African Crop Science Conference Proceedings, Vol. 9. pp. 379 - 384
Printed in Uganda.
ISSN 1023-070X/2009 $ 4.00

Comparative study of clay and organic matter content of termite mounds and the surrounding soils

F.O. ADEKAYODE[1] *& M.O. OGUNKOYA*[2]
[1]Department of Crop, Soil and Pest Management, Federal University of Technology, Akure, Nigeria
[2]Federal College of Agriculture, Akure, Nigeria

Abstract The clay and organic matter content of three randomly selected termite mounds (termitaria) were compared with the surrounding soils, in a study conducted in a fifty hectare farmland in Akure ($7^0$15'N, $5^0$15'E) Nigeria in May to June 2008. The coordinates of each termite mound were taken using an Global Positioning System (GPS) receiver (Garmin etrex model). The data were put in the ArcView GIS software as point features. Each termite mound coordinate as a point was buffered at 10 meters, 20 meters and 30 meters and each buffered zone polygonized to create a polygonal buffered areas of 0 to 10 meters (Buffered Zone 1), 10 to 20 meters (Buffered Zone 2) and 20 to 30 meters (Buffered Zone 3) away from the termitarium. Points for soil sampling pits were indicated in each buffered zone. The field work entailed locating on the ground, with the GPS receiver the sampling pits already indicated on the digital map. Soil samples were taken at the surface (0 to 15 cm) and subsoil (15 to 60 cm) for determination of clay and organic matter content. The mean values were compared using the Duncan Multiple Range Text (DMRT) at 5 % probability. The clay content of the termite mound was significantly high compared to the surrounding surface soils (0 to 15 cm) with the mean values in a decreasing order as 65, 23, 21 and 18% in termite mound, Buffered Zone 1, Buffered Zone 2 and Buffered Zone 3, respectively. The organic matter content in the subsoil (15 to 60cm) of the surrounding soils was lower than in the termite mound with mean values of 1.65%, 0.30%, 0.27% and 0.25% in the termite mound, Buffered Zone 1, Buffered Zone 2 and Buffered Zone 3 respectively. The lower clay and organic matter content of soils around termite mounds showed that termite activities could lower soil nutrient availability to plants.

Key words: GIS buffering technique, Termitaria

Introduction

Termites are social insects that build nests in soil or wood and the type of nest can be associated with the species of termites with such nests classified as ground mound, subterranean, pole and tree wood nests (Nyamapfene, 1986; Eggleton *et al*., 2002; Sileshi *et al*., 2009). The genus Macrotermes in Africa had been identified to have the most spectacular effects on the soil as they build large mounds which can be about 12 to 18 meters in diameter and up to7 meters high. This genus was reported to be responsible for over 90% of termite damage in agriculture, forestry and urban settings (Mitchell, 2002).

The mounds are features built from subsoil taken from as much as a depth of 3 meters, indicating the composition of mound soils to be closely related to the nature of the adjacent subsoil. Such correlation of termite mound and the adjacent subsoil was confirmed in the analysis of termite mound soils for gold prospering in Mali. Termite which could dig up to 10 meters below the surface bring up mineral grains which had been used to confirm the deposit of gold in many areas in Mali (Afrol News, 2008). The process of soil transportation for mound building had been reported to cause modification of soil characteristics which had been observed to promote pedo-bioperturbation and nutrient cycling. Termites as major bioturbators, created biogenic structures (galleries, nests, mounds, fungus unit chambers) that strongly influenced the physical and chemical properties of soils (Kaschuk *et al*., 2006; Jouquet *et al*., 2007).

Comparative studies of termite mound and the adjacent soils had been carried out in previous research. Kaschuk *et al*. (2006) in a study collected soil samples from top, middle and bottom of termite mounds and of the adjacent areas and observed a greater content of potassium, phosphorus, calcium, magnesium, organic carbon and lower pH in the inner part of termite mounds in relation to soil of the adjacent area. Ilse *et al*. (2007) in the study of the impact of mound building termites on surface soil properties in a secondary forest reported termite activities in a landscape to constrain re-colonization of the landscape by vegetation. Lopez-Hernandez *et al*. (2006) in the study of phosphorus forms and associated properties in fourteen mounds and adjacent soils observed mounds to contain higher total phosphorus and organic matter than the surrounding soils.

The degradative and the redeeming effects of termite activities on surrounding soils physical and chemical properties had also been reported in previous studies (Logan, 1992; Mando *et al.*, 1999) On the consideration of the degradative effects, it had been observed that areas where active mound building macrotermes were common could be difficult to cultivate because the mounds themselves would be difficult to cultivate and if knocked down with a bulldozer, might be built up again quickly. When forests were cleared, termites could attack the annual crops planted causing a great decline in crop yield. Termite attack on plant residues could denude the crop land of surface mulch thus, making it difficult to provide protective crop residue mulch (Evans, 2004; Obi *et al*., 2008). The destructive effects of termite on arable crops Mitchell (2002), Sekamatte *et al*. (2003), Sileshi *et al.* (2005) and on forest economic trees Apolinario and Martins (2004) were also reported in previous investigation. The bacteria metabolism in the guts of termites had been reported to account for a substantial fraction of production of methane an important green house gas that trap outgoing radiation leading to global warming (Rowland *et al*., 1993)

The redeeming value on soils of termite activities, was discussed in previous work. Their excrements which were rich in nitrogen and which accumulated in certain areas of the nest would be occasionally pushed out through holes made specially for that purpose. This nitrogen rich excrement could add to nitrogen content of soils around the nest (Russel, 1973). Other agriculturally beneficial roles of termites reported were rather adoptable in peasant farming which essentially were the use of termite mound soils as soil amendment (Siame, 2005; Adamou *et al*., 2007). The planting of crops and specifically edible mushroom on termite mounds was also reported (Kabasa *et al*., 2006). The industrial benefit of termite activities was also highlighted as it was revealed in the analysis of termite mound being used to indicate the contents of deeper laying levels of soil and rock. This formed the principle of using termite mound for gold prospecting in Mali (Afrol News, 2008).

The study of termite activities in a landscape carried out in the past was by cadastral study to locate termite nests while the current use of geospatial technology had provided more detailed precision investigation. Jones (1990) using aerial photographs reported a rather consistent 200 macrotermitinae mounds per square kilometer of a contiguous region in Tanzania while Verlinden *et al.* (2006) using aerial photographs, maps of indigenous land units (ILUs), geographic information systems (GIS) analysis and field observations in assessing the role of termites in agriculture, confirmed the degradative effects of termite activities in a farmland.

The high population of termite estimated at about 16 million per hectare and surpassing earthworm in dominating the soil fauna Pomeroy (1978), Brady & Weil (1999), Evans (2004) and the activities of termites in denuding the farmland of surface plant residues thereby reducing the soil organic matter content and also predisposing the farmland to accelerated erosion had made this investigation desirable.

The objective of this research was to use GIS buffering technique to carry out a precision study of soil fertility as measured in the clay and organic matter content at known distances from termite mounds.

Materials and methods

Physical setting. The research was conducted on a 50 hectare farmland in Akure ($7^0$15'N, $5^0$15E) Nigeria in May to June 2008. The farmland had been cleared of forest and used for arable crop cultivation continuously for three years before the start of the experiment. The three termite mounds studied were the three out of the several spotted in the farmland.

Preliminary computer analysis. The coordinates of the entire 50 hectare farmland were taken with the use of the Global Positioning System (GPS) receiver (Garmin etrex model) and input into the computer as a polygon feature to generate the farm boundary using GIS ArcView 3.3 software. The coordinates of the three termite mounds located at over 100 meters apart were also taken and input as point features. Each termite mound was buffered at 10 meters, 20 meters and 30 meters away and each buffered zone polygonized to create polygonal buffered areas of 0 to 10 meters (Buffered Zone 1), 10 to 20 meters (Buffered Zone 2) and 20 to 30 meters (Buffered Zone 3). Soil sampling pits were indicated on the digital map for soil sample collections for laboratory analysis.

Field work. Soil sampling pits identified on the digital map were located in the field with the use of the GPS receiver. Soil samples were taken from the termite mounds and from the surrounding buffered zones 1, 2 and 3 specifying distances of 10 meters, 20 meters and 30 meters respectively away from the termite mound. Soil samples were taken at depth of 0 to 15 cm and 15 to 60 cm and the samples analyzed for clay and organic matter content.

Laboratory analysis. The laboratory analyses of soil samples were carried out following the laboratory procedures of Canadian Society of Soil Science (Carter, 1993). The particle size distribution analysis was performed using 50 g of soil in 0.1M NaOH as dispersing agent. Hydrometer ASTM 1524 readings were taken at 40 seconds to read the percentage sand while at 2 hours to read the percentage clay. Organic carbon was determined by oxidising soil sample with dichromate solution and later titrated with ferrous sulphate [Iron II tetra oxosulphate (VI)] solution.

Statistical analysis. The three termite mounds were taken as replicates and the mean values statistically analyzed using the Statistical Package for the Social Sciences (SPSS) computer soft ware and the means of data compared using the Duncan Multiple Range Test (DMRT) at 5% probability.

Results

Figure 1 shows one of the termite mounds under investigation. The mound was about three meters high actively occupied by termites. The vegetation near the mound was being eaten up and some that were transported were observed scattered on the mound. Figure 2 showed the boundary of the farmland with the locations of the three termite mounds under investigation. The locations on the digital map were identified on the ground with the use of the global positioning system receiver. Figure 3 showed the termite mounds buffered with the buffered zones showing the distance of the zone from the mound. The buffered zones were at distances of 10m, 20m and 30m from the mound.

Table 1 and Figures 4a and 4b showed the mean values of the percentage clay and organic matter content of the termite mound and the surrounding soils. The surrounding

Figure 1. One of the termite mounds under investigation.

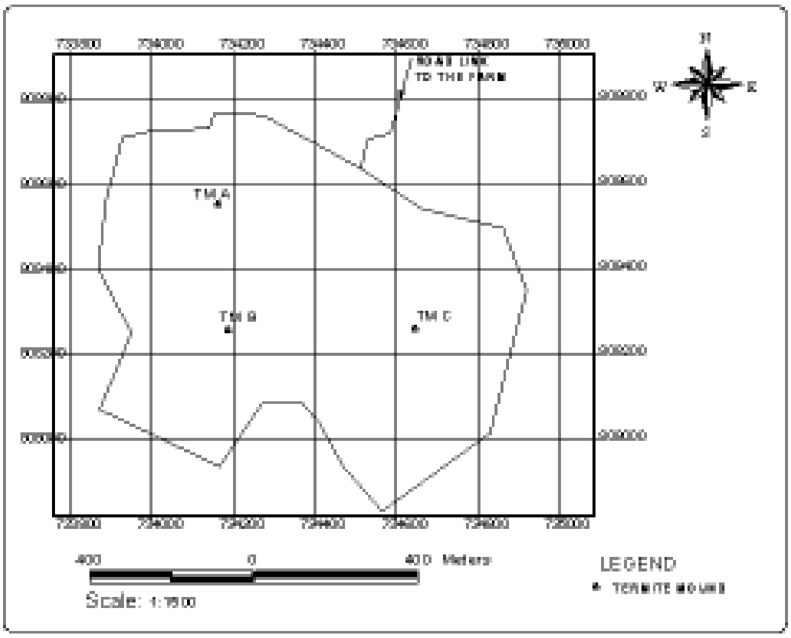

Figure 2. The locations of the three termite mounds A, B and C. TM = Termite Mound.

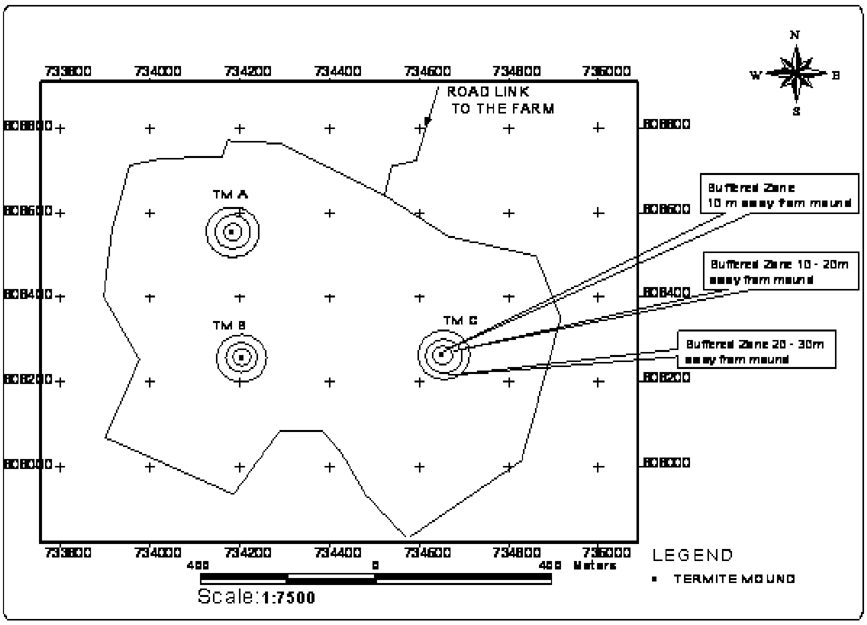

Figure 3. The three termite mounds with a typical one buffered at 10m, 20m and 30m away. TM = Termite Mound.

Table 1. The mean values of clay and organic matter content of termite mounds and the surrounding soils.

Location	Distance from termite mound in meters	% clay of surface soil (0 – 15cm)	% clay of subsoil (15 – 60cm)	% organic matter of surface soil (0 – 15cm)	% organic matter of subsoil (15 – 60cm)
Termite Mound	0	65a	65a	1.65c	1.65a
Buffered Zone 1 at 10 m radius from mound	0 – 10	23b	32b	2.17b	0.30b
Buffered Zone 2 at 20 m radius from mound	10 – 20	21b	34b	2.26b	0.27b
Buffered Zone 3 at 30 m radius from mound	20 - 30	18c	33b	2.62a	0.25b

Means followed by the same letters were not significant using Duncan Multiple Range Test at 5% probability.

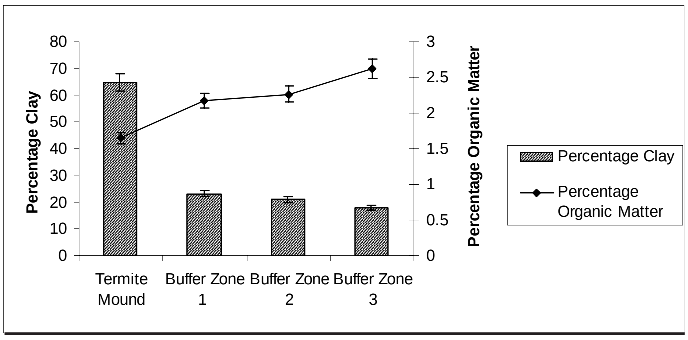

Figure 4(a). The percentage clay and organic matter of termite mound and surrounding surface soils.

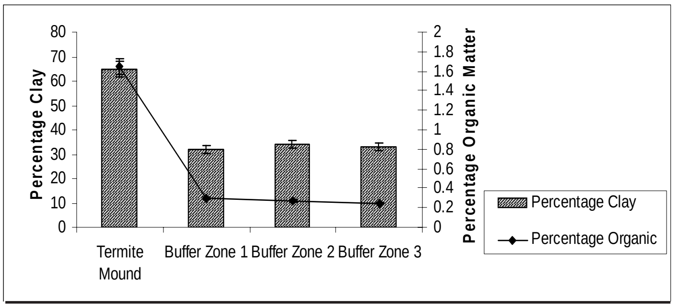

Figure 4(b). The percentage clay and organic matter of termite mound and surrounding subsoil.

soils were divided into buffer zones at distances of 10m, 20m and 30m from the mound.

When the termite mound soil was compared with surface soil of the surrounding soils, the clay content of the termite mound was significantly high compared to the surrounding soils with the significantly least value obtained in Buffer Zone 3 that was 30m away from the mound. Similarly the clay content of termite mound soil was significantly high compared to the surrounding subsoil though clay content in the subsoil did not show significant differences between buffered zones.

The organic matter content of the termite mound was significantly lower than the surrounding surface soils. The higher significant value was obtained in the Buffer Zone 3 that was 30m away from the mound indicating that as the distance increased to 20m and 30m the organic matter in the topsoil increased. The organic matter content was higher in the termite mound compared to the surrounding subsoil though there were no significant differences in organic matter values between the buffered subsoil zones.

Discussion

The termite mound showed in figure 1 was a type of nest constructed by termite especially by the genus macrotermes (Nyamapfene 1986; Mitchell, 2002). Russel (1973), in the description of termite mound had reported mounds that were up to 7.5 meters high and a diameter of 12 to 18 meters. The mound had been constructed with subsoil brought from a depth of more than 3 meters. Such termite mounds could be abundant in a landscape as reported by Jones (1990) using aerial photographs to detect a consistently 200 macroterminae moulds per square kilometer in Tanzanian landscape. Sileshi *et al.* (2009) also reported the rating by local farmers based on the mound shape the species *Macrotermes bellicosus* and *M. subhyallinus* as the most abundant in the Tororo district in Uganda.

The digital map of farm boundary with the locations of termite mounds under investigation in Figure 2 had been generated by the Global Positioning System (GPS) and the Geographic Information Systems (GIS) technology using the ArcView 3.3 soft ware. The principle applied had been the geospatial technique of data acquisition, manipulation, pre-processing, management and analysis (Brady & Weil, 1999). The data acquisition entailed the use of the GPS receiver to record the coordinates of the farm boundary and the locations of the termite mounds. The coordinates were the Eastings and Northings (UTM system) corresponding to Latitudes and Longitudes (Geodetic system). The data were entered into the computer Notepad software as polygons to generate the farm boundary while the data were entered as point features to locate the termite mounds. This was based on the principle in previous research on soil variability studies Bakhsh *et al*. (2000) and also in the digital mapping of landscape (Akingbade, 2006) and the mapping of a crop type museum (Adekayode, 2008).

The buffered zones generated around each termite mound in Figure 3 was performed using GIS buffering technique. Buffering is a geospatial technology employed to create a zone of a specified width around a point, line or polygonal area and the resulting buffer becoming a new polygon. The illustration of buffering technique in proximity analysis had been demonstrated in previous studies by which on a map of land parcels, all parcels that were within a specific distance from a point on the map could be selected. (Environmental Systems Research Institute, 1996; Ikhuoria, 1998; Uluocha, 2007).

The significantly higher clay content of the soils in termite mounds compared with the surrounding soils confirmed previous findings that soils had been transported from deep subsoil with a high clay content to build the mounds (Russel, 1983; Brady and Weil, 1999).

Kaschuk *et al.* (2006) though reported higher clay content in termite mound did not however observe any difference in the clay mineral composition between the mound and the surrounding soils.

The significantly lower organic matter content in the termite mound compared to the surrounding top soil (0-15cm) was an indication that the termite mound was built with subsoil (Brady & Weil, 1999; Sileshi *et al*., 2009). The distribution of organic matter in the surrounding soils which showed area closer to the termite mound (0 to 10cm and 10 to 20cm) to have lower organic matter content than area further away (20cm to 30cm) was as a result of the activities of termite in denuding the surrounding area of surface residue. The decomposition and mineralization of the plant residue would have increased the organic matter content (Takata *et al*., 2007). Positive correlation between organic matter and essential nutrients of nitrogen, phosphorus, sulphur and the exchangeable cations, Tisdale *et al.* (2003) could indicate areas with high organic matter to have higher content of the essential elements.

The soil depth of 15cm to 60cm with significantly organic matter compared to the termite mound was due to the transportation of subsoil by termite to build their mounds. This soil layer is usually turned up and brought to the surface during mechanization operation of ploughing, harrowing and ridging. The nutrient content of this layer would have significant consideration in predicting the fertility status of the soil. This corroborated the earlier research finding of a high nutrient content of termite mound soils (Masanori & Tooru, 2004; Chikuuvire *et al*., 2007) and the use as soil amendment (Siame, 2005).

References

Adamou, I., Pierre, N.J., Pogenet, P., Tchimbi, B. & Gonlaina, G. 2007. Soil degradation in the Sudano-Guinea savannas of Mbe, Cameroon: farmers' perception, indicators and soil fertility management strategies. Research Journal of Agriculture and Biological Sciences **3,** 907-916.

Adekayode, F.O. 2008. Buffering Stream Courses to Delineate Lowland Areas for Inland Valley Cultivation and the Study of the Soil Physical and Chemical Properties. Proceedings of the 4th Annual Conference of The School of Agriculture and Agricultural Technology, Akure, Nigeria. pp. 153 – 158.

Afrol News. 2008. Termites and humans searching more gold in Mali. [online] URL: http://www.afrol.com/index.php.

Akingbade, A.O. 2006. Introduction to Digital Mapping and GIS. In: Customised Training in Digital Mapping for Staff of the Federal University of Technology, Akure, Nigeria. 19pp.

Apolinario, F. E. & Martius, C. 2004. Ecological role of termites (Insecta, Isoptera) in tree trunks in central Amazonian rain forests. Forest Ecology and Management. **194 (1-3),** 23-28.

Bakhsh, A., Colvin, T.S., Jaynes, D.B., Kanwar, R.S. & Tim, U.S. 2000. Using Soil Attributes and GIS for Interpretation of Spatial Variability in Yield. Transaction of the ASAE **43(4),** 819-828.

Brady, N.C. & Weil, R.R. 1999. The Nature and Properties of Soils. 12E. Prentice Hall, New Jersey. 881 pp.

Carter, M.R. 1993. Soil Samples and Methods of Analysis. Canadian Society of Soil Science. Lewis Publishers, London, UK. 823 pp.

Chikuvire, T.J., Mpepereki, S. & Foti, R. 2007. Soil fertility variability in sandy soils and implications for nutrient management by smallholder farmers in Zimbabwe. Journal of Sustainable Agriculture **30,** 69-87.

Eggleton, P., Bignell, D.E., Hauser, S., Dibog, L., Norgrove, L. & Madong, B. 2002. Termite diversity across an anthropogenic gradient in the humid forest zone of West Africa. Agriculture, Ecosystems and Environment **90,** 189-202.

Environmental Systems Research Institute. 1996. ARC VIEW GIS. The Geographic Information System for Everyone. Environmental Systems Research Institute, Inc.U.S.A. 339pp.

Evans, T.A. 2004. Comparing mark-recapture and constant removal protocols for estimating forager population size of the subterranean termite *Coptotermes lacteus* (Isoptera: Rhinotermitidae). Bulletin of entomological research Volume **94(1),** 1-9.

Ikhuoria, I.A. 1998. Fundamentals of Remote Sensing, Photo Interpretation and Geographic Information Systems. St. Ambrose Computer Services, Benin-City, Nigeria.128 pp.

Ilse, L. A., Wenceslau G. T., Susan J. R., Johannes L. and Erick C.M. F. 2007. The impact of mound-building termites on surface soil properties in a secondary forest of Central Amazonia. Applied Soil Ecology **37,** 267–276.

Jones, J.A. 1990. Termites, soil fertility and carbon cycling in dry tropical Africa: A hypothesis. Journal of Tropical Ecology **6,** 291-305.

Jouquet, P., Bottinelli, N., Jean-Christophe, L., Philippe, M. & Sandrine, C. 2007. Role of the fungus-growingt termite *Pseudacanthotermes spiniger* (Isoptera, Macrotermitinae) in the dynamic of clay and soil organic matter content. An experimental analysis. Geoderma Volume **139 (1-2),** 127-133.

Kabasa, J.D., Olila, D., Okethwangu, D., Munishi, P.K.T. & Kisovi, I. 2006. Nutritive and nutriceutic potential of indigenous Bubaala mushrooms *Termitomyces microcarpus* from tthe Lake Victoria basin. African Journal of Animal and Biomedical Sciences **1,** 92-96.

Kaschuk, G., Sanntos, J.C.P. & Almeida, J.A. 2006. Termite activity in relation to natural grassland soil attributes. Science Agriculture *(Piracicaba, Braz.)* **63(6),** 583-588.

Logan, J.W.M. 1992. Termites (Isoptera): A pest or resource for small scale farmers in Africa. Tropical Science **32,** 71-79.

Lopez-Hernandez, D., Fardeau, J.C., Nino, M., Nannipieri, P. & Chacon, P. 2006. Phosphorus accumulation in savanna termite mound in Venezuela. European Journal of Soil Science **40(3),** 635-640.

Mando, A., Brussard, L. & Stroosnijder, L. 1999. Termite and mulch-mediated rehabilitation of vegetation on crusted soil in West Africa. Restoration Ecology **7,** 33-41.

Masanori, T. & Tooru, A. 2004. Soil nutrient loss caused by intensive land use and the retention of nutrients inside termite mounds in Niger, Africa. Japanese Journal of Ecology **54,** 117-124.

Mitchell, J.D. 2002. Termites as pests of crops, forestry, rangeland and structures in southern Africa and their control. Sociobiology **40,** 47-69.

Nyamapfene, K.W. 1986. The use of termite mounds in Zimbabwe peasant agriculture. Tropical Agriculture (Trinidad) **63,** 152-192.

Obi, J.C., Ogunkunle, A.O. & Melude, N.T. 2008. Effect of Termite Infestation on the Farming System Characteristics of an Endemic Area in the Guinea Savanna Region of Nigeria. American-Eurasian Journal of Scientific Research **3(1),** 1-6.

Okwakol, M.J.N. & Sekamatte, M.B. 2007. Soil macrofauna research in ecosystems in Uganda. African Journal of Ecology **45,** 2-8.

Pulleman, M.M., Bouma, J., van Essen, E.A. & Meijles, E.W. 2000. Soil Organic Matter Content as a Function of Different Land Use History. Soil Science Society of American Journal **64,** 689-693.

Pomeroy, D.E. 1978. The abundance of large termite mounds in Uganda in relation to their environment. Journal of Applied Ecology **15,** 51-63.

Rowland, C., Brauman, A., Labat, M. & Lepage, M 1993. Nutritional factors affecting methane emission from termites. Chemosphere Volume **26(1-4),** 617-622.

Russell, E.W. 1973. Soil Conditions and Plant Growth. (10th Edition). Williams Clowes and Sons Limited, Great Britain. 849 pp.

Sekematte, M.B., Ogenga-Latigo, M. and Russell-Smith, A. 2003. Effect of maize-legume intercrops on termite damage to maize, activity of predatory ants and maize yield in Uganda. Crop Protection **22,** 87-93.

Siame, J.A. 2005. Termite mounds as fertilizer. Magazine on Low External Input and Sustainable Agriculture (LEISA) **7(2),** 27.[online] URL: http://www.leisa.info/index.php?url=magazine-details.tpl&p[id]=81274.

Sileshi, G., Mafongoya, P.L., Kwesiga, F. & Nkunika, P. 2005. Termite damage to maize grown in agro-forestry systems, traditional fallows and monoculture on nitrogen-limited soils in eastern Zambia. Agriculture and Forest Entomology **7,** 61-69.

Sileshi, G.W., Nyeko, P., Nkunika, P.O., Sekematte, B.M., Akinnifesi, F.K. & Ajayi, O.C. 2009. Integrating Ethno-Ecological and Scientific knowledge of Termites for Sustainable Termite Management and Human Welfare in Africa. Ecology and Society **14(1),** 48. [online] URL: http://www.ecology and society.org/vol14/iss1/art48/

Takata, Y., Funakawa,S., Akshalov, K., Ishida, N. & Kosaki, T. 2007. Influence of land use on the dynamics of soil organic carbon in northern Kazakhstan. Soil Science and Plant Nutrition **53 (2),** 162-172.

Tisdale, S.L., Nelson, W.L., Beaton, J.D. & Havlin, J.L. 2003. Soil Fertility and Fertilizers, 5th Edition, Pearson Education, Inc. New Jersey. 634pp.

Uluocha, N.O. 2007. Elements of Geographic Information Systems. Sam Iroanusi Publications, Lagos, Nigeria. 145pp.

Verlinden, A., Seely, M.K. & Hillyer, A. 2006. Settlement, trees and termites in Central North Namibia: A case of indigenous resource management. Journal of Arid Environments **66(2),** 307-335.