Research Article

Soil Fertility Status of Termite Mounds for the Promotion of Ecosystem Services in Agro-Ecosystems

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Abstract

Treated wastewater for irrigation could form a viable alternative to substitute fresh water resources in the Jordan Valley. Yet, investing in treatment infrastructure is costly and the subsidized water prices in the Jordan Valley results are low compared to the cost price for treated wastewater. Therefore, this study examines the effect of additional water volumes on net profits of four farm archetypes and the possibilities for cost coverage of treated wastewater under various pricing scenarios. The study accounts, in a stylized manner, for positive (festination) and negative (salinization) effects of the treated wastewater quality. The results show that additional volumes are highly profitable for vegetable farms yet; salinity levels negatively affect banana farms. The scenario with the highest pricing variant provides some compensation, yet, most of the costs have to be covered by other public funds.

Introduction

With the intensification of agriculture over recent decades and the social and environmental imperative to develop sustainable agricultural practices, there is now a sharp focus on the influence of cultural systems on soil biodiversity and the role of soil biodiversity in mediating the main ecological functions of the system [1]. Termite is an endogenic exopterygotous insect, which belongs to the order Isopteran, and it is one of the numerous organisms that inhabit the soil. We have become aware that anthill soils could play a crucial role as an alternative to chemical fertilizer for farmers who have no means of buying inorganics. There is need to highlight the critical role, which anthills could play in sustainable agriculture practices as a locally available resource for the benefit of financially, and soil fertility challenged smallholder farmers. The abundance of anthills, composition and hence their impact on soil processes vary greatly depending on vegetation and land use [2]. The management practices such as continuous land preparation can cause alteration in the population structure, elimination and reduction of key species [3]. In terms of number, termites and ants predominate under agro-ecosystem [4] and in terms of diversity termite group are in abundance in natural sites than the cultivated sites [4-7] . Generally, termite thrives by construction of mounds from soil or mixture of soil and other material or within soil horizons must affect the physical and chemical characteristics of both the soil used for construction and the soil of the surrounding areas from which the materials are derived [8]. During the period of occupation of the mound, organic debris or living plant tissue is collected, often over extensive foraging areas, transported to mounds and subjected to intense degradation when termite digests it. Termite activities in the soil therefore affect the nutrient and organic matter dynamics and structure of soil. Such changes in soil properties have 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, which helps to retain soil moisture and texture. The practice of anthill soil utilization involves digging, heaping and spreading the soil on the field. Ancitve anthills are repotedly enriched with soil organic matter and inorganic nutrient elements, comprising Ca, K, Mg, Na and P, in comparison with surrounding soils [9,10]. Within the savannah and rainforest ecosystem, termites bring about an important change on the soil environment and can occupy a large portion of the land [8]. Knowledge about the impact of termites on soil fertility is not only important for understanding the ecology of tropical system but also for evaluating the potential constraints for agricultural production in our fields [4].

In Nigeria [8] recorded that the termite mounds range in size from small domed to conical structures, only a few centimeters in height and diameter to the colossal mounds built by some species of African Macrotermes which reach 9 m or more in height and 20-30 m in diameter at the base. According to [8], the particle size of soil from various termite mounds when compared with adjacent soil showed that some degree of selection of particular size fraction is general and that few termite species consistently select material within a precise range of particle size. Hesse (1955) reported further that tall, thin mounds had sand to clay ratios of 1:1 to 3:1 while larger, domed-shaped mounds had ratios of 2:1 to 18:1. According to [11], Cubitermes species mounds had 67.2% clay and 26.5% sand compared with 30.8% clay and 63.0% sand for the surrounding soils recorded that the mounds of Cubitermes scinteurensis had low proportion of 100-500 μ particle size and higher proportion of less than 100 μ particle size of soil compared to surrounding soil with higher values[12-17]. Observed that the various termite mound soil had higher values of silt and clay and lower values of sand in relation to surrounding soil from which the mounds were constructed [23]. Reported the bulk density of termitaria to be 1.112 g cm-2 compared with 1.225 g cm-3 for surrounding soils [15-17]. Reported that the bulk density of surface mound were higher than that of the surrounding soils. Elkins and Sabadol eported it [19] that the surrounding soil had less water-holding capacity relative to the various termite mounds examined. Lal (1988) found low water infiltration in mound soil in relation to bulk surrounding soil. Arshad (1982) [20] reported favourable water availability together with good drainage in termite mound soil compared to the surrounding soil [21], carried out a comparative analysis of anthill soil and surrounding soil properties in the University of Agriculture, Markudi, Nigeria and 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 and soil formation, nutrient transportation and cycling, litter decomposition, soil animal and microbial

diversity, amendment and remediation [13]. Reported that mound soil of various termite species can have either higher or lower values of organic carbon total nitrogen, available phosphorus, exchangeable calcium, magnesium and potassium, effective cation exchange capacity in relation to surrounding soils [22]. That paedogenesis, organic matter decomposition and nutrient cycling are highly influenced by termites have described it. Termite mounds can also influence water infiltration and nutrient leaching, although this effect is likely to depend on the age and whether termites or abandoned inhabits the mounds. Termites sequester SOM and plant nutrients for considerable periods in their nests, mounds, galleries and other structures recorded a higher organic carbon, C/N ratio, Ca, Mg, K, P in mounds of Macrotermes and Odontotermes species than the surrounding soils in Nigeria. however, recorded low organic carbon content but high Ca, K and Mg in Macrotermitanae as compared to their surrounding soils. In the Cerrado, Brazil soil carbon stabilization was higher in termite mound as demonstrated by higher carbon content in silt size separates [9]. Hesse found low C/N ratio in the termite mound in comparison to adjacent soils [23,24] recorded the lowest carbon content and lowest C/N ratio in the soil of Macrotermes and Odontotermes mounds. However found that the largest increase of mineralize carbon took place but with lower pH in the soil of termite mound of Macrotermes in Northern Tanzania. While citing [25] reported that termite mound exhibited higher percentage C and K content in Burkina Faso [26]. Found lower N content in the mounds of Macrotermes and Odontotermes species than the surrounding soil. Of the 46 samples consisting mainly of soil taken from mounds of 13 species, only two samples had C/N ratio lower than the soils from which they were derived, while the remaining samples consisting of carbon or containing high proportion of carbon had C/N ratio much higher than the surrounding soils. Watson found high concentration of Ca and high pH in un-identified species of African Macrotermitidae. Goodland (1965) found high Ca and Mg concentration in termitaria with Ca concentration averaging more than three times and sometimes up to seven times than those in the surrounding soil in the Repununi Savannah lands of Guyana [27]. Discovered high content of Kaolinite and higher pH and a decrease relative amount of quartz in the termite mound of Cubitermes fungifaber in humid forest of Southern Cameroon [28] . concluded in his investigation that termite mounds have high levels of Ca, P, K as well as higher amount of organic matter, which contribute to better crop development. The mounds in various ecosystems according to Lee and Wood [8] however are not static objects but are continually being eroded by rainfall and occupied mounds are repaired, enlarged by the termites while abandoned mounds are gradually eroded away. Some results of the research work carried out on physical and chemil changes in soil due to termite activity are difficult to relate to soils in our environment under different land use pattern. The elements estimated vary from one investigation to another and some of the studies lack the identification of the termites responsible for the mound structures. For instance, in North-East Thailand, if the destruction of termite mounds is economically justifiable in the short term, the strategy is not necessarily sensible further into the future, and the adoption of cultural practices consistent with the preservation of termite communities may be still be the best bet for the long-term preservation of ecosystem services [29]. Therefore, this study will enable us understand the activities of termite in our soil as it affects both physical and chemical components of the mounds, the surrounding soils as well as nutrient dynamics in termite infested soils under different land use system.

Materials and methods

General features of the study area

Geographical location

The North-West, North- East and South-Eastern parts of Nigeria, West-Africa, were adopted in the diagnostic survey, covering five agro-ecological zones; Guinea, Sudan, Sahel, Derived Savannah and Forest within land use systems; grazing land, excavated land, fallow, arable and forest (Table 1).

Sampling technique

The stratified random sampling method was utilized to divide the land use types into four groups (Peterson and Calvin, 1986). Soil samples (0-15cm depth) at 5 auger points from termite mounds and adjacent soils were collected. The samples were then air-dried at room temperature, crushed and passed through a 2mm aperture, sieved to remove roots, macro fauna and stones. Quartering was done in order to avoid bias and to ensure homogeneity.

Laboratory analysis

The < 2mm soil samples were bulked for each location and subjected to routine analysis as described by Juo (1975). Soil pH (soil/water suspension ratio) was measured using pH meter with glass electrode, particle size analysis by hydrometer method [30], total-nitrogen (N) by micro-kjeldahl method (Jackson, 1958), organic carbon (C) by wet dichromic acid oxidation method, and soil organic matter (SOM) estimated by multiplying organic C with a factor of 1.729 extracted available P. Potassium (K) and sodium (Na) were determined by flame photometry and calcium (Ca) and magnesium (Mg) by atomic absorption spectrophotometry (AAS).

Statistical analysis

All data were subjected to analysis of variance (ANOVA) using the Statistical Analysis System version (SAS 9.3 2011). Treatment means were separated using Duncan Multiple Range Testat at 5% probability level.

Results and Discussions
Termite mounds soil characteristics

Results are presented in (Table 1) for soil characteristics of benchmark termite mounds and other sites sampled for the diagnostic survey. Soil characteristics with sites, vegetation and cropping history, geo-reference and altitude of sampled sites are also displayed, the classification of soils collected during the diagnostic survey and corresponding land-use description as presented in (Table 1), revealed that the land-use pattern is predominantly savannah 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. Effects of termite mounds on soil physio-chemical properties across agro-ecological zones, are presented in (Table 2), while the effects of termite mounds on soil physico -chemical properties across land use systems, are presented in (Table 3)

Effects of Termite mounds on soil physico-chemical properties across agro-ecological zones

The detailed soil physio-chemical properties across agro-ecological zones (Table 2), showed that, the particle size of sand is very high and ranges from 807.4 g kg-1 to 902.9 g kg-1 with an average of 863.7 g kg-1 of soil and clay content were low ranging from 23.0 to 126.2 g kg-1 (average; 65.6 g kg-1) for silt, 62.2 to 84.6 g kg-1 (average of 70.4 g kg-1) for clay. The termite mounds have higher values for sand and lower values for silt and clay than the surrounding soil. Overall, the soils range from sand to loamy sand recorded higher silt and clay contents than sand in Ibadan south-west Nigeria. Agro-ecological difference in change of moisture and temperature might be responsible for this phenomenon. Soil pH ranged from 6.12 to 7.27, with an average of 6.8, making the soils to be predominantly neutral. Termite's activities generally increase pH. The soils are characteristically low in organic matter ranging from 5.9 g-1 to 12.6 g-1 , with an average of 10.0 g kg-1 . The total N varied from 2.0 to 3.1 g kg-1 with an average of 2.4 g kg-1. The exchangeable cations in order of abundance were; Mg (0.75) > Ca (0.35) > K (1.07) > Na (0.06) (c mol/kg soil). The available P varied between 3.85 to 16.24 mg kg-1, the highest value 16.24 mg/kg being observed in the graze land of the land use systems. The value might be responsible through cow dung droppings from cattle grazing. Higher organic content, C/N ratio Ca, Mg, K and P in territorial were found than surrounding soils. The base saturation of the soils was medium (68.42 to 75.73%) 71.7 % being the average. On physical properties, (Table 2), Guinea Savannah has the highest mean value for Silt (126.2 g kg-1) while it has the least mean value for both Clay (66.4 g kg-1) and Sand (807.4 g kg-1) with Loamy sand as its textural class, Sahel savannah has the highest mean value for Clay (74.1 g kg-1) and Sand (902.9 g kg-1) and has the least mean value for Silt (23.0 g kg-1) with Sand as its textural class, Sudan savannah has the second highest for Clay (70.7 g kg-1), Silt (48.3 g kg-1) and Sand (881.0 g kg-1) and has Loamy sand as its textural class. This shows significant difference among the means. This revealed that termitaria have higher clay and silt content than the surrounding soils. The termites' activity is responsible for higher values obtained. This further attests to the fact that termites' activities in their colonies promoted forces of attraction and adhesion among the soil particles of termitaria. These findings are in agreement with earlier findings by [31, 17]. 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 by [32, 33]. On chemical properties (Table 2), Guinea Savannah has the highest for OC (7.1 g kg-1), OM (12.1 g kg-1), N (3.1 g kg-1), P (9.44 mg kg-1), ECEC (3.44) and second least mean value for BS (68.42 %) while it had the least for pH (6.12). Sahel savannah has the second highest for pH (6.89), OC (6.0 g kg-1), OM (10.4 g kg-1), N (2.1 g kg-1), P (7.73 mg kg-1), ECEC (3.16), but had the highest for BS (75.73 %). Sudan savannah has the highest mean for pH (7.27), and the least for OC (4.4 g kg-1) and OM (7.6 g kg-1), while it has the second highest for N (2.0 g kg-1), P (7.75 mg kg-1), ECEC (2.80) and BS (69.29 %). This shows that there is no significant difference between means in the agro-ecological zone (Table 3). This

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

Agro-ecological zone	Location	Geo-reference and altitude	General characteristics
Guinea Savannah	Kaduna (Samaru)	11°09′52.0" N, 007°37′36.4"E, 692m asl	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 27.3oC.
	i. Arable		
	ii. Grazing land	11°10′38.2" N, 007°37′35.8"E, 691m asl	
	iii. Fallow Land	11°10′38.2" N, 007°37′35.8"E, 691m asl	
	iv. Forest Area	11°09′55.6" N, 007°37′19.8"E, 686m asl	
Sudan Savannah	Jigawa(Hadejia)	12°32′37" N, 010°08′30.1"E, 350m asl	The Sudan Savannah zone is found in the Northwest stretching from the Sokoto plains in the esteem NorthWest 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 24oC and 27oC
	i. Arable		
	ii. Grazing land	12°32′20.3" N, 010°08′18.3"E, 351m asl	
	iii. Fallow Land	12°34′29.3" N, 010°11′52.5"E, 354m asl	
	iv. Forest Area	12°32′40.7" N, 010°08′56.9"E, 352m asl	
Sahel Savannah	Bauchi (Gamawa)	12°03′34.4" N, 010°33′36"E, 350m asl	The sahel savannah zone, is heavily modified landscape of the forest/savannah transaction zone. The vegetation has been decimated with overgrassing, the wood land has been subplanted with mixture of grasses and tress. Annual rainfall 1314mm and average temperature 265.5oC
	i. Arable		
	ii. Grazing land	–	
	iii. Fallow Land	12°20′25.0" N, 010°26′44"E, 346m asl 12°03′39.5" N, 010°33′45.5" E , 366m asl	
Rainforest	Abia (Umuahia)	–	This zone is described with a delayed blustery season, accordingly guaranteeing a sufficient supply of water, advancing lasting tree development precipitation is above 2000mm, and temperature is 18 º C.
	Fallow land	05°.32.906'N, 007°.28.360'E, 125.9m asl	
	Abia (Umudike)	–	
	Arable land	05°.28.906'N, 007°.32.355'E, 118.9m asl	
Derived Savannah	i. Enugu (Nsukka)	06°.51.163' N, 007°.25.520' E, 476.7m asl	This zone is found in the tropical rainforest between the tropical rainforest and guinea savannah zones. Annual rainfall 1314mm and temperature 26.5oC.
	Grazing land	–	
	ii. Enugu (Neke Uno-NU)	06°.39.908'N, 007°.31.850'E, 208.4m asl	
	Forest area	–	

Table 2: Effects of termite mounds on soil physico-chemical properties across agro-ecological zones

Soil Parameters	Derived Savanna	Guinea Savanna	Rain Forest	Sahel Savanna	Sudan Savanna	P- value
pH	6.31+0.16ab	6.12+0.45b	4.94+0.28c	6.92+0.9a	6.53+0.74ab	<.0001
O.C. g kg-1	35.27+2.11a	7.07+3.18c	25.42+15.73b	6.01+2.66c	6.83+3.72c	<.0001
OM g kg-1	60.83+3.66a	12.13+5.5c	43.8+27.14b	10.39+4.54c	11.71+6.38c	<.0001
N g kg-1	2.42+0.93b	3.14+1.21ab	3.98+1.99a	1.98+1.13b	1.92+1.38b	0.0013
Na c mol kg-1	0.5+0.12a	0.5+0.25a	0.15+0.08c	0.31+0.15b	0.31+0.17b	0.0002
K c mol kg-1	0.04+0.02	0.1+0.08	0.04+0.01	0.06+0.05	0.1+0.17	0.4843ns
Mg c mol kg-1	0.96+0.46a	0.74+0.12a	0.24+0.16b	0.69+0.39a	0.66+0.21a	0.0034
Ca c mol kg-1	1.03+0.31	0.99+0.19	0.41+0.34	2.15+3.31	0.89+0.2	0.1238ns
Exchangeable AI+H	1.41+0.21b	1.11+0.39c	2.16+0.12a	0.76+0.15d	0.77+0.18d	<.0001
Al	0.44+0.05b	0.31+0.18c	0.58+0.22a	0.22+0.08c	0.22+0.08c	<0001
H	0.97+0.16a	0.8+0.24c	1.58+0.11a	0.53+0.19d	0.55+0.16d	<0001
Ecec	3.94+1.01	3.44+0.67	3+0.7	3.97+3.59	2.72+0.38	0.3441ns
BS(%)	62.73+7.97a	68.42+6.21a	25.28+13.55b	69.69+15.01a	71.26+8.05a	<0001
Pmg kg-1	21.45+6.96a	9.44+10.79bc	4.8+1.65c	7.01+3.65bc	13.15+10.74b	0.0002
Clay g kg-1	121.33+40.16a	66.48+7.67c	109.87+17.41ab	86.18+39.12bc	72.09+18.05c	0.0005
Silt g kg-1	246.13+27.33c	126.23+21.14d	631+234.03a	33.37+22.94d	421.51+218.56b	<.0001
Sand g kg -1	632.53+38.21c	807.37+26	827.37+34.26b	880.46+60.15a	876.61+38.61a	<.0001

* means with the same letter across rows are not significantly differed from each other at p<0.05

ns=not significant. 0C (Organic Carbon), 0.M (Organic matter), B.S (Base Saturation)

agrees with studies by [16] that there was higher organic content, C/N ratio, Ca, Mg, K and P in termitaria of Macromeres and Odontotermes species than the surrounding soil, furthermore [15] noticed an increase in organic matter in territorial as compare with adjacent soils of Podili and Talupula 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. The effects of termite mounds on exchangeable cations, (Table 2), Guinea Savannah has the highest mean value for Na (0.49 c mol kg-1), K (0.09 c mol kg-1) and Al (0.31 c mol kg-1) while it has the second highest for Mg (0.74 c mol kg-1), Ca (0.99 c mol kg-1) and has the highest mean for H (0.80 c mol kg-1). Sahel savannah has the second highest mean for Na (0.28 c mol kg-1), K (0.06 c mol kg-1) and Al (0.24 c mol kg-1) while it has the highest mean value for Mg (0.84 c mol kg-1), Ca (1.26 c mol kg-1) and had the least mean value for H (0.50 c mol kg-1). Sudan savannah has the least mean value for Na (0.27 c mol kg-1), K (0.05 c mol kg-1), Mg (0.68 c mol kg-1) and Al (0.20 c mol kg-1) and has the second highest mean for Ca (0.96 c mol kg-1) and H (0.64 c mol kg-1). This shows there is no significant difference among the means (Table 4). This supports findings by [21] who opined those termites' activities significantly increased exchangeable cations, micronutrients, organic matter content and pH of mound soil while soil acidity was decreased in an Oxisol of Cerrado region of Brazil.

Effects of Termite mounds on soil physico chemical properties across land use systems

The effects of termite mounds on soil physicochemical properties across land use systems, (Table 3), the physical properties revealed, arable land had the second highest mean value for Clay (70.2 g kg-1), Silt (60.2 g kg-1), Sand (869.6 g kg-1), Fallow land had the least mean value for Clay (62.2 g kg-1), second highest mean for Silt (52.6 g kg-1) and highest mean for Sand (885.0 g kg-1), Forest area had the second least mean value for Clay (64.6 g kg-1), Silt (61.8 g kg-1), Sand (873.4 g kg-1), Graze land had the highest mean value for Clay (84.6 g kg-1), Silt (88.6 g kg-1) and had the least value for Sand (826.7 g kg-1), this shows there is no significant difference between the mean, according to soil textural class they are all loamy sand. This supports this findings that 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 by Abe and Wakatsuki [32,33]. The effects on termite mounds on chemical properties in (Table3), showed, Arable land had the second least mean value for pH (6.57), OC (3.4 g kg-1), SOM (5.9 g kg-1) and had the second highest mean for N (2.1 g kg-1), ECEC (3.42), it had the least mean value for P (3.85 mg kg-1) and had the highest for BS (72.40 %). Fallow land had the highest mean value for pH (7.19), OC (7.0 g kg-1), SOM (12.1 g kg-1) and N (2.7 g kg-1), and had the second highest mean value for P (7.48 mg kg-1), BS (70.96 %) and had the least mean value for ECEC (2.63). Forest area had the second highest mean value for pH (6.95), OC (5.4 g kg-1), SOM (9.4 g kg-1), N (2.4 g kg-1), BS (70.76 %) and had the second least value for P (5.63 mg kg-1) and ECEC (2.82). Graze land had the least mean value for pH (6.31) and had the highest mean for OC (7.4 g kg-1), SOM (12.6 g kg-1), P (16.24 mg kg-1), ECEC (3.65), second least mean for N (2.3 g kg-1) and had least mean for BS (70.44 %) (Table 5). This shows there is no significant difference between the means. This agrees with these findings that changes in N and P content in termite mounds have often been reported. There are interspecific differences in the accumulation of macronutrients in the nests as seen from measurements of several species in one locality. On the other hand, nutrient accumulation in a particular species is affected by properties of the surrounding soil and the material used for building the mounds. The effects on termite mounds on exchangeable cations in (Table3), indicated, Arable land has the second least mean value for Na (0.26 c mol kg-1), K (0.06 c mol kg-1), Mg (0.79 c mol kg-1) and H (0.59 c mol kg-1), and had the highest mean for Ca (1.41 c mol kg-1) and Al (0.29 c mol kg-1). Fallow land has the least mean value for Na (0.25 c mol kg-1), K (0.04 c mol kg-1), Al (0.04 c mol kg-1), H (0.53 c mol kg-1), and has the second least mean for Mg (0.65 cmol kg-1), Ca (0.93 c mol kg-1). Forest area has the highest mean value for Na (0.43 c mol kg-1), had the second least mean value for K (0.05 c mol kg-1), H (0.62 c mol kg-1) and had the least mean for Mg (0.63 c mol kg-1), Ca (0.87 c mol kg-1) and Al (0.20 c mol kg-1). Graze land has the highest mean value for Na (0.44 c mol kg-1g), K (10 c mol kg-1), Mg (0.93 c mol kg-1), Al (0.28 c mol kg-1), H (0.83 c mol kg-1) and had the second highest mean for Ca (1.05 c mol kg-1). This shows there is no significant difference among the means.

Effect of termite mounds on exchangeable cations across agro-ecological zones and land-use systems

Interactions for the effect of termite mounds soils on exchangeable cations across agro-ecological zones and land-use systems are shown in (Table 4), the details indicated, guinea savannah and graze land has the highest mean value for Na (0.84 c mol kg-1), K (0.21 c mol kg-1), Al (0.52 c mol kg-1), H (1.18 c mol kg-1) while Sahel savannah

and fallow land has the least mean value for Na (0.18 c mol kg-1), Guinea savannah and fallow land has the least mean value for K (0.02 c mol kg-1), Al (0.07 c mol kg-1), Sudan savannah and graze land has the highest mean value for Mg (1.15 c mol kg-1) while Sudan savannah and fallow land has the least mean value for Mg (0.37 cmol kg-1),Sahel savannah and arable land has the highest mean value for Ca (2.39 c mol kg-1) and least mean value for H (0.27 c mol kg-1) while Guinea savannah and forest area, Sudan savannah and fallow land has the least mean value for Ca (0.79 c mol kg-1). This shows there is significant difference among the means. This supports findings by Lavelle [6] who noticed an increase in exchangeable cations. Guinea savannah and graze land has the highest mean value for Na (0.84 c mol kg-1), K (0.21 c mol kg-1), Al (0.52 c mol kg-1), H (1.18 c mol kg-1) while Sahel savannah and fallow land has the least mean value for Na (0.18 c mol kg-1), Guinea savannah and fallow land has the least mean value for K (0.02 c mol kg-1), Al (0.07 c mol kg-1), Sudan savannah and graze land has the highest mean value for Mg (1.15 c mol kg-1) while Sudan savannah and fallow land has the least mean value for Mg (0.37 c mol kg-1),Sahel savannah and arable land has the highest mean value for Ca (2.39 c mol kg-1) and least mean value for H (0.27 c mol kg-1) while Guinea savannah and forest area, Sudan savannah and fallow land has the least mean value for Ca (0.79 c mol kg-1). This shows there is significant difference among the means. This supports findings by Lavelle [6] who noticed an increase in exchangeable cations.

Effect of termite mounds on soil chemical properties across agro-ecological zones and land-use systems.

Interactions for the effect of termite mounds on soil chemical properties across agro-ecological zones and land-use systems are sown in (Table 5). Sudan savannah and forest area have the highest mean value (7.73) while Guinea savannah and graze land has the least mean value (5.45) for pH, Guinea savannah and fallow land has the highest mean value (10.6 g kg-1), (18.4 g kg-1), (4.9 g kg-1) for OC, SOM and N respectively while Sudan savannah and fallow land has the least mean value (2.1 g kg-1), (3.5 g kg-1), (2.27) for OC, SOM and ECEC respectively while Sudan savannah and forest area has the least mean value (0.6 g kg-1), (2.80 mg kg-1) for N and P respectively, Guinea savannah and graze land has the highest mean value (27.30 mg kg-1), (4.50) for P and ECEC respectively, Sahel savannah and arable land has the highest mean value (85.26%) while Sudan savannah and fallow land has the least mean value (61.6%5) for %BS. This shows there is significant difference among the means. This agrees with findings by Guo and Gifford (2002) which stated that conversion of natural soils to arable soils generally leads to a decrease in soil C stocks. According to Lal (2004), 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. 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 stabilisation of organic matter, the genesis of soil micro-aggregates and porosity, humiliation, the release of immobilised N and P, the improvement of drainage and aeration [26].

Effect of termite mounds on soil physical properties across agro-ecological zones and land-use systems.

Interactions table for the effect of termite mounds on soil physical properties across agro-ecological zones and land-use systems are indicated in (Table 6). Interactions between Sudan savannah and graze land gave the highest mean value (103.2 g kg-1), while Sudan savannah and forest area gave the least mean value (53.2 g kg-1) for clay. Interactions between Guinea savannah and graze land gave the highest mean value (151.4 g kg-1) while both Sahel savannah and fallow land and Sahel savannah and forest area gave the least mean value (21.1 g kg-1) for silt. Interactions between Sudan savannah and Fallow land gave the highest mean value (919.6 g kg-1) while Guinea savannah and graze land had the least mean (775.3 g kg-1) for sand. This shows significant difference between the means. This is in accordance with findings by Jouquet [33] that termites make channels in soil, influence soil aggregation by mixing organic matter with soil particles, and thereby modify the physical properties of soil [34-40]. Effect of termite mounds on soil physical properties across derived savannah and rain forest showed, derived savannah has the highest mean value for clay (121.3 g kg-1), silt (246.1 g kg-1) while Rain forest has the highest mean value for sand (827.8 g kg-1), this shows there is significant difference between the means. On the effect of termite mounds soils on soil chemical properties across derived savannah and rain forest. Derived savannah has the highest mean value for pH (6.30), OC (35.20 g kg-1), SOM (60.80 g kg-1), P (21.45 mg kg-1), ECEC (3.93) and %BS (62.72%) while Rain forest has the highest mean for N (3.90 g kg-1). Derived savannah also has the highest mean value for Na (0.49 c mol kg-1), K (0.04 c mol kg-1), Mg (0.95 c mol kg-1) and Ca (1.02 c mol kg-1) while Rain forest has the highest mean value for Al (0.58) and H (1.58). This shows there is significant difference among the means [41-49].

Table 3: Effects of termite mounds on soil physico -chemcial properties across land use systems.

Soil Parameters	Arable Land	Excavated Land	Fallow Land	Forest Area	Graze Land	P-value
pH	6.28+1.13	6.46+0.22	6.52+0.84	6.91+0.92	6.4+0.69	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	0.312ns
OM g kg-1	11.44+7.12	11.33+0.83	19.6+21.01	21.73+20.3	16.8+17.43	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	0.6902ns
Na c mol kg-1	0.27+0.19dc	0.1+140d	0.29+0.08bc	0.47+0.18a	0.4+0.21ab	<.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	0.0343
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	0.0065
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	0.0464
Exchangeable AI+H	1.02+0.47	0.82+0.22	0.96+0.56	0.9+0.29	0.94+0.43	0.8757ns
Al	0.29+0.1	0.26+0.08	0.28+0.22	0.9+0.29	0.27+0.11	0.27+0.15
H	0.73+0.45	0.56+0.15	0.69+0.36	0.64+0.22	0.68+0.31	0.8208ns
Ecec	4.21+3.36ab	1.9+0.59c	2.51+0.64bc	4.64+3.13a	3.01+0.92ab	0.0101
BS %	64.43+24.91ab	56.15+4.35b	62.28+13.74b	75.36+9.17a	67.99+10.64ab	0.0443
P mg kg-1	6.21+4.62b	10.3+4.19ab	10.33+8.47ab	8.91+ 9.2ab	14.71+10.87a	0.0337
Clay g kg-1	93.49+46.84a	111.53+13.29a	68.72+14.07b	67.8098+14.31b	92.12+33.73ab	0.0021
Silt g kg-1	248.9+265.76ab	197.27+230.84ab	236.32+234.38ab	163.9+188.99b	0.3679ns	0.3679ns
Sand g kg -1	848.91+68.23ab	889.28+40.1a	844.5+96.95ab	817.56+100.61b	0.0548	0.0548

*means with the same letter across rows are not significantly different from each other at p<0.05
ns=not significant. 0C (Organic Carbon), 0.M (Organic matter), B.S (Base Saturation)

Table 4. Interactions for the effect of termite mounds soils on exchangeable cations across agro-ecological zones and land-use systems.

Agro-ecological zones * Land-use systems	Na	K	Mg	Ca	Al	H
	c mol kg^{-1}					
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 5: Interactions for the effect of termite mounds on soil chemical properties across agro ecological zones and land-use systems.

Agro-ecological zones * Land-use systems	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±0.08	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±0.10	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±0.08	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±0.12	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±0.05	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±0.10	2.8±0.04	17.30±0.53	3.29±0.12	79.20±1.56

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

Table 6: Interactions table for the effect of termite mounds on soil physical properties across agro-ecological zones and land-use systems.

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

Conclusion

Increasing knowledge about the importance of termites for the maintenance of the integrity and functioning of eco-systems has not prevented them being seen as pests of crops, trees and wood. Consequently, environmentally unfriendly methods to eliminate pest species are often damaging to beneficial ones. Thus the main global impact of termites, outweighing their pest status, is clearly to provide the eco-system services. This role is however under-appreciated and more research is needed to better evaluate the importance of termite activity and diversity in tropical ecosystems. Understanding of soil fertility status of termite mounds as influenced by agro-ecological zone and land use across Nigeria and manipulation of their composition and activities would appear to be one of the ways in which balanced degradation of organic residues, maintenance of soil structure and aggregate stability and other ecological functions can be restored in degraded soils. The outcome of this research work has proven that land-use greatly affects properties of termite mounds and has given reasonable facts and figures that effective agricultural land-use are consequent of the soil fertility status. Soil-inhabiting (especially soil-feeding) termites are thought to be important for the distribution, protection and stabilisation of organic matter, the genesis of soil micro-aggregates and porosity, humiliation, the release of immobilised N and P, the improvement of drainage and aeration. In conclusion, the research work has been able to fulfil the various objectives enlisted above; therefore, the incorporation of termite mounds on the farmland is to be highly considered as well as engaging in other necessary agricultural practices such as routine soil test and analysis to enhance maximum crop productivity.

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