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EFFECT OF TERMITARIUM PRESENCE ON THE PHYSICOCHEMICAL AND MICROBIAL QUALITIES OF SURROUNDING SOIL

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Abstract

Although, termite activities are traditionally believed to pose negative impact on agroecosystem and forestry resources, studies have shown that their nests are rich in nutrients and may be a potential source of soil enrichment. We assessed the impact of two termitaria on the qualities of their surrounding soils. Termitarium samples and samples of soil taken from increasing distances from the termitaria were assessed for relative physicochemical and microbial qualities, using standard procedures. Water holding capacity increased significantly ($p<0.01$) with distance from the termitaria. Conversely, bulk density decreased significantly ($p<0.01$) with distance from the termitaria. Moisture, pH and electrical conductivity were significantly higher ($p<0.01$) in soil at one metre from the termitaria. Soil at two metres from the termitaria had the least and significant ($p<0.01$) pH and electrical conductivity of 7.036±0.17 and 526.22±218.02 mS/cm, respectively. Total organic carbon was higher in the surrounding soil, relative to termitarium soil. Soil at one meter from the termitaria had significantly higher ($p<0.05$) chloride, total organic carbon and magnesium of 49.61±11.02 mg/kg, 0.59±0.20 % and 84.90±9.70 mg/kg, respectively. Termitarium soil had significantly lower ($p<0.05$) total bacteria (119.33±33.75 × 10 CFU/g) and total fungi (34.11±4.63 × 10 CFU/g), than the surrounding soil. Total actinomycetes count was higher in termitarium soil than surrounding soil. The improved physicochemical and nutrient qualities of surrounding soil must have resulted from deposition of soil materials from the termitaria. However, we recommend further studies to establish the long-term effects of termitaria on the surrounding plant and animal biodiversity.

Keywords: Organic matter, soil minerals, soil nutrients, termites.

Introduction

Soil is the topmost layer of the earth crust that is composed of minerals, organic matter, air and water. Soil is one of the most important resources on earth, serving many functions; it serves as reservoir for many minerals and gases, it provides nutrients and anchorage for plants and moderates earth's temperature, it filters and decomposes pollutants (Balestrini *et al.*, 2015; Subi and Sheela, 2020). Soil is one the most exploited matrix on earth, and yet the least understood (Balestrini *et al.*, 2015). A proper understanding of soil structure and ecosystem functioning is crucial to soil maintenance, environmental stability and conservation of terrestrial biodiversity.

Termites are one of the most successful groups of eusocial insects that are traditionally believed to pose negative impact on agroecosystem and forestry resources, due to their feeding habit which affects forest products and manmade structures (Bignell *et al.*, 2011; Ocko *et al.*, 2019). However, the numerous beneficial impacts of termites on soil functioning and health have received relatively less attention.

Researches on termites have revealed that they play a key role in important biogeochemical soil processes, such as redistribution of soil matrix, methanogenesis, nitrogen fixation, acetogenesis and nutrient circulation (Dawes, 2010;
Subi and Sheela, 2020). In addition, of the 2,500 taxonomically characterised termite species, only two to ten percent have been recognised to have significant negative impacts on humans (Deke *et al.*, 2016).

Termites influence soil functionality via formation of incredibly strong earthen structures known as termite mounds or termitaria (Lima *et al.*, 2018; Subi and Sheela, 2020). A termitarium is, often, an elaborate underground and aboveground structure that contains series of tunnels and pores which protect termite colonies (Ocko *et al.*, 2019). Termitaria are constructed mainly from fine subsoil materials, preferentially selected by termites from surrounding soil, mixed and cemented with saliva, excreta, and other secretions (Maduakor and Onyeanuforo, 1995; Obi and Ogunkule, 2009). The

soil particles of termitaria are so compacted, that they are very rigid with moderate porosity and high water holding capacity (Ocko *et al*., 2019). Termitaria have been reported to possess improved physical properties, rich microbial mass and high chemical composition (Obi and Ogunkule, 2009). Some chemical properties, such as extractable bases, organic matter, carbon, phosphorus, nitrogen, cation exchange capacity (CEC) are reportedly higher in termitaria than in surrounding top and subsoil (Maduakor and Onyeanuforo, 1995; Ocko *et al.* 2019). Humidity, moderate temperature and organic matter in pores and tunnels of termite mounds are within the range that allows microbial communities to flourish (Obi and Ogunkule, 2009).

Termitaria have been found to impact their surrounding soils with minerals, organic matter and other properties that are associated with soil quality (Fall *et al.*, 2001; Obi *et al.*, 2019; Subi and Sheela, 2020). Termite mounds are sometimes broken and eroded, and as a result, large volumes of both mineral and organic components of the soil are vertically and laterally transferred to surrounding soil (Obi and Ogunkule, 2009; Jouquet *et al*., 2011). Since research attentions are focused more on the physicochemical impacts of termitarium, this present study aimed to assesses the relative physicochemical and microbial properties of termitaria and their surrounding soils.

Materials and methods

Description of sampling location

This study was conducted in the University of Lagos, Akoka, Yaba, Lagos, Nigeria. Two termitaria in two different locations within the university campus were sampled for this study (Figure 1). The two sampled termitaria are shown side-by-side in Figure 2.

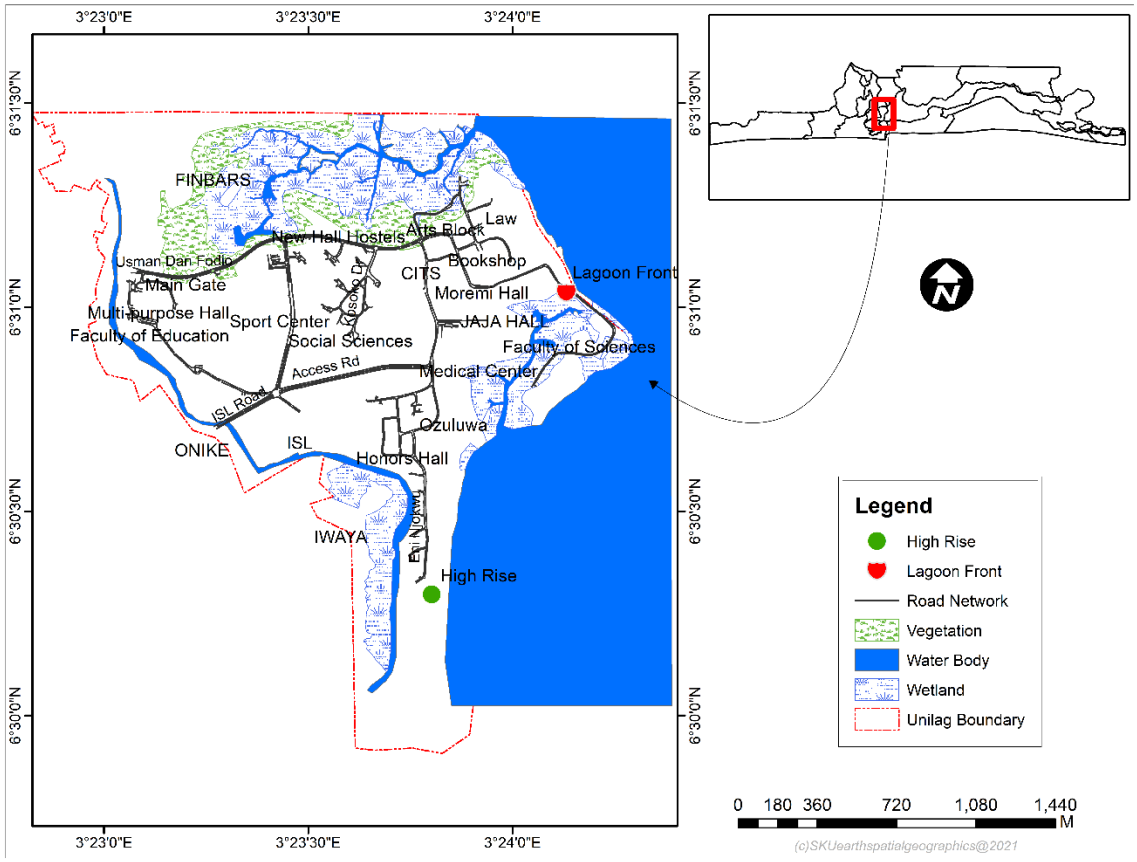

Figure 2: Map of Lagos State, Nigeria (top right) showing sampled termitarium locations in the University of Lagos (left).

Figure 2: Sampled termitaria

Collection of samples

Termitarium soil and surrounding soil samples were taken from increasing distances from each termitarium. A total of nine (9) soil samples were collected from each termitarium and its surrounding soil. A sample was taken at a point on the termitarium, and another two from the surrounding soil, at one and two metres away from the base of the termitarium, all in a straight line direction (Figure 3). This was replicated at two other points round each termitarium. The soil samples were thoroughly homogenised, air dried for one week, and sieved through a 2-mm mesh sieve. They were then packed into sterile plastic bags and kept in aseptic conditions.

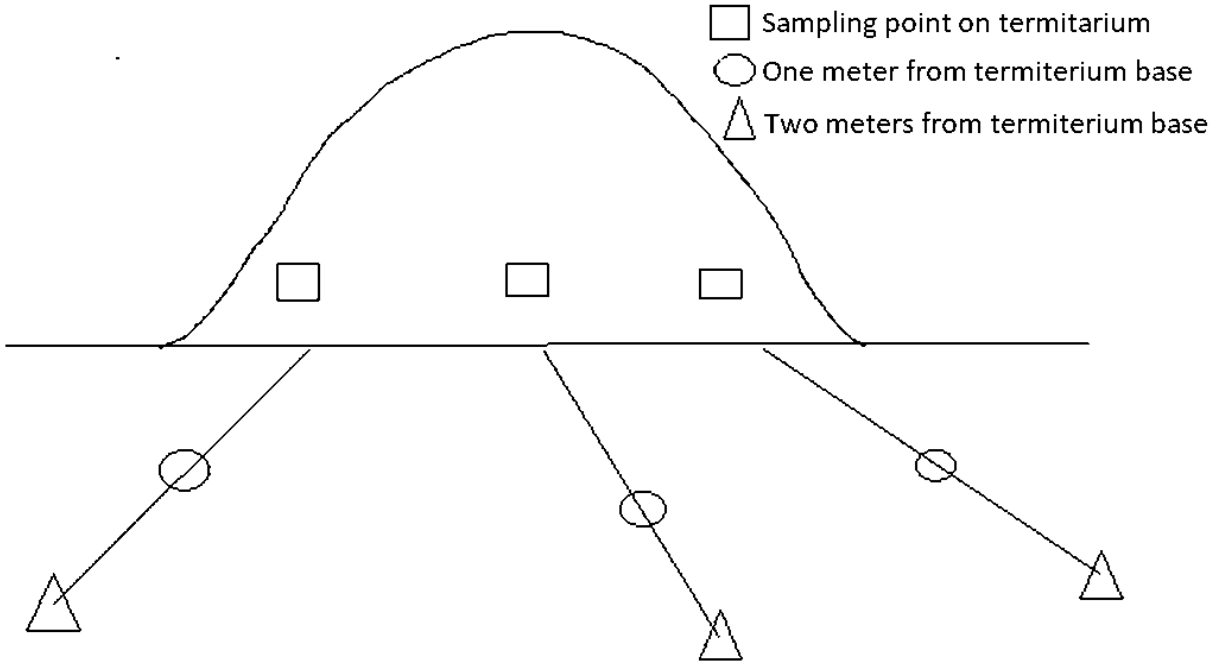

Figure 3: Graphical illustration of sample collection on the termitarium and surrounding soil.

Determination of physicochemical properties of soil samples

The soil samples were assessed for physicochemical properties using standard procedures. Soil pH was determined according to the standard procedures described by Pravin *et al.* (2014). Soil bulk density was determined by gravimetric method (Omofunmi and Oladipupo, 2018). Water holding capacity of soil samples was determined by 'Droplet Counting Method' as described by Brischke and Wegener (2019). Electrical conductivity of soil samples was determined following the procedures adapted from Pravin *et al.* (2014). The moisture content of the soil was determined according to the procedure describe by American Standard of Testing Method (ASTM) (2019). Exchangeable nitrate in soil samples was measured using the direct method described by Radojevic and Bashkin (1999).

Soil total nitrogen was evaluated using Kjeldahl method adapted from Jackson (1958). The total organic matter of the sample was estimated by using the method adapted from Chopra and Kanwar (1976). Soil chloride was determined using the mercury nitrate method described by Yokoi (2002). Available soil sulphate was determined using the gravimetric method described by Coutinho (1996). Total acidity of soil samples was measured following the 'shortcut method' described by Anderson and Ingram (1993). Exchangeable sodium, magnesium, potassium, calcium and zinc in soil samples were extracted and measured by standard methods described by Okalebo *et al.* (2002). Soil phosphorus was determined following the method described by Doolittle (2014).

Microbial counts in soil samples

Microbial communities (total bacteria, total fungi and total actinomyces) were enumerated following the standard pour plate technique as described by Collins *et al.*, (1989). Ten grams (10g) of soil sample was weighed with a sterile spatula using chemical balance. The sample was introduced into a sterile pestle and mortal and then crushed. The sample was aseptically poured into a bottle of ninety millilitres (90ml) of sterile distilled water and properly mixed together. Thereafter, 1ml portion from the dilution was aseptically pippetted with a sterile pipette and introduced into 9 ml amount of sterile water 10^{-1} dilution and from this dilution; the samples were serially diluted up to the required 10^{-5} dilutions.

Disposable Petri-dishes were set out and labelled accordingly, while inoculation was carried out using the 'standard pour-plate method'. From the 10^{-4} and 10^{-5} dilutions, aliquot (1.0 ml) of inoculums was aseptically pipette and inoculated into sterile Petri dish. Nutrient agar, potato dextrose agar and starch-casein agar were poured into the inoculums respectively and rocked clockwise and anticlockwise for even distribution of the inoculums. The plates were allowed to set properly. The Nutrient agar plates were incubated aerobically at 37±2˚C for 24 hours, three to five (3-5) days. The Potato dextrose agar plates for fungi were incubated at room temperature in an incubator set at 28 ± 2˚C, for 3-5 days. The starch casein agar plates for actinomycetes were incubated aerobically at 27 °C up to 7-10 days. At the end of the incubation period, the colony observed on the culture plates were counted using coulter colony counter. The colony or viable count per gram/ml was calculated by multiplying the average member of colonies per countable plate by the reciprocal of the dilution and reported as colony forming units/g (CFU/g).

Results

Physicochemical properties of termitaria soil and surrounding soils

The result of physical and chemical analysis of termitaria and surrounding soils is presented in Table 1. For physical parameters, water holding capacity increased significantly ($p<0.01$) with distance from the termitaria. Conversely, bulk density decreased significantly ($p<0.01$) with distance from the termitaria. Moisture, pH and electrical conductivity were significantly higher ($p<0.01$) in soil at one meter from termitarium, relative to other two sampling points. Soil at two metres from the termitarium had the least and significant ($p<0.01$) pH and electrical conductivity of 7.036±0.17 and 526.22±218.02 mS/cm, respectively.

For chemical parameters, total nitrogen, decreased with increasing distance from the termitaria. Total organic carbon was higher in termitarium surrounding soil, relative to termitarium soil. The soil at one meter from the termitaria had significantly higher ($p<0.05$) chloride, total organic carbon and magnesium of 49.61±11.02 mg/kg, 0.59±0.20 % and 84.90±9.70 mg/kg, respectively. The differences in sulphate and phosphorus contents of soils from the three sampling points were not significant ($p>0.05$).

Table 1: Physicochemical properties of termitarium soil and surrounding soils

Physical parameters	Distance from termitaria (m)			
	0	**1**	**2**	**F**
Water holding capacity (%)	31.56±8.06[a]	41.47±8.92[ab]	47.19±7.91[a]	3.19ns
Bulk density (g/cm^3)	1.44±0.13[a]	1.41±0.14[a]	1.25±0.13[b]	13.3**
Moisture (%)	20.33±3.68[a]	25.54±2.73[b]	21.01±2.96[a]	24.72**
pH	7.27±0.19[b]	7.14±0.16[b]	7.036±0.17[a]	13.03**
Electrical Conductivity (mS/cm)	604.33±4.29[a]	690.28±197.17[b]	526.22±218.02[c]	16.8**
Temperature (˚C)	29.94±0.92[a]	30.02±2.52[a]	29.61±0.82[a]	0.17[ns]
Chemical properties				
Total Nitrogen (%)	1.06±0.09[a]	0.81±0.15[b]	0.78±0.14[c]	108.23**
Nitrate (mg/kg)	9.76±3.01[a]	13.91±3.44[b]	12.17±2.60[b]	20.31**
Chloride (mg/kg)	47.56±7.26[a]	49.61±11.02[b]	41.61±7.91[a]	18.77**
Total acidity (mg/kg)	35.70±9.78[a]	40.76±55.96[b]	42.39±4.44[b]	23.24**
Sulphate (mg/kg)	10.92±3.30[a]	13.72±5.22[a]	11.57±1.59[a]	10.25[ns]
Total organic carbon (%)	0.37±0.19[a]	0.59±0.20[b]	0.44±0.25[a]	24.7**
Potassium (mg/kg)	151.71±7.79[b]	144.36±8.92[b]	137.90±8.37[a]	8.85*
Magnesium (mg/kg)	69.85±29.28[a]	84.90±9.70[b]	71.27±7.57[ab]	3.46*
Calcium (mg/kg)	129.91±32.95[b]	113.60±26.20[a]	129.31±38.15[a]	4.52[ns]
Zinc (mg/kg)	139.81±24.10[a]	124.85±32.39[a]	119.83±28.66[b]	22.83**
Sodium (mg/kg)	43.81±5.75[a]	53.44±4.45[a]	53.42±12.79[b]	35.93**
Phosphorus (mg/kg)	186.59±24.56[a]	159.97±38.71[a]	169.32±40.26[a]	1.25[ns]

Microbial counts of termitarium soil and surrounding soils

The results for microbial counts, as present in Table 2, showed that termitarium soil had significantly lower ($p<0.05$) total bacteria (119.33±33.75 × 10 CFU/g) and total fungi (34.11±4.63 × 10 CFU/g), relative to the surrounding soil. Total actinomycetes count was higher in termitaria soil than surrounding soil.

Table 2: Microbial counts of termitarium soil and surrounding soils

Distance from termitaria (cm)	Total viable bacteria × 10 (CFU/g)	Actinomycetes × 10 (CFU/g)	Fungi × 10 (CFU/g)
0	119.33±33.75[b]	43.39±7.85[b]	34.11±4.63[a]

1	133.17±13.60[a]	38.44±7.16[a]	35.78±4.94[b]
2	129.83±12.41[a]	40.11±5.70[a]	35.61±4.33[b]
F	4.57*	3.22[ns]	6.14**

Discussion

Most terrestrial organisms, termites inclusive, will usually influence the properties of the soil in which they live, directly or indirectly. This influence may be highly variable owing to differences in species habit and prevailing environmental factors. In this study, the observed decrease in soil bulk density with distance from the termitarium agrees with Ekundayo and Aghatise (1997) and Seetapong *et al*. (2021), who both reported similar findings. The implication of this result is that the termitaria assessed in this study influenced the surrounding soil bulk density. Bulk density is a soil property that also influences other soil activities, such as leaching and erosion. Bulk density provides information about the compactness of soil particles; the more compact the soil particles are, the higher the bulk density of the soil (Easton and Bock, 2016). High termitarium bulk density, as observed in this study, allows agents of erosion to wash soil nutrients (such as potassium, magnesium, sodium, total organic carbon and nitrates in this study) along the slant surface of the termitaria, to the surrounding soil. This explains the higher concentrations of some of these nutrients in the surrounding soil, relative to the termitarium soil. The gradual wash-off of these nutrients from the termitaria into the surrounding soil, and the reduced vertical leaching (owing to increased bulk density), must have resulted in a gradual accumulation of these minerals over time.

The results for water holding capacity showed no significant difference across the three sampling points. However, moisture content increased at one metre from the termitaria. Ackerman *et al.* (2007) also reported increased moisture content in surrounding soil, relative to termitaria. The increase in moisture content at one metre from termitarium, with water holding capacity remaining constant, can be associated with the difference in slope gradient of both soils. Termitaria are constructed in such a way that their surfaces are impervious to water, to prevent the weakening of the structure from within (Ahmod and Pradhan, 2018; Subi and Sheela, 2020). Consequently, rainwater that pours over the hardened, slant surface of termitaria runs directly to the surrounding soil, with only small quantity withheld by the termitaria; hence, the observed increase in moisture content in the immediate surrounding soil, relative to the termitaria.

The termitaria and their surrounding soil exhibited slight alkalinity, with a mean pH range of a little above neutral. It has been established that termitarium soils are usually acidic, neutral or slightly alkaline, because termites are barely active in soils with very high pH values (Li *et al*., 2017; Apori *et al.*, 2020). Just like all other physical parameters (except electrical conductivity and moisture), the pH of termitaria soil was not significantly different from that of soil at one metre away. This indicates that termitarium soil and the soil at one metre from termitaria are somewhat the same in physical parameters. This implies that the immediate surrounding soil is more or less an accumulation of soil washed from the surface of the termitaria.

Soil electrical conductivity (SEC), a soil health indicator that measures the ability of soil water to conduct current, was highest at a metre and least at two metres from the termitaria. SEC is usually high in soils with relatively high water content and high bulk density, permitting less water drainage and sinking of mineral salts through the pores (Rhoades and Corwin, 1990). This explains the relatively high SEC of soil at one metre from the termitaria. Soil at two metres from the termitaria had lower bulk density (allows more drainage of water and leaching of mineral salts), hence, its low SEC.

Generally, the termitaria assessed in this study impacted higher physicochemical effects on their surrounding soil (soil at one metre away), relative to the soil at two metres away. The same trend also played out with microbial activities, with soil at one metre away from the termitaria recording higher total bacteria and total fungi counts. The gradual deposition of minerals and organic matter by run-offs from the termitaria, and the relatively higher water content at one metre, must have aided the growth and multiplication of bacteria and fungi.

Conclusion

In this study, the physicochemical and microbial properties of termitarium soil were assessed, relative to their surrounding soils. Most physicochemical and microbial properties of the soil at one metre away from the termitaria were more impacted, relative to the soil at two metres away. The improved physicochemical and nutrient qualities of the surrounding soil is an indication that termitaria positively influence the quality of their surrounding soils. We recommend further studies to establish the long-term effects of

termitaria on their surrounding plant and animal biodiversity.

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