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DISTRIBUTION OF AVAILABLE TRACE ELEMEMTS IN TERMITARIUM AND ADJACENT SOILS IN GWAGWALADA AREA COUNCIL, FCT, ABUJA, NIGERIA

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ABSTRACT
The study was conducted to assess some important physico-chemical properties and micronutrient status of termitaria soils compared with the surrounding adjacent undisturbed soils around Gwagwalada, Abuja. A reconnaissance survey of the study area was carried out and six (6) different locations with termite mounds were identified. Soil samples from the termite mounds as well as from adjacent lands were collected, bulked separately prepared and analysed in the laboratory for some important physico-chemical properties as well as four metallic micronutrients, (copper (Cu), manganese (Mn), zinc (Zn) and iron (Fe)). The result showed that, all the termite mounds have higher clay fractions ranging from 22% to 34% which falls in the textural class of sandy loam. Soil pH (in water) of the termitaria ranges from 5.4 to 6.7, while in the adjacent soils was 6.1 to 6.7. Organic carbon (OC), Effective Cation Exchange Capacity (ECEC), calcium (Ca) and magnesium (Mg) were generally higher in the termitaria soils than the adjacent soils, while sodium (Na) and potassium (K) were lower in the termitaria. The result of micronutrients status of the termitaria soils varied based on location, but the adjacent soils generally gave higher values for all the micronutrients than the termitaria. These attributes indicates more desirable characteristics for crop production in termitaria soils. The termitaria soils could thus be used as incidentalb fertilizer that could improve crop production at least on small scale.

Keywords: Abuja, Adjacent soils, Available, Gwagwalada, Distribution, Trace elements, Termitarium.

INTRODUCTION
Soil organisms are known to be responsible to a varying extent for performing vital functions in the soil ecosystem. These functions affect the physical, chemical and biological processes in the soils, among others (Hawksworth, 1995). Various organisms play different roles in the breakdown and incorporation of organic matter into the mineral soil, leading to the ultimate association of the two (Brady and Weil, 2002). These "ecosystem engineers" such as termites, ants, earthworms, etc. through their bio-tubing activities, produce structures that can last for long periods of time (even outlasting the organisms that produce the) affecting organic matter dynamics and physical as well as chemical properties of soils (Lavelle, 1996). They also leave open channels through which water and air can flow (Brady and Weil, 2002) thus increasing the porosity and reducing the bulk density of the soils.

Termites, sometimes called "white ants" are found in about two-thirds of the land areas of the world, but are most prominent in the grasslands (savannah) and forest of tropical and subtropical areas (both humid and semi-arid). Generally, termites are endogenic exopterygotus insects which belong to the order *Isoptera* and it is one of the numerous organisms that inhabit the soil (Denloye *et al*., 2015).

Besides the economic importance of termites as significant agricultural pest causing serious damages and loss of crops, termites activity is a significant factor in the formation of soils in tropical and subtropical areas, and being detritivores, accelerates the decay of dead trees and grasses (meaning feeding on dead biomass) but have been occasionally noted to damage even living plants (Rupela *et al.,* 2005; and Brady and Weil, 2002).

Termites mounds have been reported to have higher organic matter than the soils from which there constructed, because termites use organic matter to cement soil mineral particles to form aggregates. This effectively contributes to the modification of the physical and chemical properties of the soil (Kaschuk *et al*., 2006).

Within the savannah ecosystem, termites bring about important change on the soil environment and occupy a large portion of the land (Lee and Wood, 1997). 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.

Gwagwalada as part of the FCT experiences two distinct seasons, which are the rainy season and the dry season. In between the two seasons, there is a distinct brief interlude of harmattan between December and January which is occasioned by the North East trade wind, the main feature of dust haze, intensified coldness and dryness. The dry season which lasts from November to March is characterized by high temperatures. The daytime temperature can rise to about 32^0C – 38^0C, while night time temperatures can be as low as 17^0C to 12^0C resulting in chilly evenings. The temperature gets much warmer during March ushering in the rainy season which last from April to October with its peak mostly in August, thus the rainfall pattern is unimodal and the mean annual rainfall ranges 1200mm to 1600mm. The rainfall is a characteristic of the Guinea savannah and increases from North to South.

Gwagwalada is located within the savannah vegetation zone of Nigeria with patches of forest, however; occur in the Gwagwa plains, the rugged hills of the South-eastern part and sedimentary rock area of the South-eastern part of the territory. Common tree species of the forest area are *Chlophora excels* (Iroko), *Kwaya grandifolia* (Benin mahogany), *Piptadeniastrum africanum* (Agboni), *Terminalia superb* (Afara), *Lophira alata* (Ekki), *Triplochiton sclerxylon* (Obeche) and *Terminalia havearensis* (Ichgbo). Some of these tree species are commonly associated with the rainforest of the Southern part of the country, but are also found in some of the forest patches of the FCT. The predominant vegetation of the FCT is however, classified into three savannah types namely.

The park or grassy savannah, most common species here are the Pakia clappertonia (African locust bean tree), *Butryospernum paradoxinum* (shea butter tree) and *Andropogon gayanus* and *Hypryhenea*. Savannah woodland has common tree species as *Afzelia, Anogeisus leocarpus* and *Khaya senegalensis.* The third savannah type is the shrub consists mainly of rough terrain close to the hill ridges. Common trees are *Anoma senegalensis, Dracacna arborea* and *Khaya grandifolia* among others (Rayar, 2000).

The Federal Capital Territory (FCT), Abuja is underlain by two (2) major geologic formations namely; undifferentiated basement complex rocks of the late Precambrian to early Palaeozoic age; and Gretaceous Nupe sand stone. Gwagwalada which is the study area falls under the undifferentiated basement complex formation. The major soil type is classified as Alfisols characterized by Aquic and Usdic moisture regime, low soil pH as a result of high rainfalls, fine sands and soils rich in iron and manganese deposits. It is also rich in low activity clays (Nwaka, 2014).

Studies on the fertility potential or influence of termitaria on soil properties is generally lacking in Abuja, and Gwagwalada specifically, which falls within the giuinea savannah, an important agricultural zone, even though a larger number of termitaria are found in the area. Therefore, the role of these termites in modifying soil properties in the area needs to be investigated. The study is posed to determine some physico-chemical properties of the soils of termitaria as indicators of the influence of termites and the variation of the effects at selected locations relative to similar surrounding undisturbed soils. The objective of the study was to evaluate the fertility potential of termitaria soils in relation to adjacent soils in Gwagwalada Area Council of the FCT, Abuja, Nigeria.

MATERIALS AND METHODS

The Study Area

The study area was Gwagwalada Area Council of the Federal Capital Territory, Abuja. The area was geographically situated within latitude 08^0 56'29^{11} N and latitude 007^0 05'31'. Gwagwalada Area Council has a land area of 1,043 km^2 and a population of 157,770 based on 2006 census figure. The area is located in the Northern Guinea savannah ecological zone, and agriculture is the predominant occupation of the indigenes and other settlers. Gwagwalada, which is one of the six Area Councils in the FCT, is bounded to the East by Kuje, and Paiko Local Government of Niger State to the West, while Kwali is to the South and AMAC Area Council and Suleja Local Government of Niger State to the North and Northwest, respectively; and observably, Gwagwalada is the main town in the Area Council.

Field Work

A reconnaissance Survey of Gwawalada Area Council was carried out by traversing its length and breadth of the area. During this exercise, six locations were marked out having termite mounds of different sizes and shapes. The six (6) areas marked out for the study and collection of soil samples were: (1) University of Abuja Main Campus; (2) University of Abuja Mini Campus; (3) Gwagwalada Kwali Road; (4) Gwagwalada Kuje Road; (5) Passo/Dobi Road; and (6) Anagada-Zuba Road.

In all the six (6) locations termite mounds were observed and assessed the level of their activeness (whether they are still having termites in them or the termites have left the mounds). Only those mounds that indicated activeness were marked for sample collection. Also, the adjacent undisturbed soils around the mounds were assessed 50m away from the mound in three different directions.

Sample Collection and Preparation

Some basic materials were used in collection of soil samples for the study. These material included cutlass for site clearing, soil auger for boring and sample collection, soil sample bags, masking tape for tagging and identification of samples, cardboard paper for spreading the samples, 50 m fibre tape for distance measurement as well as writing materials among other things. To collect the soil samples, the termite mounds were marked into three positions, apex, middle and base sections. Auger borings were made in section to collect samples for each mound. The samples collected from each section were then bulked together to form a representative composite sample. For the adjacent soil also, a minimum of 30m distance away from each mound was measured from three (3) different locations and soil samples were collected using auger to a depth of 30m which were also bulked together to form a representative composite samples of the area. This implied that in each of their area, there were two composite samples collected (from termitaria and from adjacent soils). The samples were then adequately labelled for proper identification.

Before taking to the laboratory for analysis the samples were then air-dried at room temperature for up to 14-21 days. After air-drying, the soil samples we crushed and passed through a 2.00 mm sieve mesh apertures. The sieved samples were then coded, packaged and then taken to laboratory for analysis.

Laboratory Analytical Techniques

Particle size Analysis

The relative proportion of sand, silt and clay fractions in the soil samples were determined using the hydrometer method of Bouyoucos (1962) as described by IITA (1979) and 50g of air-dried soil sample was weighed and placed in a container in a mechanical stirrer, followed by addition of 25 ml of 5% calgon, then stirred at high speed for 15 minutes. The content of the container was transferred into a 1 litter (1000ml) cylinder, diluted to mark and stirred for one minute with a wooden paddle. This was followed by inserting a Bouyoucos soil hydrometer four seconds before taking the international readings for silt and clay (<2u) after 4 seconds, but within the first one minute, and the international clay fraction (<2u) after 2 hours. The temperature of the suspension was taken after each hydrometer reading and a constant of 0.3 was added or subtracted for every degree below or above 20^0C, respectively.

Determination of Soil pH

Soil pH was determined using the glass electrode pH meter in a suspension of soil/water and a suspension of soil/0.1N KCl at a ratio of 1:2.5 (Mclean, 1983). The pH was determined after stirring the suspension of soil/water or soil/KCl solution which was allowed to equilibrate for some reasonable minutes before the electrodes were inserted into the solution. The readings were then taken on the meter and recorded.

Determination of Organic Carbon (OC)

The organic carbon was determined using the Walkley Black method (wet oxidation method). This method measures active or decomposed organic matter in the soil, then, 50g of soil was weighed into a 500 ml conical flask and 100ml of potassium dichromate VII (K_2CrO_7) and concentrated tetraoxosulphate VI acid (H_2SO_4) were added. The organic carbon obtained was then multiplied by a factor of 1.72 to obtain the organic matter values.

Determination of Exchangeable Bases and Effective Cation Exchange Capacity

The total exchangeable bases (Ca^{2+}, Mg^{2+}, Na^+, K^+ and H + Al) were determined in NH_4OAC extraction. Ca^{2+} and Mg^{2+} were obtained on an Atomic Absorption Spectrophotometer (AAS), while Na^+ and K^+ were obtained by flame photometer. Effective Cation Exchange Capacity (ECEC) was determined by summing up all the basic and acidic cations determined previously.

Determination of Micronutrients (Mn, Cu, Zn and Fe)

The soil samples were analyzed for Mn, Cu, Zn and Fe. For the total nutrient determination, sieved soil samples of 5 g were taken and crushed again to pass through a 1.00mm sieve. Then 17.5ml of concentrated 0.1N HCl acid was poured into a flask, made up to 2000 mls with distilled water and 2g of soil was weighed into 50 ml centrifuge. The solution was then decanted for reading in an Atomic Absorption Spectrophotometer (AAS).

RESULTS AND DISCUSSION

Physico-chemical and Micronutrients Properties of Termite Mounds in the Study Area

Physical Properties of Soils

The result of physical properties of the soil samples in Gwagwalada and Adjacent Soils site are presented in Table 1. The result showed that in all termite hills studied, the soil texture was uniformly sandy clay loam, while adjacent soils were sandy loam. This indicates that there was more clay accumulation in the termite hills than in the adjacent soils. Within the termite hills, the clay fraction ranges from 22 to 34%, whereas in the adjacent soils, the clay fraction ranges from 12 to 26%. This result is consistence with other researchers who reported that the soils on termite mounds exhibited a higher proportion of fine particles in particular, a threefold and twofold increase in clay content was observed in the soil in tropical savannah environments (Abbadie *et al.,* 1996; Arshad, 1982; and Maduakor *et al*., 1995). In fact selection and importation of finest soil particles from deep to upper horizons is often the main source of modification of soil texture on mounds (Grasse, 1984; and Lee and Wood, 1971).

A common trend observed in the texture of soils from mounds studied was the high clay content than in surrounding soils. Clay accumulation in a soil results in significant modification in some physico-chemical as well as morphological attributes of a soil. This may include: change in soil texture, shrinking/swelling capacity of the soil which may induce soil cracking on mounds thus increasing water infiltration rate in dry conditions and the deeper percolation of water, this could also improve distribution of roots. Clay soils are known to have high water and nutrient retention ability, thus termite mounds have the potential to hold higher percentage of organic matter and water needed for improved performance of crops (Agbede, 2009; Foth, 2009; and Brady and Weil, 2002). High clay content in soils influences the workability of wet soils leading to structural disturbances and causing soil compaction that may result in higher bulk density. Sanni (2012) reported that higher bulk density in clay soils impede root penetration, water infiltration and movement of water within the soil system.

Table 1: Physical Properties of the Soil

Site	Sample Location	Sand (%)	Silt (%)	Clay (%)	Textural class
Main Campus	Termite hill	66	08	26	Sandy Clay Loam
	Adjacent soil	54	20	26	Sandy Clay Loam
Mini Campus	Termite hill	70	08	22	Sandy Clay Loam
	Adjacent soil	74	12	14	Sandy Loam
Kwali Road	Termite hill	60	06	34	Sandy Clay Loam
	Adjacent soil	76	12	12	Sandy Loam
Passo	Termite hill	66	08	32	Sandy Clay Loam
	Adjacent soil	72	08	20	Sandy Loam
Kuje Road	Termite hill	66	12	22	Sandy Clay Loam
	Adjacent soil	74	10	16	Sandy Loam
Zuba	Termite hill	64	06	30	Sandy Clay Loam
	Adjacent soil	74	12	14	Sandy Loam

Chemical Properties of Termite Mounds and Adjacent Soils

Table 2 shows some selected chemical properties of termite hills and adjacent soils within Gwagwalada Area Council in FCT, Abuja. Soil pH of the termitaria ranges from 5.4 to 6.7 (in H_2O) and 5.2 to 6.3 (in 0.01M $CaCl_2$). On the adjacent pH in H_2O ranges from 6.2 to 6.7, while the range of pH in 0.01M $CaCl_2$ was from 5.4 to 6.4. The result showed that the soils were strongly to slightly acidic in the termitaria and slightly acidic to neutral in the adjacent soil. This implies that termites' activity in the mounds reduces soil pH values. However, the result of this study is not in conformity with that of Fageria and Baligar (2004) who reported that termite activities significantly increased soil pH of the mound soil, while the soil activity in terms of Aluminium (Al) was decreased in an Oxisol. The values obtained for soil pH in the termitaria falls within the same range recorded by Danmowa *et al*. (2011) for soils of Sokoto in Sudan Savannah of Nigeria. The soil pH indicates that it is optimum for nutrients and microorganisms availability (Brady and Weil, 2002; and Olaitan and Lombin, 1984). This is a favourable pH for the decomposition of organic matter in the termitaria that could lead to the released of nutrients immobilized in both organic matter and microbes incorporated in the soil by termites. The low pH of up to 5.4, some of the termitaria is not uncommon under organic matter decomposition since it lowers soil pH through the release of organic acids and other acidic functional groups

The organic carbon of the termitaria ranges between 0.40 to 1.01%, while in the adjacent soils, organic carbon was in the range of 0.46 to 1.11%. These values were rated as moderate to high (Chude *et al*., 2011) in both the termitaria and adjacent soils. Organic carbon is an important component of termite heaps/mounds which is not unconnected to the churning of organic materials into the soils as a result of termite activities. This explains why organic matter (OM) tends to be high in the soil than in the termitaria.

Termite mounds have been reported to have higher O.M than the soils from which they are constructed, because termites use organic matter to cement soil mineral particles to form aggregates (Kaschuk *et al*., 2006). This effectively contributes to the modification of the physical and chemical properties of the soil. Some other reports indicated higher organic matter in the adjacent soils and attributed the phenomenon to higher clay content imported from the subsoil and which is usually low in organic matter (Robert *et al*., 2007; and Black and Okwolkwol, 1999). Improvement of termitaria soils in O.M and other chemical properties has been reported by Jurgenius *et al.* (1999) which were attributed to the OM cycling in the termitaria.

In both the termite mounds and adjacent soils, the soil exchangeable acidity was in the rate of 0.40 to 0.60cmol/kg. These values were rated as moderate (Landon, 1991). At low pH, Al^{3+} are known to be released from clay lattices and become established on the clay higher contents of exchangeable acidity is often associated with horizons or soils having high clay content. The uniformity in the status exchangeable acidity on the soils of termite mounds and the adjacent soils of the area suggests that activities of termite have influence on the status of exchangeable acidity in the adjacent soils. Sanni (2011) studied soils of Gwagwalada under different land uses and reported H+ Al values of 0.20 to 0.40cmol/kg. The current result of termite mounds and the adjacent the adjacent soils showed an apparent increase in the H^+ Al^{3+} value suggesting that termites' activities have potential of increasing the exchangeable acidity. This may also not be unconnected to the high clay content which has potentials of releasing Al^{3+} oxides under poor drainage conditions (Agbede, 2009; and Brady and Weil, 2002).

The status of exchangeable cations (Ca, Mg, Na and K) in termitaria and adjacent soils was also examined. Calcium (Ca) distribution in the termite mounds around Gwagwalada ranged from 5.80 to 8.80cmol/kg with an average value of 6.77cmol/kg. On the adjacent soils, the values of Ca ranged from 4.20 to 8.40cmol/kg with a mean value of 6.13cmol/kg. The distribution of magnesium (Mg) in the termite mounds ranged from 0.83 to 1.04cmol/kg with an average value of 0.93cmol/kg, while in the adjacent soils, the Mg values ranges from 0.61 to 1.00cmol/kg with a mean value of 0.84cmol/kg. Exchangeable sodium (Na) in the termitaria ranges from 0.10 to 0.18cmol/kg with a mean of 0.14cmol/kg, while on the adjacent soil, the exchangeable Na ranges from 0.10 to 0.26cmol/kg. The result of exchangeable potassium (K) showed that the values ranges from 0.29 to 1.28cmol/kg in the termitaria, but in the adjacent soils, the values ranged from0.16 to 1.01 with a mean of 0.47cmol Cation exchange of the

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termitaria soils ranges from 8.2 to 11.4cmol/kg with a mean of 9.33cmol/kg. While on the adjacent soils, the value ranges from 6.2 to 10.4cmol/kg with a mean value of 8.73cmol/kg. This ranges of values /kg. The values obtained for exchangeable bases on termitaria were slightly higher than the adjacent soils. Danmowa *et al.* (2011) as well as Lopez-Hermandez (2001) reported similar findings.

Table 2: Physico-chemical Properties of Termitaria and Adjacent Soils in Gwagwalada

Site	Samples Location	Ph H_2O	$CaCl_2$	OC (%)	Exchangeable Acidity (H^++ Al^{3+}) ($cmolkg^{-1}$)	Cmol/kg Ca	Mg	Na	K	ECEC
Main Campus	Termite hill	5.7	5.55	1.01	0.40	6.60	1.04	0.18	0.13	8.7
	Adjacent soil	6.3	5.5	1.11	0.40	4.40	0.98	0.14	0.33	6.4
Mini Campus	Termite hill	6.3	5.5	0.4	0.60	6.40	0.83	0.13	0.29	8.5
	Adjacent soil	6.2	5.8	0.9	0.60	5.80	0.85	0.68	1.07	9.3
Kwali Road	Termite hill	6.1	5.4	0.52	0.40	6.00	0.87	0.15	0.32	8.2
	Adjacent soil	6.2	5.4	0.46	0.40	6.00	0.87	0.17	0.16	6.2
Passo Road	Termite hill	5.4	5.2	0.65	0.60	5.80	0.99	0.17	1.28	9.4
	Adjacent soil	6.2	6.0	0.73	0.60	8.40	0.83	0.21	0.37	10.8
Kuje Road	Termite hill	6.7	6.3	0.49	0.60	8.20	0.94	0.10	0.40	11.4
	Adjacent soil	6.7	6.4	0.71	0.60	7.40	1.00	0.10	0.05	10.3
Zuba Road	Termite hill	6.6	5.9	0.52	0.60	7.00	0.88	0.12	0.41	9.8
	Adjacent soil	6.6	5.5	0.63	0.60	0.60	0.78	0.26	0.38	9.4

The Effective Cation Exchange was rated as being low in both the termitaria and adjacent soils. However, the termitaria showed higher values than the adjacent soils. The lower values of the ECEC and other chemical properties in the undisturbed adjacent soils could be attributed to low activity clay (LAC) such as kaolinite which are predominant in most sandy or sandy loamy soil, coupled with low organic matter content (Adepetu, 2000; and Brady and Weil, 2002) relative to soils in termitaria enriched by the termites. Some sub-soils often used by termites in building their mounds may be richer in mineral nutrients than topsoil or rich in clay compared to very sandy surface soils, hence, greater availability of phosphorus (P), K, Ca and moisture that might have led to the observed differences (Brady and Weil, 2002).

Metallic Micronutrients status of Termitaria and Adjacent Soils

The status and distribution of metallic micronutrients in the termitaria and adjacent soils in Gwagwalada Area Council of the FCT is presented in Table 3. The available extractable copper (Cu) in the termitaria soils ranges from 1.77 to 8.94 mg/kg with a mean of 6.60 mg/kg. In the adjacent soils, Cu was in the range of 2.57 to 9.36mg/kg with mean value of 6.82 mg/kg.

The range of Cu in the soil was rated as high (NAC, 2003). It was within the range obtained by Sanni (2012) who reported values of 1.35 mg/kg to 6.27 mg/kg.

From the results obtained in Table 3, the extractable manganese (Mn) in the soils of termitaria ranges from 35.90 to 71 mg/kg with a mean value of 52.1 mg/kg, while in the adjacent soils, the Mn status was in the range 34.50 to 117.92 mg/kg. These values were similar to what Onyeari (2013) reported. These values were far above the critical values for plant requirement (Chude *et al.,* 1993). The relative abundance of the Mn in the soils of the termitaria and adjacent soils cannot be unconnected to the inherent content of the parent material which characteristically has Mn as a major constituent (Foth, 2006; Agbede, 2009; Esu, 2010; Chude *et al*., 2011; and Nwaka, 2012). The pH range of the termitaria in the adjacent soils favours relative abundance of Mn (Warmate *et al*., 2011). The study confirmed that Mn in the adjacent soils was higher than Mn in the termitaria, thus, implying that the activities of termites reduce the abundance of Mn in the termitaria soils.

Table 3: Some Micronutrients Status of Termitaria and Adjacent Soils in Gwagwalada

Sample Soil	Sample Location	Cu	Mn (Mg/kg)	Zn	Fe
Main Campus	Termite hill	8.94	66.80	4.58	124.32
	Adjacent soil	8.53	72.84	7.95	267.53
Mini Campus	Termite hill	8.94	42.78	6.97	92.22
	Adjacent soil	9.36	65.11	8.23	83.58
Kwali Road	Termite hill	1.77	54.86	3.74	40.37
	Adjacent soil	2.57	108.65	14.13	70.00
Kuje Road	Termite hill	4.18	35.90	5.56	23.09
	Adjacent soil	3.72	34.50	3.74	20.62
Passo Road	Termite hill	8.20	39.97	39.27	97.16
	Adjacent soil	8.63	80.84	7.56	132.96
Zuba Road	Termite hill	7.52	71.99	7.11	98.40
	Adjacent soil	8.12	117.92	8.37	123.09

The distribution and status of extractable iron (Fe) in the termitaria and adjacent soils as presented in Table 3, shows that Fe in the termitaria ranges from 23.09 to 124.32 mg/kg, while in the adjacent soils, the Fe distribution was in the range of 20.62 to 267.53 mg/kg with a mean value of 116.30 mg/kg. The range of values in the termitaria was lower than in the adjacent soils. However, the range of value in both the termitaria and adjacent soils was rated as very high (North-western Agricultural consultants, 2003). Sanni (2012) reported a similar finding in the soil of Dobi, a sub-urban of Gwagwalada. Sanni (2012) also reported a positive correlation between soil pH and Fe. Also, Onyeari (2013) reported higher figures for the soils of University of Abuja Teaching and Research farm. It has been found to occur at high concentration in Nigeria's soils (Adefemi *et al*., 2007). The higher levels of Fe in the adjacent soils can be attributed to rainfall and runoff which induces acidity.

The status of zinc (Zn) in the termitaria and adjacent soils is presented in Table 3. The result showed that the range of Zn in the termitaria ranges from3.74 to 39.27 mg/kg with a mean value of 11.21 mg/kg, while in the adjacent soils, the range is from 3.74 to 14 13 mg/kg with a mean value of 8.33 mg/kg. The trend in the results showed that Zn in the termitaria soils in all the locations studied was lower in Zn content than in the adjacent soils except for termitaria in Passo and Kuje Road which gave values higher than their adjacent soils. In both cases, the values for Zn indicated that it was highly abundance (North-western Agricultural consultants, 2003). The high Zn content of the soils generally could be attributed to the relatively high clay content, slightly acidic soil reaction and the organic matter content of the soils both the termitaria and the adjacent lands. All these factors favours the level of Zn in any soil. Del Castilho *et al.* (1993) and Reichman (2002) reported that the amount of organic matter found in soils also affects the bioavailability of Zn. Fotovat *et al*. (1997) reported that Zn readily forms complexes with organic matter.

CONCLUSION AND RECOMMENDATIONS

Termitaria soils differed in chemical and physical properties from the surrounding adjacent soils in Gwagwalada Area Council, located in the Northern Guinea savannah zone of Nigeria. The termitaria soils were found to higher in OC, Ca, Mg, ECEC as well as exchangeable K. The termitaria soils had an indication of lower pH and exchangeable Na than the undisturbed adjacent soils. The higher values of ECEC, OC, Ca and Mg can be attributed to the incorporation of O.M or richer subsoil into the termitaria.

Soil texture of the termitaria shows an indication of higher clay content, having sandy clay loamy texture. The increase in clay content of the termitaria is attributed to the activity of termites in modifying soil physical condition through churning soils (clay) from sub soils and cementing them with saliva, faeces and organic matter

All the termitaria were rich in metallic micronutrients (Cu, Mn, Zn and Fe) but have lower values than the adjacent undisturbed soils by termites. The high abundance of the micronutrients in all the soil is attributed to the nature of the parent material which is granites from undifferentiated basement complex. Also, the high content of the micronutrients can be as a result of accumulated organic matter in the soil. All the properties studied indicate that there are more desirable characteristics for crop production in termitaria soils.

Based on the results obtained and the conclusion deduced from the study, the following recommendations were made:

i. Spent (old) termite mounds could be used as incidental fertilizer that could improve crop production. This is because of their high organic matter content and relatively favourable pH for most crops.
ii. There was no basis for further addition or supplementation of micronutrients on the adjacent soils of the termitaria, as well as on the termitaria themselves. This was because of their relative high abundance in both the termitaria soils and the adjacent undisturbed soils in the study area.

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