CHARACTERISTICS OF TERMITE MOUND SOILS WITHIN THE UNIVERSITY OF ABUJA, SOUTHERN GUINEA SAVANNAH OF NIGERIA

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ABSTRACT

Termites engage in strange activities that have a significant impact on soil ecology. Within the University of Abuja community, a study was piloted to evaluate the chemical, physical, and some hydrological characteristics of termite mounds. Five different areas with visible termite mounds were identified and geo-referenced using a GPS device. An auger was used to sample termite mounds from the top of each of these previously noted locations at a 10 cm depth. Similarly, control soil was sampled at a distance of 1.5 m from each termite mound. From each point, three (3) samples were taken to form a composite sample. Subsampled soils (1 kg) were prepared, air dried, and used to assess the particle size distribution, hydrological, and chemical parameters. The generated data was subjected to analysis of variance (ANOVA) using the statistical application Minitab 17. The Fisher LSD Method was employed to compare pairwise means at a 0.05 level of significance. Across locations, the particle size and other parameters assessed did not differ significantly. The presence of termite mounds significantly affected the grain size distribution and hydrological parameters. The mean clay content of termite mound soil was significantly higher than that of adjacent soils. The permanent wilting point (PWP) of 14.06%, field capacity (FC) of 22.46%, and available water of 0.09 were significantly higher in termite mound soil than in adjacent soils, which had 11.12%, 18.06%, and 0.07, respectively. Combining termite mound soils with other soils can help stabilize the soil's structure and help it retain moisture, which increases the amount of water and nutrients that are accessible for crop growth.

Keywords: Biodiversity, soil functions, ecological engineers, climate change, Southern Guinea Savanna,

INTRODUCTION

Termites, like other ecosystem engineers, play key natural architectural and engineering roles as they influence a large number of important ecosystem processes (Lavelle et al*.,* 2016). The activities of ecological engineers could improve soil nutrient cycling, soil porosity (soil air and soil water), create macropores, and tunnels for enhanced soil water movement (Jouquet *et al*., 2015, Subi and Sheela 2020). For the development of mounds, termites excavate and decompose organic resources, which enhance the properties of the soil. They are of great importance in soil fertility maintenance. Termites create favourable microhabitats and form symbiotic associations with other organisms. This aids in the creation of abundant and accessible nutrients through the ingestion of organic materials and redistribution of minerals (Ali *et al*., 2013).

Termite mounds are distinct morphological features built by termites in most tropical environments (Jouquet *et al*., 2015). Mounds are formed by combing organic materials like clay, termite faeces, and saliva together with other secretions. Termite mounds are stable and resistant to erosion, rain, and predators (Mujinya *et al*. 2013; Jouquet *et al*. 2015). These mounds may be affected by different climatic conditions, vegetation, soil types, organic materials, landscape characteristics, and water depths (Ahmed *et al*., 2019).

In comparison to the soils around them, the mounds of the majority of termite species are significantly richer in clay, carbon, total nitrogen, calcium, potassium, and magnesium, making such an environment ideal for microorganisms (Nithyatharani and Kavitha 2018). Nevertheless, numerous reports on the impact of termite mounds on soil properties have been documented, with clay, for instance, ranging from high (Adhikary *et al*., 2016), comparable (Levick *et al*., 2010) and to some extent low (Ackerman *et al.*, 2007) as compared to the adjacent soils. Fungus-growing termite species, in particular, select fine-sized soil fractions for mound construction. They utilize materials from the deeper soil layers, which contain more clay and less SOM.

When compared to surrounding soils, mound soils have a significant organic C and total N content. This was associated with either the selection of clay-enriched small aggregates by termites or the assessment of material from a lower SOM content layer yet a higher clay content (Chen *et al*., 2018, Jouquet *et al*., 2015). The revelation of Shanbhag *et al*. (2017) showed that when the nearby soil had a C org content of less than 1.4 %, termite mounds tended to be richer in C org, but they became depleted in C org at concentrations greater than 1.4 %. Also, the soil carbon content of termite mounds could depend on the concerned termite species, local/regional soil type, soil properties, and related microbial processes (Jouquet et al., 2015).

Termites are able to draw water from the soil profile to great depths, maintain extraordinarily high levels of moisture in their mounds, and modify the spatial circulation of water through their built environment (Jouquet et al., 2011). Through the facilitation of upward movement of water, nutrient availability as well as soil moisture regulation are improved. Thus, this could enhance the soil's capacity to hold water, thereby ameliorating the challenges of moisture stress and allowing the restoration of degraded ecological systems through the mitigation of the consequences of climate change. There is thus a need for more site-specific assessment of termite mediated alteration of soil quality. This study aimed to assess the chemical, physical, and hydrological characteristics of termite mound soils.

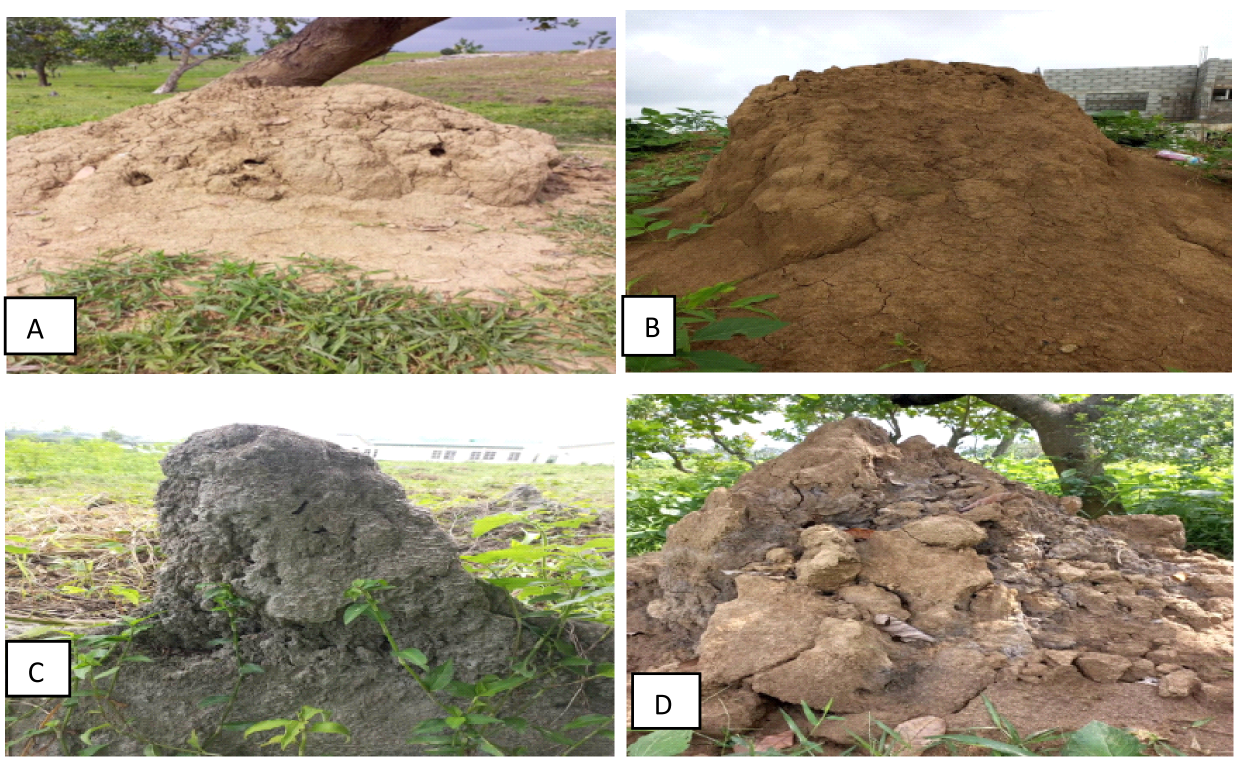
MATERIALS AND METHODS

Experimental site description

The investigation was carried out within the premises of the University of Abuja, in the Federal Capital Territory (FCT) Nigeria, geographically situated between latitudes 08° 51' and 09° 37' North and longitudes 007° 20' and 007° 51' East. This location is within the Nigerian Southern Guinean Savanna zone. Its climate is tropical humid, characterized by two seasons; the rainy season (April to Oct) and the dry season (November to March). The soils of this environment are mostly Alfisols dominated by plinthite layers. The soils of Abuja are predominantly underlain by basement complex rocks, from which a range of soils are produced (Bennett *et al*., 1979). The soils are usually shallow and mostly sandy in composition. The two main seasons in FCT are a scorching dry season and a hot, humid, rainy season. The Territory's greatest annual rainfall is around 1632 mm, with September seeing the highest amount. During the dry season, relative humidity can rise to as high as 20% in the afternoons at high elevations in the north and to approximately 30% in the far south. From November to April, the dry season is in full swing. The temperature varies between 30.4 °C and 35.1 °C, with the greatest temperature occurring in March.

Reconnaissance Soil Survey and Soil sampling.

Prior to determining the extent of termite mound coverage at the research location, a reconnaissance survey of the region was conducted. Five different areas with visible termite mounds were located in preparation for samples collection and carefully geo-referenced using a GPS device. Some of the termites mounds within the University premises are as shown in Plate 1 below. Soil samples from these previously noted termite mound locations were taken. An auger was used to extract a soil sample from each of the detected mounds at 10 cm depth. Each of the identified mounds had a soil sample collected from it using an auger at 10 cm depth. Similarly, samples were taken for a control soil at 1.5 m from the base of each termite mound. At each stage, three samples were gathered, combined to create a composite sample, and then samples weighing about one kilogram were put into a well labeled bag according to locations and land use (Table 1) and taken to laboratory.



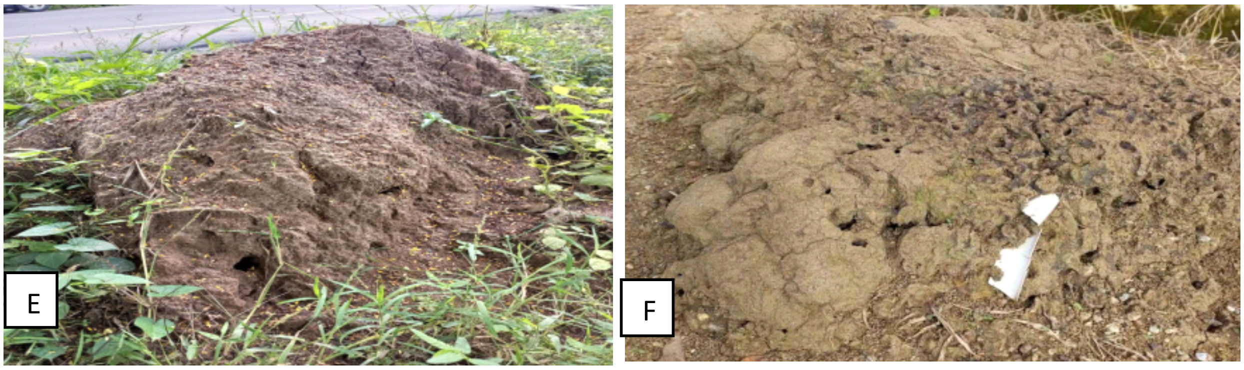


Plate 1: Photographs of of Termite Mounds within the University environment.

Table 1: Description of Sampling locations

Area	Coordinate	Elevation	Description and Land Use
1.	8.9676⁰N	246m	Land Use = Arable land – (sorghum, maize)
	7.1738⁰E		Geology = Basement complex
			Parent material = Granite and migmatites
2.	8.9751⁰N	279m	Land Use = Arable land – (sorghum, maize)
	7.1785⁰E		Geology = Basement complex
			Parent material = migmatites, schists etc.
3.	8.9769⁰N	263m	Land Use = Forestry Reserved Area
	7.1691⁰E		Geology = Basement complex
			Parent material = Granite and migmatites
4.	8.9791⁰N	276m	Geology = Basement complex
	7.1728⁰E		Parent material = Granite
5.	8.9833⁰N	275m	Land Use = Road side (fallow portion)
	7.1775⁰E		Geology = Basement complex
			Parent material = Granite and migmatites

1=Teaching and Research Farm, 2= Old Girls' hostel, 3= Forestry Reserved Area, 4= College of health Sciences, 5= Faculty of Agriculture

Sample Preparation and Laboratory Procedure

To eliminate larger than 2 mm gravel particles, the samples were run through a 2mm filter after air drying. Particle size distribution analysis utilizing the hydrometer method was done on the fine earth component (Gee and Bauder, 1986). With the help of the USDA textural triangle, the soil textures were identified.

The SPAW Hydrology software (USDA Natural Resource Conservation Services) was used to simulate, hydrological properties as Permanent wilting point, Field capacity, saturated hydraulic conductivity (SHC) and bulk density were evaluated. Total porosity was calculated using the bulk density data and the assumption that the average particle density for mineral soils is 2.65 g/m3.

According to IITA (1982), soil pH was measured at a 1:2.5 soil and water suspension using a glass electrode pH meter. The macro Kjeldhal method (Bremmer, 1962) was used to measure total nitrogen. Nelson and Sommer (1982) wet oxidation procedure was utilized to measure organic carbon. The cations were measured using Atomic Absorption Spectrophotometer. The Bray -1 method, as described by Udoh *et al.,* (2009), was used to determine the amount of available phosphorus. The CEC together with exchangeable bases were established in accordance with Udoh *et al.,* (2009). The total of K+, Ca2+, Mg2+, Al3+, and H+ was computed as the effective cation exchange capacity (ECEC). Al3+ divided by the ECEC was used to compute aluminum saturation. K+, Ca2+, and Mg2+ were added together to determine base saturation.

3.4 Statistical Analysis

Using the Minitab 17 statistical program, an analysis of variance was performed on the collected data. The Fisher LSD Method was used to compare pairwise means, and a significance level of 0.05 was used.

ARESULTS AND DISCUSSION

Particle Size Fractions across some areas within University of Abuja.

Across areas, the spread of particle sizes did not differ significantly (Table 2). Sand content across locations ranged from 692-802 g/kg. The clay content ranged between 155 and 205 g/kg.

Table 2. Mean values of the particle sizes along sampled locations

Location	Sand	Silt	Clay
	g/kg		
1	703	92	205
2	802	43	155
3	692	104	204
4	711	115	174
5	712	84	204
P value	0.731	0.733	0.737
Sdev	88	54	46

1=Teaching and Research Farm, 2= Old Girls' hostel, 3= Forestry Reserved Area, 4= College of Health Sciences, 5= Faculty of Agriculture

Particle Size Distribution (PSD) as affected by termite mound

The texture classes for the sampled termite mounds were predominantly sandy clay loam, while adjacent soils were predominantly sandy loam (Table 3). The particle size fraction was significantly ($p \leq 0.05$) affected by the presence of termite mounds (Table 4). A higher sand content (771.8 g/kg) was found in adjacent soil as against a mean lower value of 672.2 g/kg in termite mound soil. Similarly, termite mound soil had a significantly higher mean clay content of 215g/kg as against the value of 161.6 g/kg as found in the adjacent soils. This result was in consonance with the report of Abe *et al.,* (2014) that termite mound soils were higher in clay content and relatively moderate sand. The typical explanations for this phenomenon are the termites' utilization of subsoil in nest construction or fine particle selection.

According to Oku *et al.* 2020, soil physical conditions such as the particle size fraction are the framework on which other soil properties rely. The organic matter content and particle size fraction have impact on the soil's ability to retain water. Within the adjacent soil, the particle size distribution shows that the soil is predominantly sand (> 70%), hence the specific surface area is small. This predominance of sand in the soil suggests that the soil's aggregate quality is low (Oku and Babalola, 2009).

Table 3. Particle sizes distribution as influenced by termite 's activities and non-termite activity soil

	Termite Mound Soil (g/kg)					Adjacent Soil (g/kg)				
	1	2	3	4	5	1	2	3	4	5
Sand	693	772	672	592	652	713	832	712	830	772
Silt	60	61	121	181	121	124	26	87	49	47
Clay	247	167	207	227	227	163	142	201	121	181
Texture	Sandy clay loam	Sandy loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy loam	Sandy loam	Sandy loam	Loamy sand	Sandy loam

1=Teaching and Research Farm, 2= Old Girls' hostel, 3= Forestry Reserved Area, 4= College of Health Sciences, 5= Faculty of Agriculture

Hydrological characteristics of termite mound soil.

The hydrologic properties (Table 4) varied significantly ($p \leq 0.05$) among sampling points. The termite mound soil had a significantly higher Permanent Wilting Point (14.06%), Field Capacity (22.46%), and Available water (0.09), compared to 11.12%, 18.06%, and 0.07 in the adjacent soils. This result corroborates the report of Jouquet *et al.* (2011) on termites' ability to access water deep in the soil profile and also maintain high levels of moisture in their mounds. Trees around termite colonies in dry tropical savannas have been reported to retain their all-year greenness as the termite colonies are known to sustain water long into the dry season (Ali *et al*., 2013).

In contrast to the 16.3 mm/hr and 41.2 percent observed in termite mound soil, the mean saturated hydraulic conductivity (35.1 mm/hr) and porosity (42.6 percent) were significantly higher in nearby soil. This corroborates the report of Bera *et al.,* (2020), where a lower value of porosity was found in mound soil than in the adjacent soil. However, the total porosity of soils from both sampling points was within a satisfactory level (41-44%) for tropical soils, as reported by Oku and Edicha (2009). Higher saturated hydraulic conductivity (SHC) in soil has been associated with higher sand content, which was found among adjacent soils. Given that the majority of these soils came from agricultural areas, this may be attributed to how the land was managed.

Table 4. Particle size fraction and hydrological characteristics of termite mound soil

Sample point	Sand (g/kg)	Silt (g/kg)	Clay (g/kg)	Permanent wilting Point (%)	Field capacity (%)	Saturated hydraulic conductivity (SHC) (mm/hr)	Available water	Bulk density (g/cm3)	Porosity (%)
TMS	676.2b	108.8a	215.0a	14.06a	22.46a	16.32b	0.09a	1.56a	41.2b
AS	771.8a	66.6a	161.6b	11.12b	18.06b	35.1a	0.07b	1.52a	42.6a
P value	0.042	0.177	0.026	0.032	0.033	0.028	0.046	0.068	0.034

TMS= Termite mound soil, AS= Adjacent soil

As shown in tables 5a and 5b, chemical characteristics of the assessed soil were not significantly affected by sampling points. This might have happened as a result of the termite mound's effects on the surrounding soils. However, soil pH levels (Table 5a) in termite mounds were slightly higher (7.5 (slightly alkaline for pH in H_2O) and 5.7 in KCl) than in adjacent soils, 7.1 and 5.5, respectively. According to Thuyne and Verrecchia (2021), increased pH in termite mounds could be caused by alkaline earth cation saturation status, lowering of zero charge points, and microbiological activity. Soil pH is an important property that influences other soil properties such as nutrient availability, solubility, and mobility of other materials within the soil, as reported by Evans *et al.,* (2011).

The saturated electrical conductivity was high at 0.36 dS/m in termite mounds (Chude et al., 2011), while that of adjacent soil was low at 0.15 dS/m. High values of EC in the termite mound soils can be attributed to the effects of termite activities in digesting different plant materials that may have properties that encourage a higher concentration of soluble salts in the soil. The level of organic carbon was very high (>20 g/kg) for both sampling points.

Similarly, soil organic matter was 52.00 g/kg in the termite mound while that of the adjacent soils was 61.28 g/kg. Abe et al. (2014) had earlier reported a higher organic matter level in adjacent areas than the termitaria soils, which was attributed to biocycling of nutrients in the soils. The high organic matter level in the soil from adjacent areas may be subject to losses arising from plant uptake and leaching. Ali *et al*., (2013) attested that soils around termite mounds have an enormous increase in fertility due to the higher nutrient status of materials eroded from mound surfaces.

Table 5a. Soil pH and organic carbon content of termite mound soil.

Sample point	pH (H2O)	pH (KCl)	EC dS/m	OC	OM g/kg
TMS	7.50	5.70	0.36	30.10	52.00
AS	7.10	5.50	0.15	35.44	61.28
P value	0.07	0.69	0.19	0.18	0.18
SDev	0.28	0.74	0.23	5.74	9.92

Table 5b. Some chemical characteristics of termite mound soil.

Sample point	TN g/kg	AP mg/kg	E.Al Cmol/kg	Ca Cmol/kg	Mg Cmol/kg	K Cmol/kg	Na Cmol/kg	EA	ECEC	B.Sat g/kg
TMS	1.26	29.34	0.66	6.84	6.72	0.06	0.03	1.40	16.30	912.00
AS	1.48	28.12	0.62	7.38	7.64	0.08	0.02	1.20	15.10	919.06
P value	0.21	0.82	0.80	0.56	0.34	0.79	0.21	0.19	0.53	0.65
SDev	0.26	7.97	0.27	1.39	1.43	0.09	0.02	0.19	2.75	23.42

The effect of sampling points on soil hydrological properties varied substantially among locations (Fig.1-3). Available water, wilting point, and field capacity of Termite Mound Soil (TMS) were higher than those of adjacent soil (AS) to varied degrees across locations. The percentage differences between TMS and AS across locations ranged from 0 to 40% for available water; 1.5% to 38.5% for wilting point; and 0.5% to 38.9% for field capacity, respectively.

However, in Fig 2, the porosity and SHC of TMS were, to varying degrees, lower than those of AS. The percentage differences between AS and TMS ranged from 22% to 77.5% for SHC and 0% to 2% for porosity, respectively. Thus, the hydrological properties of the assessed termite mound, such as wilting points, field capacity, available water, porosity, and SHC differed across locations. French and Ahmed (2010) stressed that species, climate, soil, and land use may have an impact on termite activity, which may have a significant impact on the dynamics of the immediate soil environment.

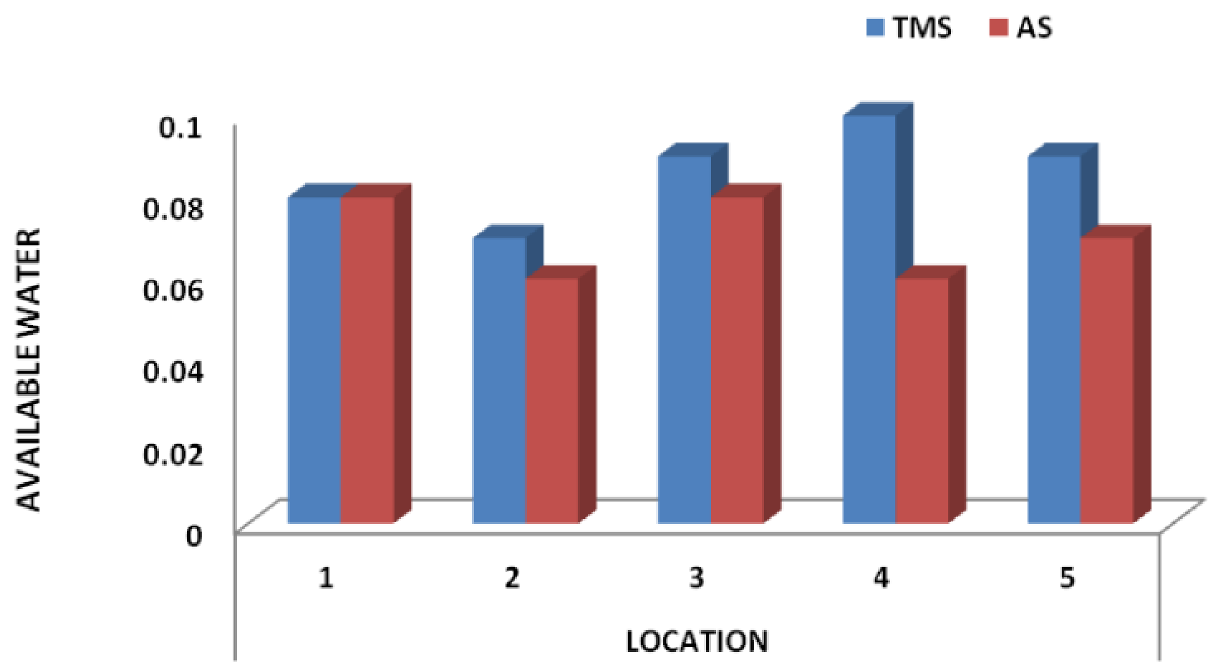


Fig 1. Available water of termite mound soil across assessed locations

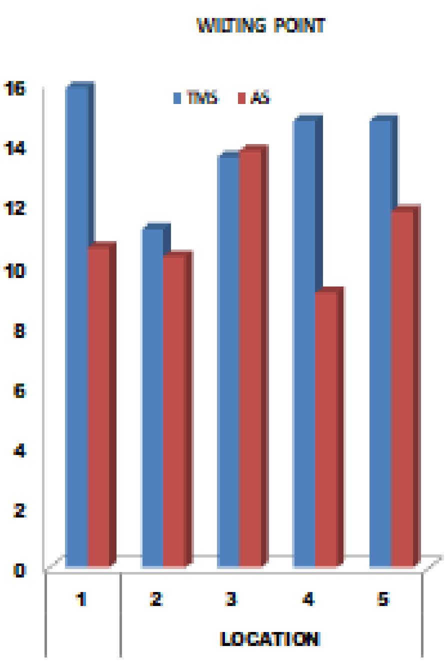


Fig.2a. Wilting point of termite mound soil across assessed locations

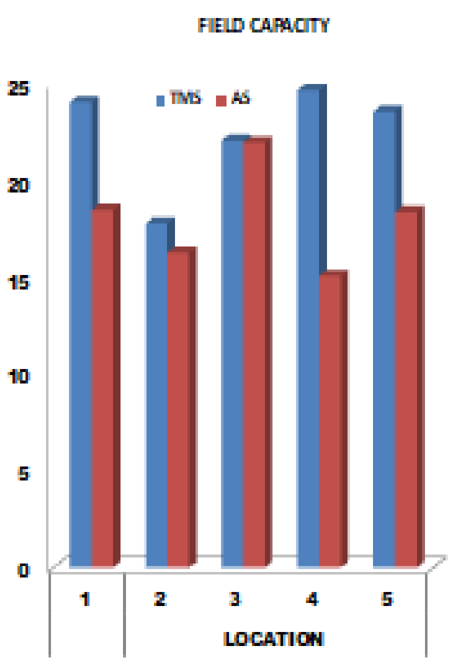


Fig.2a. Field capacity of termite mound soil across assessed locations

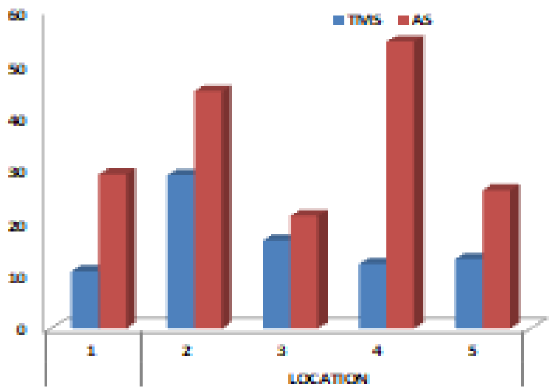


Fig.3a. Saturated hydraulic conductivity of termite mound soil across assessed locations

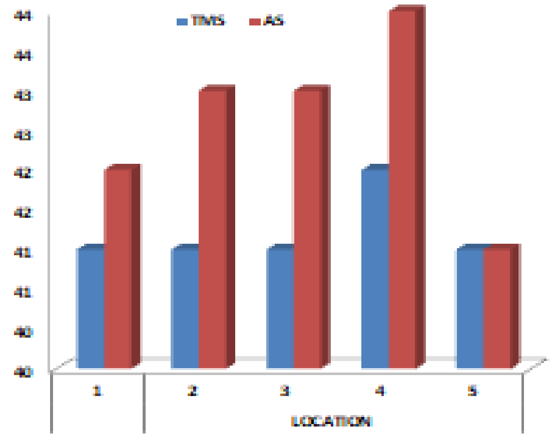


Fig.3a. Porosity of termite mound soil across assessed locations

Conclusion:

The particle size fraction of the studied termite site was suggestively affected by the presence of a termite mound. Sand fraction was low (672.2 g/kg) in mound soil compared to (771.8 g/kg) in adjacent soil. The texture class for these termite mounds was predominantly sandy clay loam, while adjacent soils were mostly sandy loam. Similarly, termite mound soil had a significantly higher mean clay content of 215g/kg as against the value of 161.6 g/kg as found in the adjacent soils. These particle fractions influenced the hydrological characteristics; while wilting points, available water and field capacity increased under termite mounds, the porosity and SHC declined. For most of the assessed soil chemical characteristics, no substantial difference was observed between sampling points (termite mounds and adjacent soils). The observed increase in nutrient levels of soils surrounding termite mounds was attributed to the erosion of high-nutrient materials from mound surfaces.

References

Abe, S.S and T. Wakatsuki, (2014). The influence of the mound-building termite (Macrotermes bellicosus) on soil clay mineralogy. *Tropics,* 22(4), 169-177.

Ackerman I. L., Teixeira, W. G., Riha, S. J., Lehmann J. and E. C.M. Fernandes (2007). The impact of mound-building termites on surface soil properties in a secondary forest of Central Amazonia. *Applied Soil Ecology*, 37(3), 267-276.

Adhikary, N., Erens, H., Weemaels, L., Deweer, E., Mees, F., Mujinya, B.B., Baert, G., Boeckx, P. and E. V. Ranst, (2016). *Communications in Soil Science and Plant Analysis*, 47(9), 1089-1100.

Ahmed, J. B., Pradhan, B., Mansor, S., Tongjura, J. D. C and B. Yusuf, (2019). Multi-criteria evaluation of suitable sites for termite mounds construction in a tropical lowland. *Catena*, 178, 359-371.

Ali I. G., Sheridan, G., John R. French, J and B. M. Ahmed, (2013). Ecological Benefits of Termite Soil Interaction and Microbial Symbiosis in the Soil Ecosystem. *Journal of Earth Sciences and Geotechnical Engineering*, 3 (4), 63-85.

Bennett, J.G., Rains, A.B., Gosen, P.N., Howard, W.S., Hutchineon, A.A., Kerr, W.B., Mansfield, J.E., Rackhan, L.R. and R.R. Innes, (1979). Land resources of central

Nigeria. Agric. Dev. Possibilities. The Kaduna Plains. LRD, Tolworth Tower, Survey, England. 58: 130.

Bera D., S. Bera and N.D Chatterjee (2020). Termite mound soil properties in West Bengal, India Geoderma Regional 22.

Chen, C., Liu, W., Wu, J., and X. Jiang, (2018). Spatio-temporal variations of carbon and nitrogen in biogenic structures of two fungus-growing termites (M. annandalei and O. yunnanensis) in the Xishuangbanna region. *Soil Biology and Biochemistry,* 117, 125-134.

Evans T. A., Dawes, T. Z. , Ward, P. R. and N. Lo, (2011). Ants and termites increase crop yield in a dry climate *Nature Communications* 2.262

French J. R. J. and B. M. Ahmed (2010). The challenge of biomimetic design for carbon neutral buildings using termite engineering. *Insect science* 17:154-162

Gee, G.N and J.W. Bauder, (1986) Particle size distribution. p 383–411. In: A Klute (ed.). 2nd ed. Methods of Soil Analysis Part 1. Physical and Mineralogical Methods. Madison, Wisconsin.

Jouquet P., Guilleux, N., Shanbhag, R. R., and S. Subramanian (2015). Influence of soil type on the properties of termite mound nests in Southern India. *Applied Soil Ecology*, 96, 282-287.

Lavelle, P., S. Alister, B., Manuel, B., George, D., Thibaud, G., Michel, J.J., José, M., Doyle, M., Jérôme, V and A, Z. Elena (2016). Ecosystem Engineers in a Self-organized Soil. *Soil Science,* 181 (3/4), 91-109.

Levick, S.R., Asner, G.P., Chadwick, O.A., Khomo, L.M., Rogers, K.H., Hartshorn, A.S., Kennedy-Bowdoin, T., and D.E. Knapp (2010). Regional insight into savanna 14 hydrogeomorphology from termite mounds. *Nature Communication*. 1, 1–7.

Seetapong, N., Chulok, S and V Thongkhong (2021). Physical properties of termite mound soil in para rubber plantation of southern border provinces Siam Physics Congress (SPC) 2021 Journal of Physics: Conference Series 1719.

Subi S and A. Merline Sheela, (2020). Review on Termite Mound Soil Characteristics and Agricultural Importance. *Journal of Agriculture and Ecology Research International*, 21(7), 1-12.

Thuyne J. V and E.P. Verrecchia (2021). Impacts of fungus-growing termites on surficial geology parameters: A review. *Earth-Science Reviews*, 223.

Mujinya, B., Mees, F.and H. Erens (2013). Clay composition and properties in termite mounds of the Lubumbashi area, DR Congo. *Geoderma*,192,304–315.

Nithyatharani, R and U.S. Kavitha (2018). Termite soil as bio-Indicator of soil fertility. *International Journal for Research in Applied Science and Engineering Technology* 6:659–61

Nelson, D.W. and L.E. Sommer, (1982). Organic carbon. Methods of soil analysis. Part 2. Agronomy Monograph9. Agronomy Society of America, Madison. 570 – 571.

Oku, E.E., Emmanuel, S.A., Odoh, N.C. and B.I. Musa (2020). Soil physical fertility status and management prescription for soil sustaining farms and ranches in Abuja, Nigeria. *Journal of Environmental and Agricultural Sciences*. 22(1), 57-63

Oku E.E. and J.A. Edicha (2009).The physical properties of some soil profiles and management of an erosion prone soil in southwestern Nigeria. *Journal of Agriculture, Forestry and the Social Sciences*, 7 (1), 180-190.

Oku, E.E and O. Babalola (2009). Effects of down slope distance on primary particle size fraction and physical parameters in erosion prone southwestern Nigeria. *Journal of Soil and Water Conservation* 8(2): 21 – 24.

Shanbhag, R. R., Kabbaj, M., Sundararaj, R. and P. Jouquet (2017). Rainfall and soil properties influence termite mound abundance and height: A case study with Odontotermes obesus (Macrotermitinae) mounds in the Indian Western Ghats forests. *Applied Soil Ecology*, 111: 33-38.

Udo, E.J., T.O. Ibia, J.A. Ogunwale, A.O. Ano, and I. E. Esu (2009). Manual of soil, plant and water analysis. Lagos: Sibon Books, Publishers Limited., Nigeria.p: 183.