FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 4 No. 2, June, 2020, pp 92 -100
DOI: https://doi.org/10.33003/fjs-2020-0402-206

EFFECT OF PHYSICO-CHEMICAL PARAMETERS ON THE ABUNDANCE AND DIVERSITY OF TERMITES AND OTHER ARTHROPODS IN TERMITE MOUNDS IN UYO, AKWA IBOM STATE, NIGERIA.

[*1]Akpan, Akaninyene Udoh, [2]Ojianwuna, Chioma Cynthia, [1]Ubulom, Peace Mayen Edwin, [1]Clement Ameh Yaro, [1]Oboho, Diligent Efiong.

[1]Entomology Unit – Department of Animal and Environmental Biology, University of Uyo, Uyo, Akwa Ibom State, Nigeria.
[2]Department of Animal and Environmental Biology, Delta State University, Abraka. Delta State. Nigeria

*Corresponding author e-mail: akpanudoh@uniuyo.edu.ng

ABSTRACT

Termites are generally regarded as pests, although they have some beneficial roles to play in the ecosystem, particularly in the soil. This study was conducted between January 2018 and April 2018, to determine the effect of physico-chemical parametrs on abundance and diversity of termites and other arthropods in termite mounds in Uinversity of Uyo Community. Soil samples were randomly collected from six termite mounds from two sites for physiochemical parameters analysis and these were temperature, pH, moisture content, nitrogen, phosphorus, magnesium, copper, sodium, potassium, manganese and iron.. The termites and other arthropods were preserved in 70% ethanol. Temperature and moisture content, copper, sodium and iron were significant. The results revealed that the physicochemical parameters affected the termite species abundance as station 1 (539) had relatively more of the termite species than station 2 (551), and also affected the diversity of the termites as station 1 (0.89) had relatively more diversity of the termites than station 2 (0.66). Also from the results, station 1 (2.06) had relatively more diversity of the other arthropod species identified in the study area than station 2 (1.59). *Macrotermes bellicosus* and *Odontermes badius* termite species were identified. *Musca domestica*, *Anopheles gambiae*, *Lasius* sp, *Archispirostreptus* sp, *Camponotus* sp, *Missulena* sp, *Chorthippus* sp, *Acheta* sp and *Blatta orientalis* were the other arthropods collected and identified. *Macrotermes bellicosus* (59.93 %; 63.52 %) was the most abundance and dominant of the termite species identified in the study areas. *Lasius* sp (45; 25.93 %) was the most abundance in station 1 with *Missulena* sp (6; 3.17 %) the least, while *Chorthippus* sp (60; 37.97%) was the most abundance species in station 2. Termites and non-termite arthropods are of great importance for ecological balance of the ecosystem.

Keywords: Termite mound, *Macrotermes bellicosus*, *Odontermes badius*, other arthropods

INTRODUCTION

Termites are social and terrestrial insects of the order Isoptera, characterized by overlapping generations of cooperative care of younger species by older species and the presence of a reproductive division of labour or a caste system (Glaciela *et al*., 2006; Lefebvre *et al.*, 2009; Tathiane *et al*., 2009).

Termite communities present great species diversity, with various types of feeding and nesting places. In terrestrial ecosystems, these insects carry the greatest responsibility - although not necessarily the dominant group, for decomposition and mineralization of carbon, thus affecting properties and soil structure (Bignell and Eggleton, 2002; Holt and Lepage, 2002). The highly successful eusocial nature of termites is also evidenced by their historical success and widespread distribution throughout many areas of the world (Hughes, 2008). Termites together with other arthropods, are mostly involved in the ingestion and manipulation of organic and mineral matter, forming subterranean tunnels and chambers which assist in the redistribution of soil layers, aeration, porosity and increased drainage.

Termites are dominant arthropod detritivores important in the decomposition process. Their influence on decomposition processes at any site is likely to be governed to a large extent by the species composition and abundance, and the local termite assemblage (Jones and Eggleton, 2000). There are over 660 known species of termites in Africa but species abundance and diversity varies within and between regions (Kambhampati and Eggleton, 2000).

Termite and other athropods abundance, and diversity and species richness can be used as a tool for determining environmental integrity (Wekhe *et al.*, 2019). However, the abundance and diversity of different termite and other arthropod species in termite mound in tropical ecosystems could be affected by the mound's physico-chemical properties, land-use practices such as agricultural practices and habitat fragmentation (MEA, 2005).

Termite mounds (termitaria) are among the most conspicuous feature and pinnacle of many landscapes, particularly in tropical and subtropical regions, strongly influencing the soil properties (Levick *et al.*, 2010; Afolabi *et al.*, 2014). Termite mounds have distinct morphology compared with the surrounding topsoil (Abe *et al.*, 2009). According to Cancello *et al.* (2014) termite mound's growth, abundance and volume vary regionally due to variation in climate, vegetation cover, soil properties, biomass abundance, slope and groundwater depth. In northern Nigeria, for instance, Ekundayo and Orhue

(2002) in their study of distribution and abundance of termite mounds reported high densities of termite mounds in the area.
.

The termites mounds, apart from the ecological functions, serve as habitat to many species of other arthropod fauna, who have adapted to use them for shelter and other needs such as feeding, reproduction and micro-climate (Malaka, 2016).

It is pertinent to note that quantitative data relating to the effect of physico-chemical parameters of termite mound on termite and other arthropods assemblage, are scanty especially in Southern Nigeria, hence the need for this research, and the results obtained from this will serve as baseline information for abundance and diversity of termites and other arthropods assemblage in termite mounds in this part of the country.

MATERIALS AND METHODS

STUDY AREA

The study was carried out between January 2018 and April 2018 in the main campus of University of Uyo, Uyo, Akwa Ibom State, Nigereia.

STUDY SITES

The study sites were carefully chosen in the main campus.

Study site 1: This site lies between Latitude 5°03'98.45" and 5°2'23.442" N, and Longitudes 7°9'83.445" and 7°5'904.02"E (Figure 1). The site is characterised with cultivated crops such as cassava (*Manihot esculenta*), pumpkin (*Telfairia occidentalis*), waterleaves (*Talinum triangulare*) and yams (*Dioscorea alata*). The termite mounds in this site measure up to an average height of 1.4m.

Study site 2: It lies between Latitude 5°03'71.916" and 5°2'13.89" N, and Longitudes 7°9'78.278" and 7°58'41.802"E (Figure 1). The site is characterised by the presence of shrubs such as *Chromolaena odorata* (Siam weed), *Aspilia africana*, grasses; *Cymbopogon citratus* (lemon grass), *Pennistrum purpureum* (Elephant grass) and cover crop (*Centrosema* sp) and the mounds measure up to approximately 1.9m.

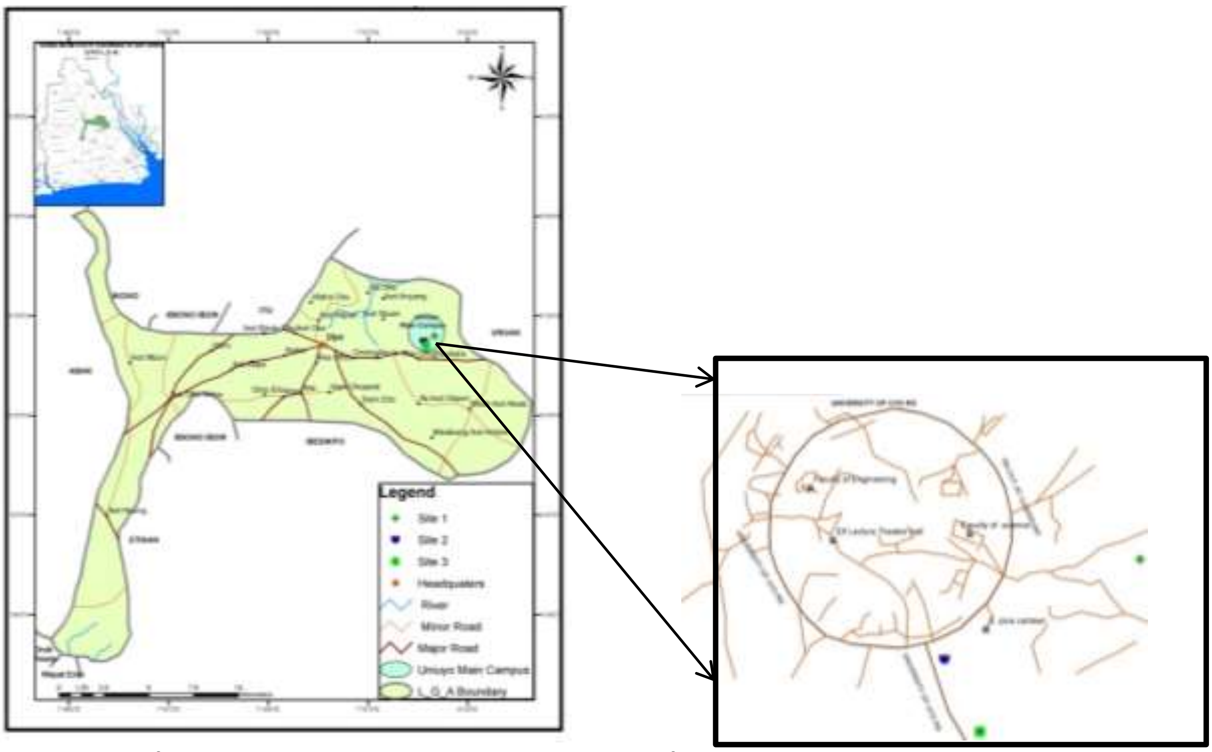

Figure 1: Map of Uyo Local Government Area showing University of Uyo Main Campus and the Study Sites (Cartography Studio, Department of Geography and Natural Resources Management, University of Uyo, Nigeria).

Samples Collection

Mound samples collection

The sand from the termite mound samples were collected to analyse for temperature, hydrogen ion concentration (pH) and weight (using Electronic Balance® Model FET-300). Nitrogen (N), Phosphorus (P), Magnesium (Mg), Copper (Cu), Sodium (Na), Potassium (K), Manganese (Mn) and Iron (Fe) were also determined. The sand was digested with HNO_3^-/HCL before analysing for the parameters as described by AOAC (2010). The digest solutions of the soil samples were prepared by weighing 1 gram of each of the samples. These were digested with aqua regia (HCl and HNO_3) at130ºC using electric hotplate for 30 minute. The filtered was made up to 100ml after filtration using 100ml volumetric flask. Standard solutions of the metal to be analyzed were prepared. The atomic absorption spectrophotometer (model: varian spectra 100, Australia.) was set with power on for ten minutes. The standard metal solutions were injected to calibrate the AAS using acetylene gas. An aliquot of the digest solutions were injected and the concentrations obtained from the AAS.

Termite and other arthropod species collection

The termite and other arthropods were collected from six termite mounds selected from the two study sites in every two weeks of every month from January 2018 to April 2018. The collection was done after excavation of the termite mound with shovel. The flying arthropods over the termite mound were collected with mosquito sweep net. The collected termites and other arthropod species were preserved in a well labelled container with 70 % ethyl alcohol and taken to the Entomology Laboratory, Department of Animal and Environmental Biology, University of Uyo. Uyo. In the Laboratory the termites and other arthropods were sorted and stored in 70 % ethyl alcohol. The termites and other arthropods were identified by Insect taxonomist using relevant taxonomic keys provided by Harvey *et al*. (1989) and Constantino (1999).

Data analysis

Mean and standard error analysis of the termite mound parameters, and correlation analysis of the relationship between termite mound parameters and the termite and other arthropod species, were analyzed using SPSS (Statistical Package for Social Science 20.0). Diversity indices *H* and species richness of the termite and other arthropods species were calculated using Paleontological Statistics (PAST 3.0).

RESULTS

Termite mound parameters

The range value, mean and standard error results on the termite mound metal and physico-chemical parameters are presented in table 1.

Termites and other arthropod species

The termites and orther arthropod species are represented in table 2. Two species of termites; *Macrotermes bellicosus* and *Odontermes badius*, were identified. The results on the relative abundance of the termites and other arthropods are presented in table 3.

Diversity indices of the termite species and other arthropods sampled

Station 1 had relatively high diversity *H*; 0.8923 and species richness; 0.318 of termite species than station 2 (Table 4). The results on correlation relationship between termite mound physicochemical parameters and the abundance of the termites and non-termite arthropod species are presented in table 5, 6 and 7.

Table 1: Range value, mean and standard error (SE) of Metal and Physicochemical Parameters of the termite mound in the study stations .

Parameters	Station 1		Station 2		t– value
	Range value	Mean and SE	Range value	Mean and SE	
Temperature (ºC)	20-30	24.5±0.54	20-30	26.5±0.23	2.45*
pH	5.00-6.00	5.45±0.14	6.00-7.00	6.75±0.06	-0.80
Moisture content	100-140	138.56 ± 20.71	150-200	192.47± 1.91	-2.42*
Nitrogen	0.30-0.40	0.36 ± 0.21	0.01-0.02	0.02 ±0.002	1.60
Phosphorus	3.00-4.00	3.46 ± 0.84	2.00-2.50	2.27±0.02	1.37
Magnesium (Mg)	2.00-2.30	2.12 ± 0.03	1.00-2.50	2.01±0.13	0.67
Copper (Cu)	0.50-1.00	0.89 ± 0.07	0.50-1.00	0.65±0.07	2.58*
Sodium (Na)	0.30-0.5	0.49 ± 0.01	0.30-0.40	0.32±0.05	3.06*
Potassium (K)	0.50-0.70	0.64 ± 0.32	0.10-0.30	0.15±0.005	1.49
Manganese (Mn)	2.00-2.50	2.06 ± 0.61	0.50-1.50	1.09±0.01	1.60
Iron (Fe)	5.00-6.00	5.73 ± 0.16	5.50-7.00	6.39±0.09	-2.87*

* Significant at $p \leq 0.05$.

Table 2: The Termite and other Arthropods assemblage of the termite mounds studied.

Group	Order	Family	Scientific Name	Common Name
Termites	Isoptera	Termitidae	*Odontermes badius*	Light head termites
			Macrotermes bellicosus	Thick head termites
		Unidentified termites		
Other arthropods	Diptera	Muscidae	*Musca domestica*	Housefly
	Diptera	Culicidae	*Anopheles gambiae*	Mosquito
	Hymenoptera	Formicidae	*Lasius* sp	Black garden ant
	Spirostreptida	Spirostreptidae	*Archispirostreptus* sp	Giant African millipede
	Hymenoptera	Formicidae	*Camponotus* sp	Black carpenter ant
	Araneae	Actinopodidae	*Missulena* sp	Spider
	Orthopera	Acriididae	*Chorthippus* sp	Grasshopper
	Orthopera	Gryllidae	*Acheta* sp	Field cricket
	Blattodea	Blattidae	*Blatta orientalis*	Oriental cockroach

Table 3: Relative abundance of Termite and Non-termite arthropods

Group	Order	Scientific name	Number of individual		Relative abundance (%)	
			Station 1	Station 2	Station 1	Station 2
Termites	Isoptera	*Odontermes badius*	165	201	30.61	36.48
		Macrotermes bellicosus	323	350	59.93	63.52
		Unidentified termites	51	-	9.46	0
			539	**551**	**100**	**100**
Non- termites Arthropods	Diptera	*Musca domestica*	31	-	16.40	0
	Diptera	*Anopheles gambiae*	9	-	4.76	0
	Hymenoptera	*Lasius* sp	49	21	25.93	13.29
	Spirostreptida	*Archispirostreptus* sp	14	7	7.41	4.43
	Hymenoptera	*Camponotonus* sp	22	-	11.64	0
	Araneae	*Missulena* sp	6	40	3.17	25.32
	Orthoptera	*Acheta* sp	7	16	3.70	10.13
	Orthoptera	*Chorthippus* sp	16	60	8.47	37.97
	Blattidea	*Blatta orientalis*	5	1	2.65	0.63
		Unidentified non termites Arthropods	30	13	15.87	8.23
			189	**158**	**100**	**100**

Table 4: Diversity indices for Termites and other Arthropods

Indices	Termites		Other Arthropods	
	Station 1	Station 2	Station 1	Station 2
Dominance D	0.46	0.54	0.15	0.24
Shannon *H*	0.89	0.66	2.06	1.59
Margalef (Species richness)	0.32	0.16	1.72	1.18

Table 5: Correlation of termite mound parameters with termite species in stations 1 and 2

Soil Parameters	Station 1			Station 2	
	Macrotermes bellicosus	***Odontermes badius***	**Unidentified termites**	***Macrotermes bellicosus***	***Odontermes badius***
T(°C)	0.542*	-0.465	0.342	0.675*	0.530*
pH	0.321	-0.123	0.231	-0.569*	0.259
Moisture content	0.428	-0.993*	0.602*	0.543*	0.907*
N	-0.547*	0.981*	-0.0488	0.118	0.629*
P	-0.497	0.999*	-0.538*	0.508*	0.889*
Mg	-0.738*	0.965*	-0.255	0.622*	0.944*
Cu	-0.995*	0.540*	0.459	-0.920*	0.987*
Na	-0.698*	0.978*	-0.310	0.605*	0.936*
K	-0.527*	0.820*	-0.509*	0.887*	0.997*
Mn	-0.552*	0.521*	-0.483	0.010	-0.524*
Fe	-0.812*	0.928*	-0.140	0.737*	0.984*

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

Table 6: Correlation of termite mound parameters with other arthropods species in station 1

Parameters	Mus	Ano	Las	Arc	Cam	Mis	Ach	Cho	Bla	Uni
T(°C)	-.034	-.358	.542*	-.453	-.501*	-.412	-.079	.329	.501*	-.037
Moisture content	.307	-.371	-.473	.862*	.970*	-.921*	.307	.602*	-.391	.921*
N	-.175	.982*	.588*	-.923*	-.795*	.859*	-.175	-.488	.512*	-.859*
P	-.233	.991*	.539*	-.899*	-.829*	.888*	-.233	-.538*	.461	-.888*
Mg	.076	.658*	.771*	.990*	-.618*	.704*	.076	-.255	.710*	-.704*
Cu	.924*	.540*	.999*	-.830*	.068*	.047	.724*	.459	.999*	-.047
Na	.018	.978*	.733*	-.980*	-.662*	.744*	.018	-.310	.668*	-.744*
K	-.199	.960*	.568*	-.914*	-.809*	.871*	-.199	-.509*	.491	-.871*
Mn	-.170	.335	.592*	-.925*	-.791*	.856*	-.170	-.483	.517*	-.856*
Fe	.192	.536*	.840*	-.981*	-.522*	.616*	.192	-.140	.787*	-.616*

mus – *Musca*, anop – *Anopheles*, Las – *Lasius*, Arc – *Archispirosteptus*, Cam – *Camponotus*, Mis – *Missulena*, Ach – *Acheta*, Cho – *Chorthippus*, Bla – *Blatta*, Uni – Unidentified termite arthropods.
*Correlation is significant at the 0.05 level (2-tailed)

Table 7: Correlation of termite mound parameters with other arthropods species in station 2

Soil Parameters	*Las*	*Arc*	*Mis*	*Ach*	*Cho*	*Bla*	*Uni*
N	-.639*	-951*	.512*	-.512*	.873*	-.588*	-.128
P	-.593*	-.999*	.461	-.461	.843*	-.539*	-.070
Mg	-.811*	-.965*	.710*	-.710*	.967*	-.771*	-.372
Cu	-.994*	-.540*	.999*	-.999*	.888*	-.999*	-.898*
Na	-.776*	-.978*	.668*	-.668*	.951*	-.733*	-.318
K	-.621*	.825*	.491	-.491	.861*	-.568*	-.105
Mn	-.644*	-.385	.517*	-.517*	.876*	-.592*	-.134
Fe	-.874*	-.928*	.787*	-.787*	.990*	-.840*	-.478
Moisture content	.529*	.993*	-.391	.391	-.799*	.473	-.007

Las – *Lasius* sp, Arc – *Archispirosteptus* sp, Mis – *Missulena* sp, Ach – *Acheta* sp, Cho – *Chorthippus* sp, Bla – *Blatta orientalis*, Uni – Unidentified termite arthropods.
*. Correlation is significant at the 0.05 level (2-tailed)

DISCUSSION

The result of the range of temperature which was significant could be said to be favourable for the survival of the termite species, as Wekhe *et al.* (2019) reported 20.8 - 25.2 °C for substerranean termite species in Port harcourt, Nigeria, and that they depend mostly on temperarture for foraging and build of mounds. According to Dahlsjo *et al.* (2014) termite and other arthropods species composition and abundnace depend on the temperature regimes of 20-30 °C, to carry out their activities, as high temperatures; assembly 30 °C above, tend to retard arthropods abundance and diversity.

The results of the internal pH of the mounds of the two study stations was acidic and not significant. The range falls within the range reported by Abe *et al.* (2009) (5.9-7.6), Susumu *et al* (2009) (5.4-7.6) and Wekhe *et al.* (2019) (5.3-6.0). According to Wekhe *et al.* (2019) the pH may not have affected the termite species abundance. However, it could be deduced that the pH result may have affected the composition and abundance of other arthropod species; *Musca domestica, Anopheles gambiae, Camponotonus* and *Blatta*, as expressed in the relative abundance results in station 2.

The high internal moisture content result of the mounds which was significant does not agree with Timothy and Corbin (2009) who reported 16.7 and Wekhe *et al.* (2019) (9.71-19.46). It could be deduced that the level of the moisture content may have affected the abundance of *Odontermes badius* and other arthropod species; *Archispirostreptus* sp, *Blatta orientalis*, *Missulena* and *Chorthippus* sp, in the University community, , and their ability to feed on available food material (Wekhe *et al.*, 2019). Dahlsjo *et al.* (2014) reported that the abundance and diversity of termites, and non-termite arthropods and its social behaviour is affected by moisture contents of the surrounding environment. However, from the correlation anyalsis it could also be deduced that nitrogen, phosphous, magnesium, copper, sodium and iron of the mound internal wall also affected he abundance of *Macrotermes bellicosus* and *Archispirostreptus, Blatta orientalis, Lasius* sp, *Missulena* sp, and *Chorthippus* sp in University of Uyo, Akwa Ibom State, Nigeria.

Two species of termites; *Odontermes badius* and *Macrotermes bellicosus*, were identified in the termite mounds with *Macrotermes bellicosus* the dominant termite species in the University community, but there were other unidentified termites species. The internal physicochemical parameters results of the mounds may have favoured the dominance of *Macrotermes bellicosus* in the Communtiy. This agrees with Aiki *et al.* (2013), who reported four species of termites in termite mounds within Zuru Local Government Area of Kebbi state, Nigeria. They further reported that *Macrotermes bellicosus* and *Odontermes badus* were the dominant termite species. Wekhe *et al* (2019) reported five species of termites in River State University Campus, River State, Nigeria, with *Macrotermes* sp as the dominant favoured by climatic factors and soil nutrient content.

The other arthropod species encountered during the study included housefly (*Musca domestica*), mosquito (*Anopheles gambiae*), black garden ant (*Lasius* sp), giant African millipede (*Archispirostretus* sp), black carpenter ant (*Camponotus sp*), field cricket (*Acheta sp*), spider (*Missulena sp*), acridid grasshopper (*Chorthippus sp*) and oriental cockroach (*Blatta orientalis*). Choosai *et al.* (2009) and Bartel *et al.* (2010) stated that the abundance and diversity of the termites and other arthropods may have been affected by anthropogenic factors such as cattle grazing and farm work in the main campus of the University of Uyo. Nevertheless, knowing the importance of termite and other arthropods species identified in this research study to adjacent soil and serving as food source to higher animals in the community, it is pertinent to protect termites mounds from human and animal attack.

CONCLUSION

The mound physiochemical parameters affected the abundance and diversity of termites and other arthropods in the mounds. The present of other arthropods in the termite mounds in Uyo, Akwa Ibom state, Nigeria, shows that termites do not exist alone in the mound.

REFERENCES

Abe, S. S., Yamamoto, S., Wakatsuki, T. (2009). Physicochemical and morphological properties of termite (*Macrotermes bellicosus*) mounds and surrounding pedons on a toposequence of an inland valley in the southern Guinea savanna zone of Nigeria. *Soil Science and Plant Nutrition*. 55:514–522.

Afolabi, S. G., Ezenwa, M. I. S and Dauda, A. (2014). Physical and Chemical Characteristics of Mound Materials and Surrounding Soils of Different Habitats of Two Termite Species in Minna, Nigeria. *Production Agriculture and Technology*. 10(2): 186-192.

Aiki, I. P., Majeed, Q., Adamu, T., Bandiya, H. M. and Suleiman, M. (2013). A Survey of Termites Species Found Within Zuru Local Government Area of Kebbi State, Nigeria. *International Journal of Applied Research and Technology*. 2(6): 169 – 173.

Association of Official Analytical Chemist (AOAC). (2010). Official Methods of Analysis of Association of Official Analytical Chemists. 18th Edition, Washington, DC.

Bartel, R. A., Haddaad, N. M. and Wright, J. P. (2010). Ecosystem engineers maintain a rare species of termites. *Oikes.* 119:883-890.

Bignell, D. E. and Eggleton P. (2002). Termites in ecosystems, p. 363−387. *In*: T. Abe; M. Higashi & D. E. Bignell (eds). Termites: Evolution, Sociality, Symbioses, Ecology**.** *Dordrecht.* Kluwer Academic Publishers, 466.

Cancello, E. M., Silva, R. R., Vasconcellos, A., Reis, Y. T. and Oliveira, L. M. (2014). Latitudinal variation in termite species richness and abundance along the Brazilian Atlantic Forest Hotspot. *Biotropica*. 46(4). 441-450.

Choosai, C., Mathieu, J., Hanboonsong, Y. and Jouquet, P. (2009). Termite mounds and dykes are biodiversity refuges in paddy fields in north-eastern Thailand, *Journal of Environmental Conservation*. 36: 71-79.

Constantino, R. (1999). An illustration key to Neotropical termite genera (Insecta: Isoptera) based primarily on soldiers. *Insect Systematics and Evolution.* 31: 463-472.

Dahlsjo, C. A. L., Parr, C. L., Malhi, Y., Meir, P., Eggleton, P. (2014). Describing termite assemblage structure in a Peruvian lowland tropical rain forest: A comparison of two alternative methods. *Insect Society*. 40-41.

Ekundayo, E.O. and Orhue, E. R. (2002). Properties of termite mounds soil in the Niger Delta region of Southern Nigeria. *J. Sci. Technol. Res*., 14: 15-21.

Glaciela, K., Julio, C. P., Jaime, A. A., Deise, C. S. and João, F.B. (2006). Termite Activity in Relation to Natural Grassland Soil Attributes. *Science and Agriculture.* 63 (6): 583-588.

Harvey M.S., Yen A. L., Milledge G.A. (1989): Worms to Wasps: An Illustrated Guide to Australia's Terrestrial Invertebrates. Melbourne, Oxford University Press: 201.

Hughes, W. O. (2008). Ancestral monogamy shows kin selection is key to the Evolution of Eusociality. *Science* 320:1213-1216.

Holt, J. A. and Lepage, M. (2002). Termites and soil properties, pp. 389–407. *In* T. Abe, D. E. Bignell and M. Higashi (eds.), Termites: Evolution, Sociality, Symbioses, Ecology. Kluwer Academic Publ., Dordrecht, NL.

Jones, D. T. and Eggleton, P. (2000). Sampling Termite Assemblages in Tropical Forests: Testing a Rapid Biodiversity Assessment Protocol. *Journal of Applied Ecology.* 37: 191–203.

Kambharnpati S. and Eggleton, P. (2000). Taxonomy and phylogeny of termites. In: Abe T,Bignell DE, Higashi M, Editors. *Termites: evolution, sociality, symbioses, ecology*. Kluwer Academic Publishers. 1-23.

Lefebvre, T., Chaline, N., Limousin, D., Dupont, S. and Bagneres, A. G. (2009). The phyllogeographic structure of an Island subspecies of termites *Reticulitermes lucifongus corsicus*. *BMC Evolutionary Biology* 8:38-43.

Levick, S. R., Asner, G. P., Kennedy-Bowdoin, T. and Knapp, D. E. (2010). The spatial extent of termite influences on herbivore browsing in an African savannah. Biological Conservation. 143: 2462-2467.

Malaka, S. L. (2016). *Insects and the Economy. Are Termites Devourers or Builders*? A Public Lecture. The Department of Zoology, Faculty of Science, University of Lagos, Akoka, Lagos, Nigeria. 105.

Millennium Ecosystem Assessment (MEA). (2005).Available:https//www.org/sites/defaults/PD

F/ecosystem…/MEA-A-Toolkit-pdf (Retrieved from May 26, 2020.)

Susumu, S. A., Sadahro, Y., Toshiyuki, W. (2009). Soil particle selection by mound – building termite *Macrotermes bellicosus* on a sandy loam soil catena in Nigerian tropical savanna. *Tropical Ecology*. 449-452

Tathiane, S.S., Carlos, E.G., Leila, S.L, Helga, D.A., Joao, H.M., Manoel, R.A and Teresa, T.G. (2009). Chemical, physical and micromorphological properties of termite mounds and adjacent soils along a toposequence in Zona da Mata, Minas Gerais State, Brazil. *Catena*. 76: 107–113.

Timothy, M. J., Corbin, C. C. (2009). Effect of cellulose concentration on the feeding preferences of the termite *Reticulitermes flavipes* (Isoptera: Rhinotermitidae). *Sociobiology*. 1(53):3

Wekhe, C., Ugbomeh, A. P., Ebere, N. and Bawo, D. D. S. (2019). Subterranean Termites of University Environment in Port Harcourt, Nigeria. *Asian Journal of Biology*. 8(1): 1-10.