839	5.7575
16	7.4844	5.7522
17	7.4813	5.7613
18	7.483	5.7633
19	7.4811	5.7477
20	7.4822	5.7675

The georeferenced map of AAUA also superimposes the boundary layer for plot sampling. After the plot sampling, a reconnaissance survey ground-truthing) was carried out to assess the ground conditions of each location before the establishment of the timber graveyard in each of these selected locations.

2.3.2 Wood sample selection and Preparation

Triplochiton scleroxylon (Obeche) wood was processed to 35×35× 450 mm according to ASTM D3345-17 (2017) and one hundred samples were obtained. All the samples were labelled for easy identification and their initial weight was obtained using a weighing balance, after which they were oven-dried at a temperature of 103±2^{0}C for twenty-four (24) hours until a constant weight was obtained. The oven-dried weight of each sample was also obtained and this served as the initial weight of each of the samples with respect to weight loss assessment.

2.3.3 Field Test

The field (Timber graveyard) test was carried out at the20 locations within the AAUA campus. Each of the selected sites was cleared with wood shavings spread to stimulate termites' activities. Five wood stakes were buried to a depth of 225mm below the ground surface and at the spacing of 1000 × 1000 mm from each other (Fig. 11). The weekly visual assessment was carried out for twelve (12) weeks to assess the severity of termite attack on the wood samples in each of the selected twenty (20) locations and ratings were done according to ASTM D 3345-17 (2017). At the end of the twelve (12) weeks testing period, the entire sample was withdrawn and re-weighed using a gravimetric method to assess the level of degradation by termites.

2.3.4 Termites Collection and Identification

Termites' specimens which include workers 'and soldiers' were collected at each location using a plastic insect specimen bottle filled with 10ml of ethanol. The collected specimens were taken to the Center for Termites` Research, Identification, and Management, Department of Biology, the Federal University of Technology Akure for proper identification.

The identification procedure involved both internal and external morphology assessment of the obtained specimens. Internal morphology was carried out after enteric valve armature of the termites were removed, dissected, and fixed in alcoholic Boun's fluid, after which they were dehydrated in dioxane and observed under a scanning electron microscope while external morphology for the termite's identification was carried out after the termites were fixed in dehydrated ethanol series (70 to 100%), the termites were observed under scanning electron microscope using the Mandible, Antenna, Pronotum, Labrum, Hyaline tip Fontanelle and postnotumfor clearer identification.

2.3.5 Soil Properties Determination

Soil physical properties from the study sites (Bulk density, Moisture content, and Organic matter) were determined from soil samples obtained from the twenty (20) selected locations following standard laboratory procedures.

2.3.6 Preparation of Termite Severity Probability Map

At the end of the weekly assessments period, weight loss values and data obtained from the ASTM D3345-17 visual rating assessment for each location were used to prepare a termite infestation/severity probability map using the IDW function in ArcGIS software's Spatial Analyst for data interpolation with a moderate weighting value and following USDA standard color codes to assign the different severity levels (Peterson *et al.*, 2006):

2.3.7 Experimental Design and Data Analyses

The experimental design used for the research is Complete Randomized Design (CRD) with 20 selected locations constituting the treatment. The data obtained from the fieldwork was analyzed using the Statistical Package for Social Sciences (SPSS) version 21. Descriptive statistics of the investigated variables were obtained, while analysis of variance (ANOVA) (α = 0.05) was carried out to determine if there were significant differences in the investigated variables as observed in the twenty (20) selected locations and the mean separation was carried out using Duncan New Multiple Range Test (DMRT) where a significant difference is observed.

III. RESULTS

3.1 Termite Identification

The results revealed that six termite species are prevalent within the AAUA campus area with the *Ancistrotermes cavithorax* and *Microtermes spp.* having the most abundant termite species prevalent within the campus area. This result supports the works of Harris (1971) and Akande (1992) who reported that termite species are wide across vegetation zones in Nigeria.

Termite identification carried out across the twenty selected locations within the AAUA campus area in Table 2 and Figure 3 showed that *Ancistrotermes cavithorax* species is the most abundant termite species found within the AAUA campus, with its presence identified eight (8) out of the eighteen locations where termite species were obtained, followed by the *Microtermes species* which was identified in seven out of the eighteen locations within the campus area, and *Trinervitermes species* which was identified in four (4) out of the eighteen locations, while *Odontotermes pauperan*, *Macrotermes subhyalinus*, and *Amitermes evuncifer* had a minor presence in the campus area; as was identified in just one location respectively within the campus area.

TABLE 2
TERMITE SPECIES IDENTIFIED IN THE 20 SELECTED LOCATIONS ACROSS THE AAUA CAMPUS AREA

location	Termite species					
	Odontotermes pauperan	*Trinervitermes species*	*Ancistrotermes cavithorax*	*Microtermes species*	*Macrotermes subhyalinus*	*Amitermes evuncifer*
Location 1	-	+	-	-	-	-
Location 2	-	+	-	-	-	-
Location 3	-	-	-	-	-	-
Location 4	+	-	-	-	+	-
Location 5	-	-	-	-	-	-
Location 6	-	-	+	-	-	-
Location 7	-	+	-	-	-	-
Location 8	-	+	-	-	-	-
Location 9	-	-	+	-	-	-
Location 10	-	-	+	+	-	-
Location 11	-	-	+	+	-	-
Location 12	-	-	+	-	-	-
Location 13	-	-	+	-	-	-
Location 14	-	-	-	-	-	+
Location 15	-	-	+	-	-	-
Location 16	-	-	-	+	-	-
Location 17	-	-	-	+	-	-
Location 18	-	-	-	+	-	-
Location 19	-	-	-	+	-	-
Location 20	-	-	+	+	-	-

Where ''+'' means presence and ''–'' means the absence

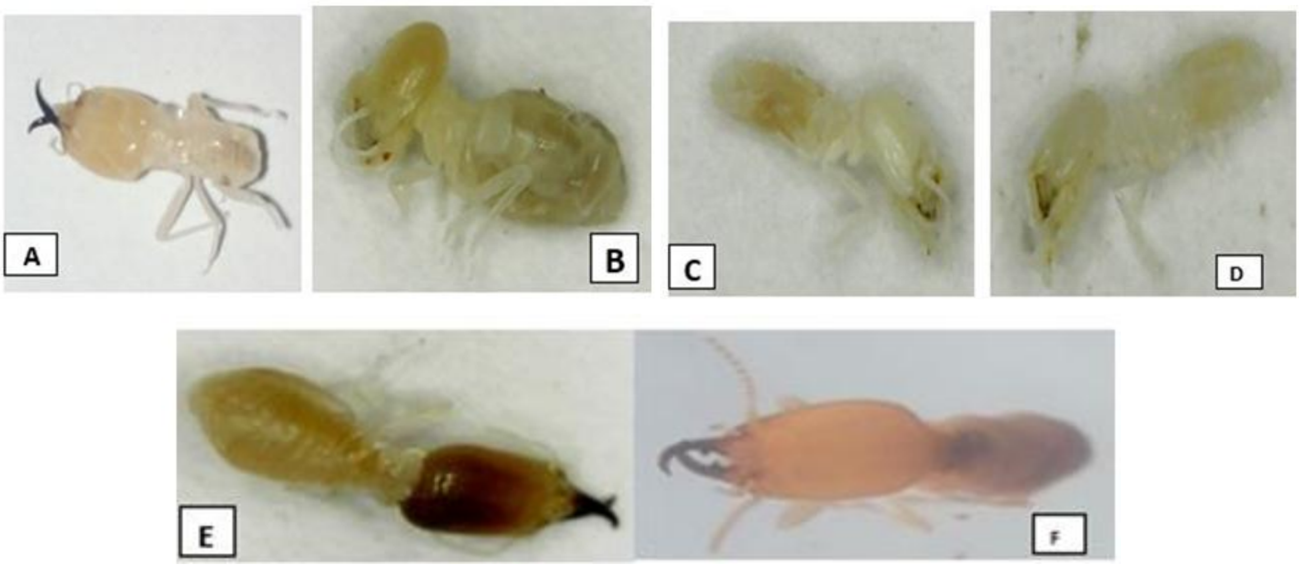

FIGURE 3: Termite species identified at the locations used for this study. A: *Ondototermes pauperan,* B: *Trinervitermes spp.,* C: *Ancistrotermes cavithorax,* D: Microtermes *spp.,* E: Macrotermes *subhyalinus* F: Amitermes *evuncifer*

FIGURE 4: Evidence of Termite activities at some of the selected study sites.

3.2 Relationship between Termite Severity and Soil Properties

The result of the investigated soil properties carried out in this study showed that soil properties viz bulk density, moisture content, soil organic matter, and soil water holding capacity varied from one location to another, although the values were not significantly different for some locations, and is believed to have played a role in the distribution of the termite species identified within the campus area. Concerning bulk density (**fig 5**), it was observed that location 18 had the highest bulk density of 1.76±0.01g/cm^{3}while location 2 had the least bulk density of (1.08±0.01g/cm^3).

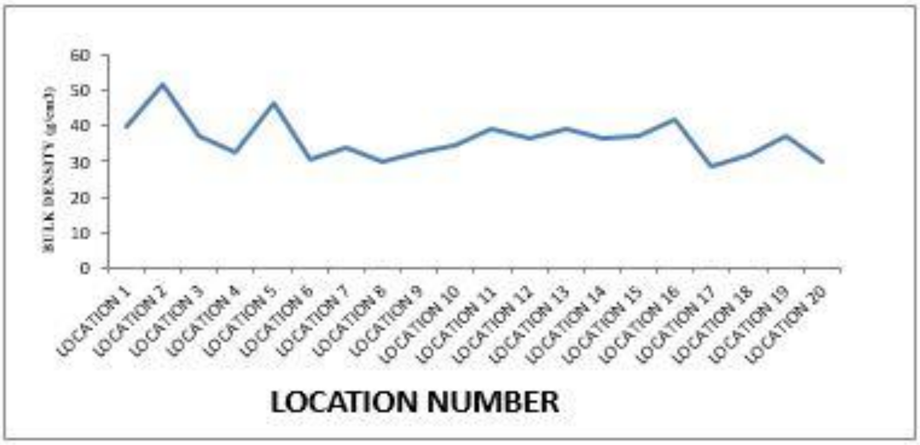

FIGURE 5: Bulk density of soil samples obtained from the 20 selected locations across the AAUA campus area

The moisture content (**fig 6**) of the soil samples from the 20 selected locations in the AAUA campus area, shows that location 3 has the highest moisture content value of (19.78±0.03) while location 8 (7.19±0.02) had the lowest moisture content value.

FIGURE 6: Moisture content (%) of soil samples was obtained from the 20 selected locations across the AAUA campus area.

The soil organic matter (**fig 7**) content in the 20 selected locations within the AAUA campus, ranged from 21.29±0.04%location 2 to (6.08±0.02) location 1. A similar result is observed with the soil water holding capacity (**fig 8**) of the soil in the 20 locations, which ranged from51.72±0.02% location 2 to 28.82±0.02% for location 17.

FIGURE 7: Organic matter content (%) of soil samples obtained from the 20 selected locations across the AAUA campus area.

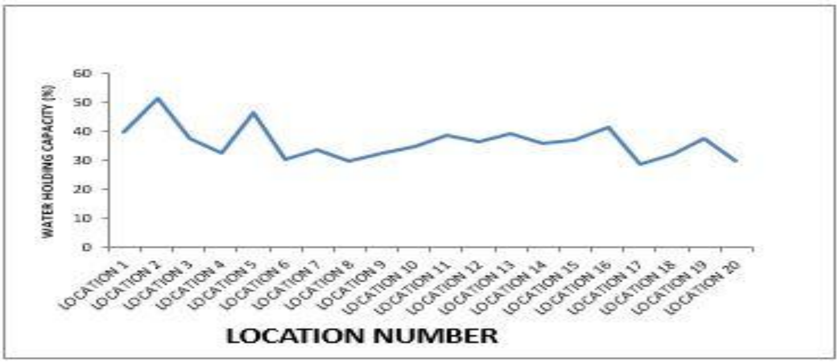

FIGURE 8: Water holding capacity (%) of soil samples obtained from the 20 selected locations across the AAUA campus area.

Although the values were not significantly different for some locations and are believed to have contributed to the distribution of the termite species identified within the campus area, as well as the severity of their activities as revealed by the spearman's rank correlation (Table 3) between the investigated soil properties in the 20 selected locations across AAUA campus and termite severity of attack; measured as a function of the visual ratings of the wood samples in these locations with *Ancistrotermes cavithorax* and the *Microtermes spp* adapting to a greater range of variations.

From the results, as shown in **Table 3**, it can be observed that there is a moderate positive correlation between the visual rating of wood samples observed in the twenty selected locations within the AAUA campus and their water holding capacity, which was statistically significant at 0.05 probability level (rs = 0.510, P = 0.05).

TABLE 3
SPEARMAN'S RANK-ORDER CORRELATION MATRIX FOR VISUAL RATINGS AND INVESTIGATED SOIL PROPERTIES OBSERVED IN THE 20 SELECTED LOCATIONS WITHIN THE AAUA CAMPUS

		Moisture Content	Organic Matter	Water Holding Capacity	Bulk Density
VISUAL RATING	Correlation Coefficient	0.347	0.175	0.510*	-0.239
	Sig. (2-tailed)	0.133	0.461	0.022	0.310

**** = Correlation is significant at the 0.05 level (2-tailed)***

IV. DISCUSSIONS

There was no termite presence in locations 3 and 5 throughout the period of this study hence no species were recorded under them as shown in Table 2. Termites play important ecological roles in reworking the soil profile and the destruction of material meant for building, construction, agriculture, and forestry (Lee and Wood, 1971; Milked and Mike, 1982; Joni, 1990; Black and Ekwakol, 1997; Gummier and Nyanganji, 2005). However, termites are very sensitive to the environmental condition while establishing colony or during foraging activities, therefore has to deal with different soil types together with their properties (Ali et al., 2013: Haverty and Nutting, 1976)

Generally, an adequate moisture content level is necessary for burrowing activities, as well as to ensure longer distances and larger coverage areas. An increase in soil moisture in rates that will not interfere or limit the free movement of the termites, bring an increase in termite activities. **.** The moisture content of all the 20 selected locations across the AAUA campus area in this study ranged from 7.19% to19.78%, which is well within the range favorable for termite activities. Once inside the building, termites will continue to maintain contact with the ground (for moisture) and the nest center (the center of the communication). (Ali *et al.*, 2013; Ghaly and Edwards, 2011; Wong and Lee, 2010; Arab and Costa-Leeonardo, 2005; Su and Puche, 2003; Ahmed, 2000).

Termites feed on a very variety of organic detritus like dry grass, decaying leaves, animal dung, hummus, and living or dead wood (Brossard et al, 2007) due to the ability to decompose lignocellulosic biomass and dead organic matter in tropical and sub-tropical regions. (Jounguet et al, 2002; Mahaney et al. 1999)

Since termites are known to increase the organic matter content of the soil and modify the clay composition of this soil; all in a bid to construct nests that are erosion-resistant (Jouquet et al. 2002). This can then be concluded that both *Ancistrotemes cavithorax*and *Microtermes spp.* are well adapted to soil of both high and low organic matter content, hence, their wide distribution across these locations.

In this study, wood exposed to soil with high water-holding capacity showed low resistance to termites attacks, the result of this work corroborates with the report from Jurgenrius *et al* (1999) and Owoyemi *et al* (2017) revealed that soil properties are one of the factors contributing to the level of attacks of termites when considering the effect of soil bulk density on the rate of termite attacks.

4.1 The severity of Termite Activities on the Campus Area

The results of the weight loss assessment of *Triplochiton scleroxylon* wood samples in the 20 selected locations across the AAUA campus area were summarized in **Figure 9**. It was observed that locations with higher weight loss values, have similar low visual ratings, with higher weight loss values recorded for locations where *Ancistrotermes cavithorax*, *Microtermes spp*, and *Macrotermes subhyalinus* species were identified, and the attack increases getting with the presence of *Macrotermes subhyalinus,* and this correlated with the observations of Owoyemi *et al*. (2017) which reported the aggressive nature of this termite species.

FIGURE 9: Severity of termite activities across the 20 locations within the AAUA campus as measured by the gravimetric weight loss and the ASTM D3345-17 visual rating.

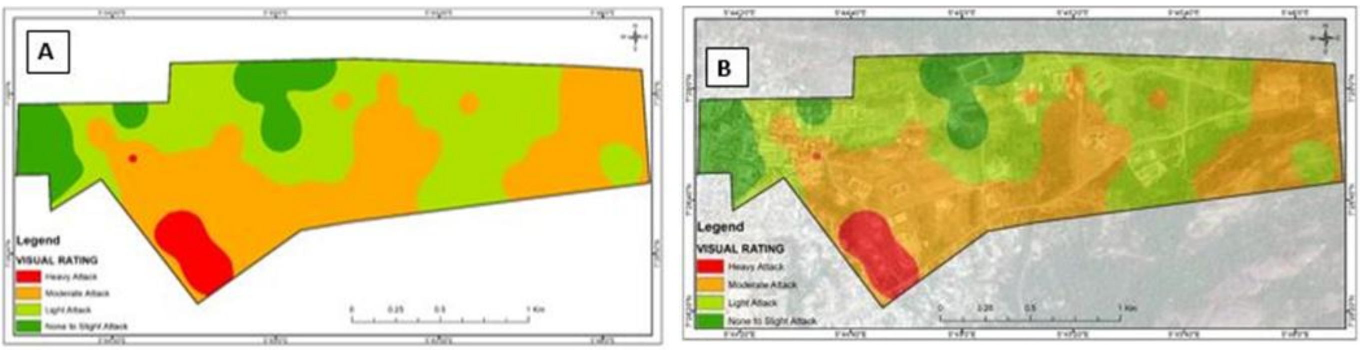

FIGURE 10: Termite Infestation Probability Map of AAUA campus; A: Map showing the termite severity on the campus-based on the visual ratings of the selected locations, B: Termite severity of the AAUA campus superimposed on the extracted Google earth imagery showing other known features that fall within the campus boundary.

The result showed that locations 3 and 5 had no evidence of termite presence throughout the 12 weeks of testing, indicating that the weight loss values observed in these locations and invariably in all the 20 selected locations across the campus area had contributions from other wood biodeteriorating agents other than termites. The weight loss recorded in these locations can be due to micro bacterial activities and /or fungi activities which can be favoured by the high organic matter and moisture content. This report corresponds to previous knowledge that apart from the biting action, most termite species maintain a symbiotic interaction with a greater community of microorganisms which helps them in breaking down their food materials (Ali *et al*., 2013; O'Brien and Slaytor, 1982).

4.2 Termite Severity Probability Map of AAUA Campus Area

The termite infestation probability map of the AAUA campus prepared using the ArcGIS software is presented in Figure 10, after twelve (12) weeks of exposure across the twenty selected locations within the AAUA campus area. It was observed that termite activities were ongoing in almost all areas within the AAUA campus area; except locations 3 and 5 within which no termite species or foraging activity were observed. These locations could be found around Mass Communication Department (location 3) which is waterlogged during the rainy season, and could be responsible for the absence of termite activities in these areas. Location 5 besides the Faculty of Social and Management Sciences is a very rocky soil area with little or no moisture making it difficult for termites to burrow in the earth making it difficult for termites to thrive.

Areas under light termite activities or probability of light to moderate attacks involve a host of important university installations such as University Eastern Gate, University Senate Building, Entrepreneurship building, beside the V.C Lodge e.t.c. Other areas under moderate attack and severity of termite activities include the incomplete student hostel opposite the University Health Centre, open field opposite Handball court, school Library, New Faculty of Art, the Farm Gate, Teak plantation in front of Advancement Office, the University farm, while the areas that recorded high termite activities with heavy severity of attack include the university sports complex and chemistry laboratory, zenith female hostel.

A sharp transition could be easily be noticed between the regions belonging to the different severity (color-coded) levels (Fig. 10a &b).this implies that almost every part of the AAUA campus area is at the risk of termite attack, Therefore, from the foregoing, adequate caution and design considerations must be taken when constructing buildings within the campus area, putting into consideration construction measures against termite ingress and infestation of the buildings; especially in the areas under moderate to heavy severity of termite attack.

V. CONCLUSION

The study has established the presence of termites activities within the AAUA campus with *Ancistrotermes cavithorax* most associated with aggressive foraging activities within the campus area co-existing with the *Microtermes species*. Activities of termites have imparted negatively on wooden structures in buildings. The knowledge of its prevalence is important when sitting building in a residential environment. The termite's probability map developed for AAUA will serve as a guide for what pre-constructional methods to adopt in a new environment; while it will also guide on what remedial approaches to take in areas where buildings have been erected already. Studies on termites' severity should be conducted periodically as termites move from one location to another as evidenced in the periodic swarming activities of winged termites.

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