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EFFECT OF TERMITES (*GNATHAMITERMES Perplexus*) INFESTATION ON SPATIAL VARIATION OF SOIL PROPERTIES AND HORTICULTURAL CROPS GROWTH

[1]Abdallah, Y. and [2]Jibrin, A. D.
[1]Crop Protection Unit, Department of Agriculture and Technical Services,
Bauchi State Agricultural Development Program (BSADP) PMB 050, Bauchi, Nigeria.
[2]Department of Crop Production, Faculty of Agriculture and Agricultural Technology,
Abubakar Tafawa Balewa University, PMB 0248, Bauchi, Nigeria.
Corresponding Authors' E-mail: fialdawji@gmail.com **Tel.:** +2348034579808

ABSTRACT
The study was conducted to evaluate the effect of termites (*Gnathamitermes perplexus*) infestation on spatial variation of soil properties and horticultural crops growth in Alkaleri Local Government area of Bauchi State, Nigeria. A total of 68 soil samples were collected from two (2) location; 34 each from termites infested area and in a location without termite's infestation. Results showed that the soils were characterized by very low to medium organic matter content, very low to low levels of nitrogen content, available phosphorus range between low and high, exchangeable bases (calcium, magnesium) in both soils ranges between very low and low, Sodium content ranges between medium and high with only slight variation in Cation exchange capacity (CEC). Results of soil analysis further revealed that pH (water) and pH ($CaCl_2$) of both soils of the study area were acidic in nature. Correlation analysis showed that there was positive and significant relationship between pH versus CEC at 0.044**; organic matter versus CEC at 0321**; and calcium versus CEC at 0.909**. Correlation was again significant at $P \leq 0.05$ levels between available phosphorus versus calcium at 0.307* and available phosphorus versus CEC at 0.263*. T-test carried out revealed that the activities of termites in the infested soil placed the nutrients status higher compared to the surrounding soils without termites infestation. The study concluded that termite's activities have also affected the lateral and spatial variation of both chemical and physical soil properties and horticultural crops growth in the research area. The study recommended that government, cooperate organizations and private individuals should encourage and provide adequate funding for a further research in both soils and horticultural crops infested with termites and farmers be enlightened to adopt modern techniques and skills for soil and fertility management.

Keywords: Ecosystem, Fertility, Organism, Productivity, Roots, Sustainability.

INTRODUCTION
The soil system plays a pivotal role in the major geochemical cycles. Soils have the capacity to assimilate great quantities of organic waste, turning it into beneficial humus and converting the mineral nutrients in the wastes to forms that can be utilized by plants and animals (Brady and Weil, 2002). Soils supply plants with inorganic nutrients in the form of dissolved ions. These minerals include such metallic elements as potassium, calcium, iron and copper as well as such nonmetallic elements as nitrogen, sulphur, phosphorus and boron. From the food chain, humans and other animals usually obtain the minerals they need (Tuley and Mary, 1975).

A fundamental role of soil in supporting plant growth is to provide a continuing supply of dissolved mineral nutrients in amount and proportions appropriate to plant growth (Brady and Weil, 2002). The productive capacity of soils depends on many factors, including the flora and fauna. Soil fauna, especially earthworms and termites, are important components of the soil ecosystem. An understanding of the effects of soil micro fauna and their effects on the ecosystem is very important to soil quality and crop production (Watson *et al.,* 1985).

The termite's ability to adapt to arid environment has led them to fill the important role of decomposition where common decomposes such a bacteria, and fungi cannot function. Australia for example offered an ideal place to study the effects of dry environments on termites because of the low precipitation elevated heat levels of desert ecology and savannah (Ratcliff *et al.,* 1975). Termites are social insects of the order isopteran with about 3,000 known species of which 75% are classified as social feeding termites. The diet of soil feeding termites consists of non-cellular organic materials. Their guts are formed by five compartment that present rising gradients of pH up to 12.5 and different status of oxygen and hydrogen (Breuning-Madsen *et al.,* 2005; and Donovan *et al.,* 2001). Termites consume roughly 20% by weight of litter fall and about 10% of annual primary production in the tropical wet forest of Ghana (Usher, 1978) and are therefore very important agents in nutrients recycling (Wagner *et al.,* 1991; and Wood and Sand, 1978).

Soil feeding termites transport soil particles for mound building and such process can affect soil formation and characteristics. It is evidenced that termites modify soil characteristics due to great volume of soil transported for mound construction which promotes a strong pedo-bioperturbation and affects nutrient cycling and soil physical properties. The modification of soil profiles activity depends on the fact that termites remove soil from various depths and bring it to the surface in form of covered runways or mounds from which it is distributed by water and wind erosion (Wagner *et al.,* 1991).

Furthermore, the wood-eating termites are important agents, moving soil materials from the deeper soil horizons to the dead wood on surface of the forest floor. When the wood has been eaten and partly replaced with soil material by the termites, the termites leave the place and the soil material is later incorporated in the soil. Termites are known to disbud soil materials (Kaschuk *et al.,* 2006) because the collect particles from different soils depths deposit main in mounds. Hence the various contents of the soil can be different from those of the adjacent soils. This perturbation may have impacts on soil from those of the adjacent soils. This perturbation may have impacts on soil variation.

Alkaleri local government area (LGA) of Bauchi State is one of the areas in Nigeria where termite's infestation in soil has become prevalent, and tremendously felt. Extensive areas of horticultural, agricultural and non-agricultural lands are affected. Almost all kinds of crops are affected. Farmers always complain through various extension service outlets, about the menace, devastation and destruction of termites on horticultural crops. The disturbance impacted on soils is also a matter of great concern and by implications; the soil perturbation will surely have effects on soil variation and precision agriculture. Although, it is of immense importance to note that termites contribute to the breakdown of organic material in or at the surface of soil (Watson, 1975). High soil organic matter content and favourable soil structure depend on the activities and species diversity of soil fauna. The activity of soil macro fauna (e.g., termites and earthworms) is critical to the sustainable maintenance of favourable soil structure and mineral cycling (Lal, 2008). Unfortunately, no work has been done on the effects of termite's infestation on spatial variation of soil properties and horticultural crop growth in the study area. Therefore, the study was set out to determine the spatial variation of soils that are infested by termites activities, document the spatial variation of soils that are not infested by termites activities (as control) and to evaluate the effect of termites infestation on soil variation and horticultural crop growth in the study area.

Termites are common biological agents that produce significant physical and chemical modifications to tropical and sub-tropical soils (Nye, 1955). They generally go through a sequence of action from fetching and carrying, to cementing mineral particles into mounds by their salivary secretion (Wood *et al.*, 1978; Donovan *et al.*, 2001; and Lopez-Hernandez *et al.*, 2006). It has been shown that termite's activities increase the content of organic matter in soils and modifies the clay mineral composition of these soil materials (Snyder, 1984). Termites have significant impacts on the mobility of trace elements that are generally considered to be non-essential to living systems (Breuning-Madsen, 2004). Nevertheless, it cannot be altogether denied that the dynamics of mobility of trace elements may hold significant clues as to understandings of the processes of reorganization of soils minerals and relocation of chemical elements that constitutes the framework of soil minerals (Creffield, 1991). However, it might be of interest to note that termites generally build epigeous nest having homogenous structures even with varied nest shapes (Brady and Weil 1996). The materials needed for construction of the nests are taken by termites from immediate environment generally limited to a few meters surrounding the needed area, the minerals of the soil represent often the basic used materials and termites mix oil materials with wood and excrement for construction of the nest (Breuning-Madsen *et al.*, 2004).

MATERIALS AND METHODS

The Study Area

The specific area evaluated for the study is located at 3km away from Alkaleri town in Alkaleri Local Government area (LGA) at 10°15′34.80″N 10°20′4.20″E, 1053 meters above sea level. Temperature of the area typically varies from 59°F to 101°F and is rarely below 54°F or above 105°F. The area has average wind speeds of more than 9.4-5.1 miles per hour with an average total rainfall accumulation of 7.3 inches and average humidity level of 20%-50% (Tuley and Mary, 1975). Alkaleri LGA is situated along Futuk road with fairly flat agricultural farmlands that are cultivated to onion, pepper, sorrel, amaranth, tomato, eggplant (*gauta*), millet, sorghum, maize and cowpea in between plants stands. The soils of the study area are severely infested by termites. There is remarkable evidence of termite's infestation as a result of cursory observation of the crop residues with apparent symptoms of termite's infestation decaying and decomposing crop residues in the field.

Sampling Techniques and Sample Size

To obtain the samples, two (2) sampling techniques used were random sampling and systematic sampling techniques. In the study area, there are four (4) big temnitarium (termite mounds) about 50m apart perpendicularly located. Soil samples were taken in the field using these techniques by measuring total area of 25x25m. The area was totally divided into 25 smaller blocks and each measuring 5x5m and soil samples taken by stratified random sampling technique. This was done by taking samples in each time; soils samples were collected in the exact position and mix together with soils collected at 4 angles of 5x5m block. It was later put in polythene bag as one (1) sample. The idea is to give and equal chance of representation in the whole sample during analysis.

Stratified random sampling technique was used to collect a total of 25 surface (0 – 15cm) soil samples from the termite's infested soil surface, and a total of nine soil sample from the termites infested sub-soil surface (35 – 50cm). This same technique was also applied in the collection of soil samples from termite's non-infested area. A total of 25 soil samples were obtained in the soil surface of non-infested by termites and nine samples were also taken from the sub-surface soils of non-infested area, making a total of 28 soils samples covering both termite's infested and non-infested areas. The technique was applied in collecting all the 68 soil samples for both infested and non-infested areas. The total number of samples was taken from: (a) Termites infested area (Surface = 25 and Subsurface = 9) and (b) Termites non-infested area (Surface = 25 and Subsurface = 9) making 68 as the total number of samples collected.

Methods of Data Collection

Data were collected using primary sources. Data from field and laboratory analysis of soil samples here refer to as primary data and data from existing works which constitute relevant literature and other data on climate and geology, among others formed the Secondary data. A reconnaissance survey of the study area was carried out by meticulously selecting and identifying termites infected soils (farm lands) having termites mounds with termites presence of plants residues and surrounding trees area along Futuk road in Alkaleri area was selected for the study. The area has high infestation of termites with termite's infestation symptoms on plant residues after the previous farming season's harvest. There are presences of quite a number of termite's mounds within and around the study area; whereas there are about 100 meters across the infested area where no symptoms of termite's infestation.

Laboratory Analysis of Soil Samples

Particle Size Analysis: This was determined by the hydrometer method (Walkley and Black, 1965).

Soil pH (Water and CaCl Solution): The pH of the soils was potentiometrically measured in suspension of 1:2:5: (soil: liquid: mixture) measurements were both in water ad 1M $CaCl_2$ solution because the difference between the two values could give an idea about the soil potential or reserve acidity.

Organic Carbon: The Walkley-black wet oxidation procedure (Walkley and Black, 1934) was followed in determining the matter content. For the conversion to organic matter factor 1.7.2 was used.

Total Nitrogen (TN): Total Nitrogen content determined using the classic Kjeldahl method followed by stream distillation (Bremner, 1965). It involved the digestion of the soil with sulphuric acid (H_2CO_4) and hydrogen peroxide whereby nitrogen could be converted to ammonia sulphate and the ammonia evolved was titrated with standard acid.

Available Phosphorus (AP): Available phosphorus was determined using Bray and Kurt (1945) No. 1 method.

Exchangeable Bases (Ca, Mg, K, Na): Exchangeable cations were determined by leaching the soils with ammonia acetate at pH 7.0 potassium and sodium in the leachate were determined by flame photometric method while calcium and magnesium were determined by atomic absorption spectrometry.

Exchangeable Acidity: The exchangeable acidity was determined by KCl method (Page *et al.*, 1982) while the exchangeable acidity determination was performed by percolating soil with 1M KCl solution. The acidity in the percolate was then measured by titrating it with 0.025m NaoH.

Analytical Techniques

Correlation analysis t-test and other descriptive statistics constitute the major statistical techniques adopted to explain and describe the soil data, standard deviation, mean; range and coefficient of variation are some of the statistical tools that were used in the presentation and interpretation of the data.

RESULTS AND DISCUSSION

Soil analysis presented in Table 1 and Table 2 shows that the sand contents of the soil was generally high. This is because the soils are mainly underlain by acolian (or wind-drifted) materials (Olowolafe and Dung, 2000). According to Brady and Weil (2002), when the sand contents exceeds 75% in a sample, the soil is a sandy one. Particle size analysis of both termite infested soils and the surrounding soils not infested indicates that the percentage of sand in all samples exceed 75%. Hence, the soils of the study area are sandy in nature. The implication is that there may have high rates of infiltration and leaching. This may lead to low base status.

The results of the particle size analysis of termite infested soils indicate that sand percentage ranges from 72% to 94% with a mean value of 86.06%, clay percentage ranges from 4% to 22% with mean value of 8.82% and silt percentage ranges between 2% and 46% with a mean value of 6.35%. Particle size analysis also indicates that soils with termite infestation are mainly coarse-textured and the dominant textural classes are mostly loamy sand. The result of particle size analysis of soils not infested by the activity of termites indicate that sand percentage ranges between 80% and 94% with a mean value of 89.12%, clay percentage of the soils not infested by termites ranges between 4% – 18% with a mean value of 7.18% while silt percentage in the termite non infested soil ranges between 2% – 8% with a mean value of 3.71%.

Particle analysis shows that soils not infested by the activity of termites are mainly loamy sand and sand as the dominant class. The difference in the textual class of the termite infested soils and soils without termite infestation clearly demonstrate the significant role of termite in disturbing the soils and also in the addition of dead plant material and thereby nutrient recycling (Wagner *et al.*, 1991).

Organic Matter Content

Result of the chemical analysis shows that organic matter content (OC) of the termite infested soils ranges between 0.060% and 0.720% with a mean value of 0.299% (Table 1) and that of the surrounding soils without the activity of termites ranges between 0.10% and 0.29% with a mean value of 174% (Table 2). Hence, this indicates that the organic matter content of e termite infested soils ranges between very low to medium while that of soils without termite's infestation ranges between very low and low (Ilaco, 1995; and Lobry de Bruyn, 1999).

The activities of termites were able to raise the organic matter content of the infested soils slightly above that of the surrounding soils without termite's infestations. This indicates that termites often act as primary decomposers in dry climates where there is no enough moisture for organisms like fungi, earthworm, micro-bacteria and beetles (Akamigbo, 1984). The low level of organic matter can be attributed to poor soil management practices, bush burning, overgrazing and the removal of crop residues. Olowolafe and Dung (2000) have obtained a similar result for soil on the Jos Plateau.

There was a significant correlation between organic matter and calcium at 0.376** (Table 3). This is to say that organic matter is responsible for wholesome amount of Ca in the soils. Organic content plays a significant role in agricultural production. It supplies plant nutrients, enhances cation exchange capacity, improves soil water retention capacity, and enhancement of soil aggregate stability. Organic matter content also improves soil structure by providing good soil aeration, permeability and increasing rate of infiltration and water holding capacity. The organic matter of both soils is very low, with termites infested soils having a mean value of 0.298% and soils without termite infestation having a mean value of 0.741% (Ilaco, 1985; and Brady and Weil 1996). This results shows that there is need for continuous addition of organic matter, through adoption of several agronomic and good management practice by addition of organic fertilizers (green manure), incorporation of crop residues in the soils, increasing humus content, addition of poultry droppings, and cow-dung. As organic matter declines, plant nutrients such as nitrogen and phosphorus are mostly at risk (Reullen, 1971).

Soil Reaction (pH): **pH (H_20)**

The result of the chemical analysis shows that pH (H_20) of the termite infested soils ranges between 5.10 and 7.50 with a mean value of 6.30 value of 6.30 (Table 1) and that of the surrounding soils without termites' activity ranges between 4.70 and 6.80 with a mean value of 5.41 (Table 2). The pH (H_20) of the termite infested soils is higher than that found for the surrounding soils without termites' activity. The pH (H_20) of the termite infested soils ranges between very strongly acidic and very slightly acidic while that of the surrounding soils not infested by termite ranges between strongly acidic to slightly acidic (Ilaco, 1985; and Pearce, 1997).

Soil pH is an important property that determines the availability of plants nutrients. The soils evaluated in the research area for the termite infested soils are generally slightly acidic with pH ranging between 6.1 and 6.5 while the soils without termites infestation are moderately acidic with pH value ranging between 5.6 and 6.0 (Pomeroy, 1976; and Ilaco, 1985).

Most of the tropical crops perform best under the pH values that ranges from 5.0 - 6.5 (Martin, 2000). Most of horticultural and agricultural crops such as pepper, onion, sorrel, amaranth, tomato, millet, maize cowpea and soybeans cultivated in the research area have their pH values in which they perform minimally despite sound agronomic and management practices by farmers within these communities. The sources of hydrogen ions in the soils that causes acidity are carbonic acid (when carbon-dioxide gas from soil air dissolves in water thus weak acid is formed), precipitation (rain, snow, fog and dust) among others (Lal, 1988). Lal (1998) further stated that at pH levels below 4.0 - 4.5, the H* ions are of sufficient concentration to be toxic to plants mainly by damaging the root membranes.

Cation Exchange Capacity

The cation exchange capacity (CEC) of the termite infested soil ranges between 3.40 - 9.40cmol/kg^{-1} with a mean value of 5.238 (Table 1) and that of the surrounding soils not infested by the activity of termite ranges between 3.10cmol/kg^{-1} - 9.60cmol/kg^{-1} with a mean value of 4.464cmol/kg^{-1} (Table 2). There is only a slight variation in the CEC of both termite infested and non-infested soils. There is significant correlation between organic matter and CEC at 0.325** and organic matter vs. calcium at 0.376** as shown in Table 3.

Total Nitrogen

The result of chemical analysis shows that the total nitrogen (TN) content of termites infested soils ranges between 0.193% and 0.530% with a mean value of 0.239% (Table 1) while the total nitrogen content of soils not infested by the activity of termites ranges between 0.19% and 0.26% with a mean value of 0.228% (Table 2). The total nitrogen of both soils ranges between very and low levels of nitrogen. High temperature, as often occurs on the surface of the soil in tropical areas favors the volatilization of organic matter and leaching in the drainage water may account for the low levels (Wagner *et al.*, 1991; and Lobry de Bruyn and Canacher, 1990). A good supply of nitrogen stimulates root growth and development as well as the uptake of other nutrients. Plants respond quickly to increased availability of nitrogen their leaves turning deep green in color. Nitrogen increase the plumpness of cereal grains, the protein content of both seeds and foliage (Usher, 1978; and Limbarg, 1974).

Nitrogen is also essential for plant growth as it is a constituent of all proteins and, hence, of all protoplasm. It is generally taken up by plants either as an ammonium or nitrate ions but the absorbed nitrate is rapidly released probably to ammonium ions and some of the carbohydrates synthesized in the leaves are converted into amino acids mainly in the green leaf itself (Wagner *et al.*, 1991). Hence, as the level of nitrogen supply increases compared to other nutrients, the extra protein produced allows the plant leaves to grow larger and hence to a larger surface available for photosynthesis. Nitrogen increases the size of the cells and gives them a thinner, wall hence makes leaves more succulent. Excessive amounts of nitrogen give leaves with such large thin walled cells that they are readily attracted by insects and harmed by hash weather such as droughts and frosts (Krishna and Weesner, 1970).

The deficiency of nitrogen in soils are responsible for stunted growth and pale yellowish green color (chlorosis) (Tayasu *et al.*, 1998) and plant growing under this type of condition are highly affected, which results in low yield and poor growth quality. A very low nitrogen supply also gives leaves, small cells and thick walls and the leaves in consequence become harsh and fibrous.

Available Phosphorus

The results of the chemical analysis shows that available phosphorus (AP) of the termite infested soils ranges between 4.48ppm and 50.40ppm with a mean value of 14.93ppm (Table 1) and available phosphorus for soils not infested by termite activities ranges between 1.96ppm and 7.84ppm with a mean value of 4.63ppm (Table 2). The result of the chemical analysis confirms that there is a higher amount of available phosphorus in the termite infested soils compared to the figures observed from the soils without termites. The available phosphorus of the termite infested soils ranges between low and high values while that of the soils without termite infestation is low. The high amount of available phosphorus (AP) in the termite infested soils could be attributed to the close correlation between soil organic matter and available phosphorus (Ilaco, 1985; and Krishna and Weesner, 1970). The high and positive correlation at 0.600** indicates significant correlation between organic matter and available phosphorus (Table 2). There is significant correlation between available phosphorus and CEC at (0.26**) (Table 3).

The result shows that the phosphorus level of both infested and non-infested soils are low which requires addition of phosphorus during crop production on both sides. Plants take up their phosphorus almost exclusively as inorganic phosphate ions probably principally as the H_2PO4^{-}ion^{2} for they may take this up more easily than the HPO_3^{-1}. Other phosphate besides ortho-phosphate acts as phosphate fertilizers. For example, in Meta and pyro-phosphates, it is probable that these anions are hydrolyzed to ortho-phosphate before being absorbed. Plants are however relatively inefficient users of phosphates in the fields for rarely more than 20 - 30 of the amount supplied' as fertilizer is taken up.

Exchangeable Bases (Ca, Mg, K, Na)

Calcium (Ca)

The result of chemical analysis shows that calcium content of the termite infested soils ranges between 1.60cmol/kg^{-1} and 5.20cmol/kg^{-1} with a mean value of 2.850cmol/kg^{-1} (Table 1) and calcium content of the surrounding soils without termite's infestation ranges between 1.20cmol/kg^{-1} and 5.00cmol/kg^{-1} with a mean value of 2.238cmol/kg^{-1} (Table 2). The Calcium content of the termite infested soils ranges between very low and medium and that of the surrounding soils without termites ranges between low to medium (Black and Okwakol, 1997). The result indicates that the activities of termites could not raise the calcium content above that of the surrounding soils without termite's infestation. There is significant correlation between calcium and CEC at 0.909** and Calcium versus Magnesium at 10.405** (Table 4). Calcium appears to be essential for the growth of meristems and particularly for the proper growth and functioning of roots tips. It is also present as calcium pectate which is a constituent of the middle lamellae of the cell walls and possibly for this reason, it tends to accumulate in the leaf. Calcium is also helps in cell elongation and division, membrane permeability and the activation of several critical enzymes.

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Magnesium (Mg)

The result of chemical analysis shows that magnesium content of termite infested soils ranges between 0.83cmol/kg^{-1} and 1.5cmol/kg^{-1} with a mean value of 0.429cmol/kg^{-1} (Table 1) while that of the surrounding soils without termites ranges between 0.17cmol/kg^{-1} and 2.16cmol/kg^{-1} with a mean value of 0.685cmol/kg^{-1} (Table 2).

The magnesium content of the termite infested soils ranges between low and medium and that of the surrounding soils without termite infestation ranges between very low and medium (Ilaco, 1985; and Creffield, 1991). The results confirms that there is a higher magnesium content in the termite infested soils as compared with that obtained from the surrounding soils without termites. This implies that there is significant correlation between magnesium and CEC at 0.534** and Magnesium versus Calcium at 0.405** as presented in Table 3.

Sodium (Na)

The result of chemical analysis shows that sodium content of termite infested soils ranges between 0.35cmo/kg^{-1} and 1.39cmol/kg^{-1} with a mean value of 0.636cmol/kg^{-1} (Table 1) while that of the surrounding soils without termites activities ranges between 0.61cmo/kg^{-1} and 0.78cmol/kg^{-1} with a mean value of 0.67cmol/kg^{-1} (Table 2). The amount of sodium contained in soils with termites is lower than that of soils without termites. The sodium content of soils infested by termites ranges between medium and high while that of the surrounding soils without termites is medium (Tayasu *et al.,* 1998). Sodium does not seem to be an essential element for any crop even for salt marsh plants yet certain crops grow better in the presence of available sodium supplies than in their absence, the sodium in these cases appearing to carry-out some functions that potassium usually fulfills. Sodium also increases the succulence of plants that is the amount of water held by unit dry weight of leaf tissue. This may be the reason why it appears to increase the drought resistance of these plants.

Sodium helps certain varieties of horticultural crops to grow in potassium deficient soil, thus, it prevents an accumulation of other cations that may be toxic to the plants. Horticultural crops can be divided into groups with respect to their relative needs of sodium compared to potassium, some need sodium for optimum growth, some benefit if available sodium is present, some can tolerate part of their potassium supply being replaced by sodium and some can make no use of sodium even if the potassium supply is restricted. The relationship among soil parameters has been reported by Field (1993); Park (1996); and Agboola and Corey (1973) who empirically justify by the results of correction analysis among variable.

Table 1: Surface and Sub-surface Soil Properties of Study Site with Termites Infestation

Soil Variables	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Clay	18	4	22	8.82	4.064	16.513
Silt	44	2	46	6.35	7.126	50.781
Sand	22	72	94	86.06	4.445	19.754
Water	2.4000	5.1000	7.5000	6.300000	0.4886593	0.239
CaCl	3.000	3.8000	6.8000	5.247059	0.7431445	0.552
OC	0.6600	0.0600	0.7200	0.298941	0.1494209	0.022
TN	0.337	0.193	0.530	0.23921	0.066911	0.004
AP	45.9200	4.400	50.4000	14.927059	9.0337386	81.608
Ca	3.6000	0.6000	5.2000	2.850000	08239778	0.679
Mg	1.4970	0.0830	1.5800	0.429882	0.3278690	0.107
K	27.9600	0.0400	28.0000	1.465794	4.719121	22.70
Na	1.04	0.35	1.39	0.6362	0.19487	0.083
H_Al	0.7	0.1	0.8	0.265	0.1495	0.022
CEC Valid N (list wise)	6.0000	3.4000	9.4000	5.23835	1.3133383	1.725

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Table 2: Surface and Sub-surface Soil Properties of Study Site without Termites Infestation

Soil Variables	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Clay	4	4	18	7.81	2.59	8.756
Silt	6	2	8	3.71	1.567	2.456
Sand	14	80	94	89.12	3.198	10.228
Water	2.10	4.70	6.80	5.4059	0.45921	0.211
CaCl	1.10	3.80	4.90	4.3735	0.25383	0.064
OC	0.19	0.10	0.29	0.1741	0.04995	0.022
TN	0.07	0.19	0.26	0.2283	0.019434	0.0000
AP	5.88	1.96	7.84	4.6214	1.67522	2.806
Ca	3.80	1.20	5.00	2.2382	0.79849	0.638
Mg	1.99	0.17	2.16	0.685	0.40776	0.166
K	0.09	0.01	0.10	0.441	0.01777	0.000
Na	0.17	0.61	0.78	0.6700	0.05560	0.003
H_Al	0.70	0.10	0.80	0.3882	0.21144	0.045
CEC Valid N (list wise)	6.50	3.10	9.60	4.4647	1.38911	1.930

Table 3: Correlation of Position between Variables using Predictive Analytics Software

S/N	Correction	Value	Level of significance
1	Available phosphorus vs. organic content	0.600**	**Correlation is significance at 0.01 level
2	Calcium vs. C.E.C	0.909**	**Correlation is significance at 0.01 level
3	pH ($CaCl_2$) vs. C.E.C.	0.440**	**Correlation is significance at 0.01 level
4	Organic content vs. potassium	0.325**	**Correlation is significance at 0.01 level
5	Available phosphorus vs. C.E.C	0.263**	**Correlation is significance at 0.05 level
6	pH ($CaCl_2$) vs. potassium	0.067**	Not significant
7	Magnesium vs. C.E.C	0.534**	**Correlation is significance at 0.01 level
8	pH ($CaCl_2$) vs. calcium	0.506**	**Correlation is significance at 0.01 level
9	Total nitrogen vs. H_Al	0.142**	Not significant
10	Organic content vs. Calcium	0.376**	**Correlation is significance at 0.01 level
11	Calcium vs. magnesium	0.405**	**Correlation is significance at 0.01 level
12	Potassium vs. potassium	0.223	Not significant
13	pH (water) vs. potassium	0.116	Not significant
14	pH ($CaCl_2$) vs. Organic Content	0.682**	**Correlation is significance at 0.01 level
15	pH ($CaCl_2$) vs. available phosphorus	0.596**	**Correlation is significance at 0.01 level
16	pH ($CaCl_2$) vs. magnesium	0.008	Not significant
17	Available phosphorus vs. calcium	0.307*	**Correlation is significance at 0.01 level
18	Available phosphorus vs. potassium	0.010	Not significant
19	C.E.C vs. calcium	0.909**	**Correlation is significance at 0.01 level
20	pH (water) vs. organic content	0.577**	**Correlation is significance at 0.01 level
21	Sodium vs. organic content	0.13	Not significant
22	Potassium vs. organics content	0.067	Not significant
23	Magnesium vs. H_Al	0.055	Not significant
24	Total Nitrogen vs. Available phosphorus	0.023	Not significant
25	pH (water) vs. available phosphorus	0.0611**	**Correlation is significance at 0.01 level
26	pH (water) vs. total nitrogen	0.014	Not significant
27	pH (water) vs. calcium	0.442**	**Correlation is significance at 0.01 level
28	pH (water) vs. C.E.C	0.350**	**Correlation is significance at 0.01 level
29	pH ($CaCl_2$) vs. potassium	0.063	Not significant
30	Sodium vs. potassium	0.587	Not significant
31	Potassium vs. Calcium	0.189	Not significant

Table 4: Negative Correlation between Variables using Predictive Analytics Software

S/N	Correction	Value	Level of significance
1	Available phosphorus vs. organic content	-0.399**	**Correlation is significance at 0.01 level
2	Total Nitrogen vs. pH ($CaCl_2$)	-0.036	**Correlation is significance at 0.01 level
3	Potassium vs. H^+Al	-0.126	**Correlation is significance at 0.01 level
4	Organic content vs. magnesium	-0.014	**Correlation is significance at 0.01 level
5	Available phosphorus vs. magnesium	-0.199	**Correlation is significance at 0.05 level
6	Magnesium vs. sodium	-0.190	No significant
7	Total Nitrogen vs. potassium	-0.058	**Correlation is significance at 0.01 level
8	Total Nitrogen vs. C.E.C	-0.007	**Correlation is significance at 0.01 level
9	pH ($CaCl_2$) vs. H_Al	-0.452**	Not significant
10	Sodium vs. C.E.C	-0.087	**Correlation is significance at 0.01 level
11	Total Nitrogen vs. calcium	-0.039	**Correlation is significance at 0.01 level
12	pH (water) vs. magnesium	-0.167	Not significant
13	Total Nitrogen vs. Magnesium	-0.030	Not significant
14	Calcium vs. sodium	-0.190	**Correlation is significance at 0.01 level
15	pH ($CaCl_2$) vs. sodium	-0.448**	**Correlation is significance at 0.01 level
16	Organic matter vs. sodium	-0.376**	Not significant
17	Magnesium vs H_Al	-0.55**	**Correlation is significance at 0.01 level
18	Total nitrogen vs. potassium	-0.058	Not significant
19	pH ($CaCl_2$) vs. total nitrogen	-0.036	**Correlation is significance at 0.01 level
20	Total Nitrogen vs. organic content	-149	**Correlation is significance at 0.01 level
21	Magnesium vs. available phosphorus	-0.199	Not significant
22	Available potassium vs. sodium	-0.339**	Not significant
23	Calcium vs. H^+Al	-0.70	Not significant
24	Magnesium vs. potassium	-0.103	Not significant
25	pH ($CaCl_2$) vs. H^+Al	-0.452**	**Correlation is significance at 0.01 level
26	pH (water) vs. sodium	-0.314	Not significant
27	Sodium vs. magnesium	-0.143	Not significant
28	Available phosphorus vs. H_ Al	-0.083	Not significant

As presented in Table 1 and Table 2 (summary of the surface and subsurface soil data), soil texture has been modified by the activities of termites with clay having a mean value of 8.82% for the infested soils and while the non-infested soil has a mean value of 7.18%. Silt has a mean value of 6.35% for the infested soils and a mean value of 3.71% for the termite not infested soils. Sand has a mean value of 86.06% recorded for soils with termite's activities and a mean value of 89.12% for the non-infested soils. The result for this analysis also shows that pH (water) has a mean value of 6.300% for soils that are affected by termites activities, while the termite non-infested soils has a mean value of 5.405%. These results indicate that the pH of termite infested soils is higher than that of the surrounding soils without termite's infestation by Donovan *et al*. (2001).

Soils pH of termites infested area is slightly acidic which the surrounding soil without termite activities is strongly acidic (Eurocon and Landon, 1991; and Ilaco, 1985). The activities of termites in both soils analyzed could have contributed to the difference in the pH values. Certain nutrient elements are more readily available at higher pH range (Eurocon and Landon, 1991). This is the reason why higher levels of some element like; available phosphorous, potassium, sodium and calcium are recorded in soil with termite's infestation.

The levels of organic content (OC) are relatively higher in the termite infected soils compared to the surrounding soil not infested by the activities of termites as reported by Field

(1993). The mean value of surface and sub-surface organic matter content of infested soils is 0.298% (Table 2) while that of soils without termite infestation is 0.174% (Table 2). The lower level of organic matter content evaluated could be as a result of soil erosion, burning of crops residues immediately after farming operation and probably due to mineralization sometime occurred in tropical climates (Mizota and Reeuwijk, 1989). Soil erosion processes, burning of crop residues after harvesting operations may have contributed to the total nitrogen content of both soils, even though the total nitrogen content of the infested soils is slightly higher (Breuning-Madsen *et al.*, 2004). Furthermore, there is significant difference between infested and non-infested soils in their available phosphorous content and this element has a mean value of 14.93ppm (Table 1) while non-infected soil has a mean value of 4.63ppm (Table 2).

One factor that determines this content is the soil pH (Field, 1993; and Lobry de Bruyn and Canacher, 1990). It becomes much more available at pH levels 6.0 - 8.0 while it becomes less available at lower pH (<6.0) where the element is liable to be fixed by Al, Fe and Mn (Mizota and Reeuwijk, 1989). Exchangeable calcium content of termite infested soils is lower than that of soils without termites, the calcium content of the termites infested soils has a mean value of 2.85cmol/kg^{-1} and the surrounding soil without termite's activities has a mean value of 2.23cmol/kg^{-1}. Exchangeable soils are higher than that of soils without termite infestation. A mean value of 1.465cmol/kg^{-1} was recorded from soil infested with termite activities while soils without termite's activities have a mean value of 0.44cmol/kg^{-1}.

Exchangeable magnesium content of the termite infested soils is lower compared to the soil without termite. The magnesium content in termite infested soil has a mean value of 0.429cmol/kg^{-1} while a mean value of 6.685cmol/kg^{-1} is recorded in the surrounding soils without the activities of termite. Exchangeable potassium of both infested and non-infested soils ranges between very high and medium and the exchangeable calcium and magnesium ranges between low and very low and between medium and low on both soils, respectively (Myles, 2003). Cation exchange capacity (CEC) is higher in the infested soils compared to the non-infested soil and the result of this research has shown that termite activities enhanced fertility variables in soils, and generally affects soil characteristics. Termite's activities also produce significant physical and chemical modification in topical and sub-tropical soils; termites are important component of the soil ecosystem.

CONCLUSION AND RECOMMENDATIONS

The study concluded that the low level of nutrients status observed in the research area could be attributed to soil erosion apparently sheet and rill erosion in certain places. Removal of horticultural crops residues after harvesting operation season-in season-out, overgrazing and the influence of tropical climates particular in the study area. Furthermore, the activities of termites in the research area have led to an increase in organic matter content (OC), available phosphorus (AP), total nitrogen (TN), and soil pH. Termites play a very important role in decaying of dead plant materials and thereby nutrients circulation. They produce significant physical and chemical modification to tropical and sub-tropical soils thus bringing variability in soil proprieties. The activities of termites also have an effect on the lateral and spatial variations of both physical and chemical properties of soils. Termites are the most important decomposers in dry environment because of their ability to recycle nutrient, form soil, and retain moisture, and the activity on soil is also related to the effect of termites on the mobility of a number of soils element that are generally considered very essential for the support and growth of horticultural crops and all forms of life. The study recommended as follows:

1. Government, cooperate organizations and private individuals should encourage and provide adequate funding for a further research in soils infested with termites with a view

of utilizing the findings of the research to improve horticultural crop production in the study area.

2. Farmers should be enlightened through extension services outlet to adopt modern techniques and skills for soil and fertility management.
3. Farmers should be encourage to incorporate crop residues on soil after harvesting operation, so that it will be prone to decomposition by termites and recycle back to soils as nutrients.
4. Government and private research centre/institutes should engaged through adequate extension services in educating farmers about the role and significance of termites in modification of soils and how it affect horticultural/agricultural crops production.
5. Finally, further research should be conducted to unearth the positive and negative activities of termites on both soils and horticultural crop production.

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