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Research Article

Effects of Termite mounds on Agro-Ecosystems in Semi-Arid Zones of Nigeria

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Abstract: Termites activities related to the management of tropical and sub-tropical ecosystems, have been little studied. We evaluated, the effects of termite mounds, on soil fertility, as influenced, by different agro-ecology, in Semi-Arid parts of Nigeria. Samples of soil were taken from termitaria and surroundings. The samples were analyzed for physical and chemical properties. Data were analyzed using analysis of variance and means separated with Duncan Multiple Range Test at 0.05 probability level. Physical properties of termitaria had higher Clay + Silt contents, associated with good structure, increased water holding capacity with good drainage. Chemical properties showed increased organic matter, higher total nitrogen, available phosphorus, exchangeable calcium, magnesium and potassium, effective cation exchange capacity, than the adjacent or surrounding soils. The physical and chemical properties of termitaria are far better, significantly ($p<0.05$), across agro-ecology, with Guinea savanna having, highest improvement, in contrast to Sudan and Sahel Savanna. Improvement in physical and chemical properties of termitaria was attributed to the activities of termites. As the case may be, study revealed, termite mounds are enriched in mineral resources that can be used as organic amendments on sustainable basis. Farmers rather than removing completely termitaria, could be used in soil tillage, for crop production.

Keywords: Soil Fertility, Soil Management, Soil Amendment, Agricultural Land Use, Organic Matter, Tropical and Sub-tropical ecosystems

Introduction

Over recent years, intensification of agriculture, coupled with high costs, and poor accessibility of inorganic fertilizers to resource-poor farmers, other inputs are oftentimes proposed, as alternatives [20]. Soil biodiversity's [2], that is anthill soils [21], inhabited by termite insect, of the order isoptera [5], role is now being focused, as an alternative to chemical fertilizer [10,2].

Termites play integral role [3] in soil development, being one of the primary soil producers. Active anthills, in arid and semi-arid systems, are reportedly enriched with soil organic matter and inorganic nutrient elements, comprising Ca, K, Mg, Na and P, in comparison with surrounding soils [2]. Termite activities according to [9], affect nutrient and organic matter dynamics and structure of soil. Such changes had profound influence on the productivity of the ecosystem via carbon sequestration, nutrient cycling and soil texture. Anthill soils are known to minimize nutrient losses and act as a form of manure [19], which helps to retain soil moisture and texture.

There is therefore need, to highlight hidden potentials, the critical role, which the anthills could play, in sustainable agriculture practices, as a locally available resource. Within the savanna and rainforest ecosystem, termites bring about an important change on the soil environment and occupy a large portion of the land [20].

In studies carried out by [10], on comparative analysis of anthill soil and surrounding soil properties in the University of Agriculture, Markudi, Nigeria, found out that differences in the chemical properties of the anthill and the surrounding soils, was as a result of ecosystem services, from termite, which included among others, bioturbation [21] and soil formation, nutrient transportation and cycling [24], litter decomposition [11], soil animal microbial diversity, amendment and remediation [18]. In the tropical and Sub-tropical Agroecosystems, the destructions and damages to crops and farm structures by termites have resulted in the reduction of crop productivity. The usual practice of anthill soil utilization by farmers, involves digging, heaping and spreading the soil on the field, in most cases, the anthill soils, are considered undesirable, and as such, removed completely from the field.

Therefore, the justification of this study was to enable us to understand the impact of activities of termites, on the ecology of tropical system, evaluating the hidden potentials for agricultural production. Samples of soils were collected, from the fields, across arid and semi-arid parts of Nigeria, from termitaria and surroundings, and evaluated, on comparative analysis of anthill soil and surrounding soil properties. Termite infested soils, nutrient dynamics enrichment, both physical and chemical components of the mounds, was discovered to be far better than the surrounding soils.

The study observed, the differences in the physical and chemical properties of the anthill in comparison with the surrounding soils, was as a result of ecosystem services, from termite. Judging from the findings of the study, it is suggested, in mitigating the effects of high costs, and poor accessibility of inorganic fertilizers, anthill soils utilization could be employed on sustainable basis, found as internal off-farm inputs, alternative, to chemical fertilizer, for resource poor farmers.

Materials and Methods

General features of the study area

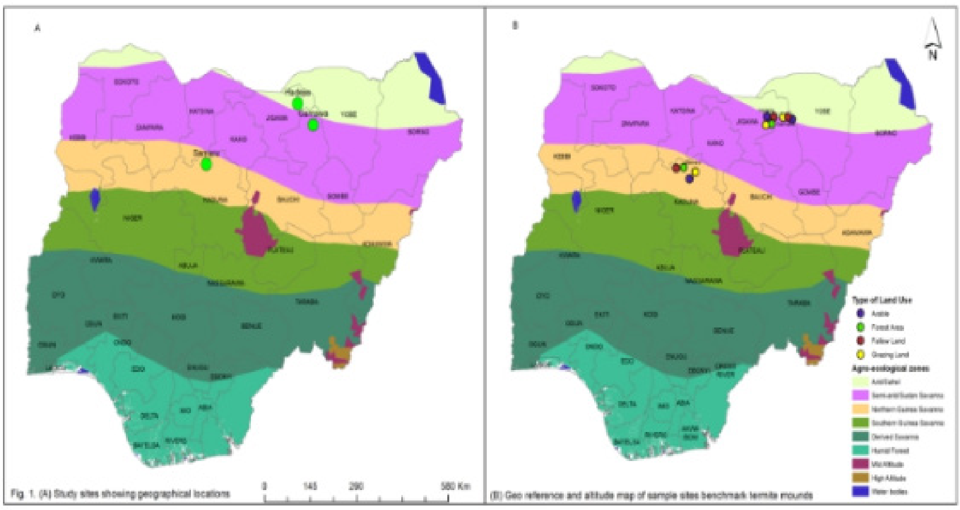

Figure 1: (A) Study sites showing geographical locations. (B) Geo reference and altitude map of sample sites of benchmark termite mounds.

Study site geographical location

Figure 1 The study sites covered semi-arid and arid parts of Nigeria.

1. Samaru town (11°09´52.0” N, 007°37´36.4”E, 692m above sea level), North–Central, in the Guinea savanna agro-ecology, 90 km north of Kaduna and 289km of capital Abuja. The Guinea savannah zone is the broadest environmental zone, covering about 50% of the country. It has unimodal precipitation of about 1051.7 mm per annual and an average temperature of 27.3°C.

2. Hadejia town (12°32´37” N, 010°08´30.1”E, 350m above sea level), North– West in the Sudan savanna agro-ecology, Jigawa State, 617 km north-west of Abuja. The Sudan Savannah zone is found in the Northwest stretching from the Sokoto plains in the extreme Northwest to the Central highland bordering Niger Republic and covers over one-quarter of Nigeria's total area. Annual rainfall is about 60mm and the temperature ranges between 24°C and 27°C.

3. Gamawa town (12°03´34.4” N, 010°33´36”E, 350m above sea level) Northeast in the Sahel savanna agro-ecology, Bauchi State, 650 km north-east of Abuja. The Sahel savannah zone is heavily modified landscape of the forest/savanna transition zone. The vegetation has been decimated with overgrazing, the wood land has been subplanted with mixture of grasses and tress. Annual rainfall 1314mm, and average temperature was 265.5°C between August 28th, 2018, and September 24th, 2019.

A more detailed site description has been reported in Table 1.

Sampling Technique

Fieldwork was conducted between August 28th, 2018, and September 24th, 2019.

The stratified random sampling method was utilized as described by [7].

150 Samples of soil (0-15cm depth) replicated 3 times at 5 auger points from termite mounds and 2 m away adjacent undisturbed soils were collected in the benchmark villages covering Arable, Excavated, Grazing, Fallow Land and Forest Area.

The samples were then air-dried, at room temperature, crushed and passed through, a 2-mm aperture, sieved, to remove roots, macro fauna and stones. Quartering was done in order to avoid bias and also to ensure homogeneity.

Physico-chemical analysis of the soil samples

The < 2mm soil samples were bulked for each location and subjected to routine analysis as described by [12].

The soil pH was determined in (1:2 Soil/water suspension ratio) and measured using pH meter with glass electrode, The total organic carbon (C) determined by Wet dichromic acid oxidation method. Available P was analyzed using the bray 1 acid method. Total-nitrogen (N) was determined by a flame photometer, while and Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) were determined by the atomic absorption spectrophotometer, after extracting with 1.0 M neutral ammonium acetate. The particle size analysis was determined by Hydrometer method.

Statistical analysis

All data were subjected to analysis of variance (ANOVA) using the Statistical Analysis System version [23]. Treatment means were separated using New Duncan Multiple Range Test at 0.05 probability level.

Results and Discussions

Benchmark termite mounds and site characteristics

The characteristics of benchmark termite mounds and other sites sampled (Table 1), for the diagnostic survey revealed that the land-use pattern is predominantly savanna with mosaic forest. The high timberland trees have been decimated, and the woodland that used to exist is presently implanted with a blend of grasses and scattered trees.

Agro-ecology	Location	Geo-reference and altitude	General characteristics
Guinea Savannah	Kaduna (Samaru)		The Guinea savannah zone, is the broadest environmental zone, covering about 50% of the country. It has unimodal precipitation of about 1051.7 mm per annual and an average temperature of 27.3°C.
	i. Arable ii. Grazing land iii. Fallow Land iv. Forest Area	11°09′52.0” N, 007°37′36.4”E, 692m asl 11°10′38.2” N, 007°37′35.8”E, 691m asl 11°10′38.2” N, 007°37′35.8”E, 691m asl 11°09′55.6” N, 007°37′19.8”E, 686m asl	
Sudan Savannah	Jigawa (Hadejia)		The Sudan Savannah zone is found in the Northwest stretching from the Sokoto plains in the esteem North West to the Central highland bordering Niger Republic and covers over one-quarter of Nigeria’s total area. Annual rainfall is about 60mm and temperature ranges between 24°C and 27°C
	i. Arable ii. Grazing land iii. Fallow Land iv. Forest Area	12°32′37” N, 010°08′30.1”E, 350m asl 12°32′20.3” N, 010°08′18.3”E, 351m asl 12°34′29.3” N, 010°11′52.5”E, 354m asl 12°32′40.7” N, 010°08′56.9”E, 352m asl	
Sahel Savannah	Bauchi (Gamawa)		The Sahel savannah zone, is heavily modified landscape of the forest/savannah transition zone. The vegetation has been decimated with overgrazing, the wood land has been subplanted with mixture of grasses and tress. Annual rainfall 1314mm and average temperature 265.5°C
	i. Arable ii. Grazing land iii. Fallow Land	12°03′34.4” N, 010°33′36”E, 350m asl 12°20′25.0” N, 010°26′44”E, 346m asl 12°03′39.5” N, 010°33′45.5”E , 366m asl	

*above sea level(asl)

Table 1: Location of benchmark termite mounds and other sites sampled for the diagnostic survey.

Effects of Agroecology on Termite Mounds Soil Physical Properties

Table 2 showed (p<0.05) significant difference in physical properties across agro-ecology with Guinea savanna having the highest Silt (126.23 g/kg), least Clay (66.40 g/kg) and Sand (807.37 g/kg) contents, classified as Loamy sand.

Soil Parameters	Guinea Savanna	Sahel Savanna	Sudan Savanna	Adjacent Soils	P- value
pH	6.1+0.45b	6.9+0.9a	6.5+0.74ab	4.2+0.35b	<.0001
O.C. g kg^{-1}	7.07+3.18c	6.01+2.66c	6.83+3.72c	5.01+3.67c	<.0001
OM g kg^{-1}	12.13+5.5c	10.39+4.54c	11.71+6.38c	8.66+3.44c	<.0001
N g kg^{-1}	3.14+1.21ab	1.98+1.13b	1.92+1.38b	0.82+1.68b	0.0013
Na c mol kg^{-1}	0.52+0.25a	0.31+0.15b	0.31+0.17b	0.21+0.16b	0.0002
K c mol kg^{-1}	0.04+0.08	0.06+0.05	0.04+0.17	0.02+0.04	0.4843ns
Mg c mol kg^{-1}	0.74+0.12a	0.69+0.39a	0.66+0.21a	0.39+0.29a	0.0034
Ca c mol kg^{-1}	0.99+0.19	2.15+3.31	0.89+0.2	0.05+2.41	0.1238ns
Exchangeable AI+H	1.11+0.39c	0.75+0.15d	0.77+0.18d	0.56+0.14d	<.0001
Al	0.31+0.18c	0.22+0.08c	0.22+0.08c	0.12+0.06c	<0001
H	0.80+0.24c	0.53+0.19d	0.55+0.16d	0.44+0.36d	<0001
Ecec	3.44+0.67	3.97+3.59	2.72+0.38	1.23+0.68	0.3441ns
BS(%)	68.42+6.21a	69.69+15.01a	71.26+8.05a	54.78+14.03a	<0001
Pmg kg^{-1}	9.44+10.79bc	7.01+3.65bc	13.15+10.74b	6.44+09.55b	0.0002
Clay g kg^{-1}	66.40+7.67c	86.18+39.12bc	72.09+18.05c	62.33+18.13bc	0.0005
Silt g kg^{-1}	126.23+21.14d	33.37+22.94d	51.30+18.56b	42.56+33.44d	<.0001
Sand g kg $^{-1}$	807.37+26	880.45+60.15a	876.61+38.61a	895.11+40.16a	<.0001
Textural Class	Loamy Sand	Sand	Sand	Sand	

Table 2: Effects of Agroecology on Termite mounds soil physico- chemical properties

* Means values within a column followed by the same letters are not significantly different at $p<0.05$

Ns =not significant, OC (Organic Carbon), 0.M (Organic matter), B.S (Base Saturation), Adjacent soils (Means)

In contrast to Sudan savanna with Clay (72.09 g/kg), Silt (51.30 g/kg) and Sand (876.61 g/kg) and Sahel savanna, sand (880.45 g/kg), Clay (86.18 g/kg) and Silt (33.37 g/kg), classified as Fine sand, compared with adjacent surrounding soils with average of 62.33 g/kg Clay, 42.56 g/kg Silt and 895.11 g/kg Sand.

Termites' activity may have been responsible for the higher clay and silt contents in termitaria.

This further attests to the fact that termites' activities in their colonies promote forces of attraction and adhesion among the soil particles of termitaria.

These findings are in agreement with earlier findings of [2], who found out in their study, that in the termite mound soil, 67.7% of clay aggregates had particle size greater than 2 μ compared with 48.1% in undisturbed soil and 19.2% of silt size particles were incorporated in aggregates in the mound soil while 5.6% were aggregates in undisturbed soil. [16] also reported that the termite mound had 94% fine materials (clay + Silt) compared to 52% clay and silt in adjacent soil in West Africa. [16] observed mounds had significantly higher clay content than the surface surrounding soils.

These results confirmed work by [4] in Ibadan South-West Nigeria, with recorded higher silt and clay contents in termite mounds than surrounding soils. Agro-ecological differences in change of moisture and temperature might also be responsible for this phenomenon observed. [1] reported soil transported by termites generally contains higher proportions of finer sized particles, and therefore typically demonstrates different clay mineral compositions than those predominating at the original surface stated. Chemical changes are brought about by the incorporation of organic matter while physical changes appear to be due to selection and sorting of certain particles resulting in a change of structure and particle size distribution [16]. The changes in texture brought about by redistribution of mounds and other structures in the surface is likely to be accompanied by changes in physical properties such as structural stability, bulk density, infiltration rate, permeability and water holding capacity [16].

Effects of Agroecology on Termite mounds' soil chemical properties

As indicated in Table 2, ($p<0.05$) non-significant difference was observed in chemical properties across agro-ecological zones with Guinea savanna having highest OC (7.0OM (12.13 g/kg), N (3.14 g/kg), P (9.44 mg/kg), Mg (0.74 c mol /kg) and K (0.10 c mol /kg) than Sahel savanna OC (6.0 g/kg), SOM (10.93 g/kg), N (1.98 g/kg), P (7.01 mg/kg), Mg (0.69 c mol /kg) and K (0.06 c mol /kg) and Sudan savanna OC (6.83 g/kg) SOM (11.71 g/kg), N (1.92 g/kg), P (13.15 mg/kg), Mg (0.89 c mol /kg) and K (0.10 c mol /kg), in the termitaria, compared to observed high and low values of OC (4.2 – 9.3 g/kg), SOM (7. 26 – 16.1 g/kg), N (0.01 – 5.2 g/kg), P (3.55 – 10.23 mg/kg), Ca (0.10 – 1.12 c mol /kg) and K (0.01 – 0.21c mol /kg) in the adjacent surrounding soils.

Soil pH ranged from, 6.1 to 6.9, in the termite mounds with, an average of 6.5, making the soils to be predominantly neutral compared to the surrounding soils with an average of 4.2. According to [3,4] termite's activities generally increase pH. These findings are in agreement with [17] who reported mound soil of various termite species can have higher or lower values of pH, organic carbon, total nitrogen, available phosphorus, exchangeable calcium, magnesium and potassium, effective cation exchange capacity in relation to the surrounding soils.

It has been described by [17] that pedogenesis, organic matter decomposition and nutrient cycling are highly influenced by termite. [6] in their investigation in Australia found out that exchangeable Ca, Mg, K were generally high in termite modified soils than unmodified samples.

[9] reported further that CACO3 were occasionally found usually in a band near the base of the mound and sometimes the quantity may be sufficient that the mound may be used as a fertilizer in the initial agricultural system. This agrees with studies by [8] that there was higher organic content, C/N ratio, Ca, Mg, K and P in termitaria of Macrotermes and Odontotermes species than the surrounding soil, furthermore [22], noticed an increase in organic matter in termitaria as compared with adjacent soils of Podili and Talupula [22] with 96.40+0.88 in India.

The mechanism behind the influence of termites on nest pH is not clear, but an increase in pH may result from an increase in basic cations, whereas a decrease in pH may result from an accumulation of organic matter.

Effects of Land Use on Termite Mounds Soil Physical Properties

Table 3 showed ($p<0.05$) non-significant difference in physical properties across land use systems, with Escavated Land having highest Silt (382.40 g/kg), and Clay (111.53 g/kg) contents with least Sand (506.07 g/kg), while the lowest Silt (163.90 g/kg) and highest Sand (743.98 g/kg) contents were recorded in the Graze Land, in the termite mounds, contrasting characteristically with lower Sand (607.20 g/kg), Silt (296.40 g/kg) and Clay (96.40 g/kg) on average in the surrounding soils. Higher clay and silt contents in termitaria, may be attributable to the termites' activity, across Land Use, in contrast to the surrounding soils.

Soil Parameters	Arable Land	Excavated Land	Fallow Land	Forest Area	Graze Land	Adjacent soils	P-value
pH	6.3+1.13	6.5+0.22	6.5+0.84	6.9+0.92	6.4+0.69	5.3+0.63	0.2637ns
O.C. g kg^{-1}	6.65+4.17	6.53+0.6	11.36+12.18	12.63+11.76	9.76+10.11	9.42+0.67	0.312ns
OM g kg^{-1}	11.50+7.12	11.30+0.83	19.64+21.01	21.84+20.3	16.88+17.43	16.25+0.69	0.3139ns
N g kg^{-1}	2.25+1.02	1.53+0.88	2.42+1.72	2.22+1.75	2.47+1.16	1.23+0.42	0.6902ns
Na c mol kg^{-1}	0.27+0.19dc	0.15+140d	0.29+0.08bc	0.47+0.18a	0.43+0.21ab	0.12+0.10	<.0001
K c mol kg^{-1}	0.08+0.06ab	0.03+0.02b	0.04+0.02b	0.14+0.2a	0.07+0.07ab	0.01+0.01a	0.0343
Mg c mol kg^{-1}	0.67+0.39ab	0.48+0.21b	0.52+0.19b	0.88+0.39a	0.73+0.27ab	0.21+0.31b	0.0065
Ca c mol kg^{-1}	2.18+3.26	0.44+0.16	0.71+0.31	2.25+3.06	0.86+0.32	0.14+0.23	0.0464
Exch AI+H	1.02+0.47	0.82+0.22	0.97+0.56	0.91+0.29	0.95+0.43	0.62+0.70	0.8757ns
Al	0.29+0.1	0.26+0.08	0.28+0.22	0.27+0.11	0.27+0.15	0.20+0.02	0.9904ns
H	0.73+0.45	0.56+0.15	0.69+0.36	0.64+0.22	0.68+0.31	0.42+0.77	0.8208ns
Ecec	4.21+3.36ab	1.93+0.59c	2.51+0.64bc	4.64+3.13a	3.01+0.92ab	1.08+0.96	0.0101
BS(%)	64.43+24.91 ab	56.15+4.35b	62.28+13.74b	75.36+9.17a	67.99+10. 64ab	66.4+0.98	0.0443
Pmg kg^{-1}	6.21+4.62b	10.3+4.19ab	10.33+8.47ab	8.91+ 9.2ab	14.71+10.87a	8.42+0.36	0.0337
Clay g kg^{-1}	93.49+46.84a	111.53+13.2 9a	68.72+14.07b	67.8098+14.3 1b	92.12+33. 73ab	96.40+0.88	0.0021
Silt g kg^{-1}	248.91+265. 76ab	382.4+355.6 5a	197.27+230.84 ab	236.32+234.38 ab	163.9+188. 99b	296.40+0.56	0.3679ns
Sand g kg^{-1}	657.60+68.23 ab	506.07+9.92b	734.01+40.1a	695.87+96.95 ab	743.98+100. 61b	607.20+0.39	0.0548
Textural Class	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam		

Table 3: Effects of Land Use on Termite Mounds Soil Physicochemical Properties

* Means values within a column followed by the same letters are not significantly different at $p<0.05$
ns=not significant, 0.C (Organic Carbon), 0.M (Organic matter), B.S (Base Saturation), Adjacent soils (Means)

Effects of Land Use on Termite Mounds Soil Chemical Properties

Table 3. Changes in chemical properties across Land Use showed ($p<0.05$) non-significant differences in pH, OC, SOM, and Exchangeable cations, with Forest Area having the highest values in the termite mounds compared with the surrounding soils.

These findings, changes in N and P contents observed in termite mounds, in relation to the surrounding soils, agreed with the reports of [19,13]. There are interspecific differences in the accumulation of macronutrients in the nests as seen from measurements of several species in one locality as reported by [19]. On the other hand, [14] discovered nutrient accumulation in a particular species is affected by properties of the surrounding soil and the material used for building the mounds.

Termite mounds Interaction effects on Agroecology and Land Use soil chemical properties

The effects on Interactions (Table 4) of Guinea savanna and Graze Land indicated, highest Na (0.84 c mol kg^{-1}), K (0.21 c mol kg^{-1}), Al (0.52 c mol kg^{-1}), and H (1.18 c mol kg^{-1}) while the least Na (0.18 c mol kg^{-1}) were recorded in Sahel savanna and fallow land, K (0.02 c mol kg^{-1}), Al (0.07 c mol kg^{-1}) in Guinea savanna and fallow land. With the highest Mg (1.15 c mol kg^{-1}) in Sudan savannah and graze land, the least Mg (0.37 c smol kg^{-1}), occurred in Sudan savanna and Fallow land. With the highest Ca (2.39 c mol kg^{-1}) and least H (0.27 c mol kg^{-1}) in Sahel savannah and arable land, the least Ca (0.79 c mol kg^{-1}) were observed in Guinea savannah and forest area and Sudan savannah and fallow land.

Agro-ecology * Land-use	Na (c mol Kg^{-1})	K	Mg	Ca	Al	H
Guinea*Arable	0.19±0.01	0.09±0.02	0.82±0.01	0.94±0.15	0.35±0.13	0.71±0.07
Guinea*Fallow	0.38±0.01	0.02±0.00	0.85±0.04	1.21±0.04	0.07±0.03	0.64±0.07
Guinea*Forest	0.57±0.01	0.06±0.01	0.57±0.00	0.79±0.18	0.28±0.00	0.65±0.11
Guinea*Graze	0.84±0.01	0.21±0.01	0.72±0.00	1.01±0.04	0.52±0.02	1.18±0.04
Sahel*Arable	0.21±0.00	0.05±0.00	1.03±0.01	2.39±0.08	0.37±0.04	0.27±0.03
Sahel*Fallow	0.18±0.00	0.08±0.00	0.72±0.00	0.80±0.03	0.23±0.02	0.41±0.02
Sahel*Forest	0.40±0.02	0.04±0.00	0.68±0.00	0.86±0.07	0.13±0.01	0.57±0.00
Sahel*Graze	0.27±0.00	0.04±0.00	0.92±0.07	0.97±0.03	0.22±0.04	0.73±0.09
Sudan*Arable	0.37±0.02	0.04±0.00	0.54±0.01	0.89±0.02	0.16±0.04	0.80±0.03
Sudan*Fallow	0.20±0.01	0.03±0.00	0.37±0.02	0.79±0.01	0.31±0.04	0.56±0.09
Sudan*Forest	0.33±0.01	0.03±0.00	0.64±0.00	0.96±0.09	0.20±0.06	0.63±0.02
Sudan*Graze	0.21±0.00	0.06±0.00	1.15±0.02	1.18±0.02	0.11±0.00	0.57±0.08

Table 4: Termite mounds Interaction effects on Agroecology and Land Use soil chemical properties

The interaction effects showed ($p>0.05$) significant differences. This supports findings by [17,25] who reported increase in exchangeable cations in Land Use Systems termite's mounds.

Effects of termite mounds interactions in Table 5 on soil chemical properties indicated Sudan savannah and Forest area with pH (7.7), and Guinea savannah and Graze land (5.4), showed, neutral to acidic reaction. With Guinea savannah and fallow land highest in (O.C 10.6 g kg^{-1}), (N 4.9 g kg^{-1}) the least (O.C 2.1 g kg^{-1}), and (N 3.5 g kg^{-1}), in Sudan savannah and fallow land. With Guinea savannah and graze land highest (P 27.30 mg kg^{-1}), content Sudan savannah and forest area had the least (P 2.80 mg kg^{-1}). Highest % Base saturation (85.26%) was observed in Sahel savannah and arable land with the least (61.6%5) in Sudan savannah and fallow land. These significant differences observed agreed with findings by [2] who found out that conversion of natural forest to arable land generally leads to decrease in soil C stocks. According to [2] agriculture can reduce the soil C pool by a factor of two to three. This is particularly important in tropical regions, where SOM turnover is faster than in temperate regions [17]. In some cases, the decrease in SOM due to agricultural practices can threaten the sustainability of agricultural production. In particular, soil-inhabiting (especially soil-feeding) termites are thought to be important for the distribution, protection and stabilization of organic matter, the genesis of soil micro-aggregates and porosity, humification, the release of immobilized N and P, the improvement of drainage and aeration [17].

Agro-ecology* Land-use	pH	OC	SOM	N	P (mg kg^{-1})	ECEC	BS (%)
		← g kg^{-1}					
Guinea*Arable	6.22±0.01	2.6±0.00	4.5±0.00	2.4±0.02	0.90±6.40	3.12±0.15	65.71±2.64
Guinea*Fallow	6.65±0.05	10.6±0.04	18.4±0.1	2.3±0.03	3.90±0.40	3.18±0.18	77.58±2.00
Guinea*Forest	6.12±0.01	8.8±0.06	15.1±0.1	4.9±0.10	2.90±0.36	2.95±0.30	68.28±1.49
Guinea*Graze	5.45±0.05	6.2±0.03	10.4±0.1	2.8±0.03	27.30±1.05	4.50±0.05	62.07±1.13
Sahel*Arable	6.57±0.11	4.7±0.01	8.2±0.03	2.1±0.02	3.80±0.36	4.33±0.16	85.26±1.30
Sahel*Fallow	7.68±0.06	8.3±0.07	14.3±0.1	2.9±0.01	11.76±0.61	2.43±0.03	73.65±0.39
Sahel*Forest	7.00±0.05	5.1±0.03	8.8±0.05	1.6±0.01	11.20±1.40	2.71±0.10	73.94±0.51
Sahel*Graze	6.33±0.12	5.9±0.03	10.2±0.1	1.4±0.04	4.13±0.30	3.16±0.23	70.06±2.18
Sudan*Arable	6.92±0.01	2.8±0.00	4.9±0.02	1.7±0.04	3.86±0.20	2.81±0.02	66.24±2.14
Sudan*Fallow	7.25±0.05	2.1±0.03	3.5±0.08	2.8±0.04	7.03±0.70	2.27±0.01	61.65±2.39
Sudan*Forest	7.73±0.10	2.5±0.03	4.3±0.05	0.6±0.02	2.80±0.70	2.81±0.08	70.06±2.75
Sudan*Graze	7.15±0.05	10.1±0.06	17.4±0.1	2.8±0.04	17.30±0.53	3.29±0.12	79.20±1.56

O.C- (Organic Carbon), SOM- (Soil Organic Matter), BS- (Base Saturation).

Table 5: Termite mounds Interaction effects on Agroecology and Land Use soil chemical properties

The effects on Interactions (Table 6) of Guinea savanna and Graze Land indicated, highest clay (103.2 g kg^{-1}) in Sudan savannah and graze land, while the least (53.2 g kg^{-1}) was in Sudan savannah and forest area. Silt (151.4 g kg^{-1}) was highest in Guinea savannah and graze land while the Sahel savannah and forest area had the least (21.1 g kg^{-1}). Sand content was highest (919.6 g kg^{-1}) Sudan savannah and Fallow land with the least (775.3 g kg^{-1}) in Guinea savannah and graze land.

Agro-ecological zones * Land-use systems	Clay	Silt	Sand	Textural class
	← g kg^{-1}			
Guinea*Arable	60.0±0.00	103.3±0.73	834.6±0.73	Loamy fine sand
Guinea*Fallow	56.0±0.00	119.6±1.65	824.4±1.65	Loamy fine sand
Guinea*Forest	73.2±0.00	130.5±0.57	796.2±0.57	Loamy fine sand
Guinea*Graze	73.2±0.00	151.4±1.68	775.3±1.68	Loamy fine sand
Sahel*Arable	83.7±0.57	26.9±0.57	889.3±0.57	Loamy fine sand
Sahel*Fallow	67.6±0.00	21.1±0.28	911.2±0.2	Fine sand
Sahel*Forest	67.6±0.00	21.1±0.28	911.2±0.2	Fine sand
Sahel*Graze	77.6±0.00	22.8±0.00	899.6±0.00	Fine sand
Sudan*Arable	63.2±0.00	50.5±1.52	886.2±1.52	Fine sand
Sudan*Fallow	63.2±0.00	17.2±0.00	919.6±0.00	Fine sand
Sudan*Forest	53.2±0.00	33.8±1.15	912.9±1.15	Fine sand
Sudan*Graze	103.2±0.00	91.6±0.00	805.2±0.00	Loamy fine sand

Table 6: Termite mounds Interaction effects on Agroecology and Land Use soil physical properties

These significant differences produced two distinct classes ranging from Loamy Sand to Fine Sand. This is in accordance with findings by [8], that termites make channels in soil and influence soil aggregation by mixing organic matter with soil particles and thereby modify the physical properties of soil.

Conclusions

The anthill soils sampled, revealed, physical properties of termitaria had higher Clay + Silt contents associated with good structure and increased WHC with good drainage.

Chemical properties showed increased SOM, total N, available P, exchangeable Ca, Mg and K, effective CEC, improvement over the adjacent or surrounding soils.

Consequently, the results revealed enrichment, of anthill soils by termite activities over the surrounding soils.

Therefore, the incorporation of termite mounds on farmland is to be highly considered if encountered on the farmers' fields.

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