Effects of Locations On- and Off- Epigeal Termitaria on Vegetation Lifeforms in Katolo Sub-Location of Kisumu County, Kenya

Wyclife Agumba Oluoch[1*],

[1]Department of Geography and Natural Resource Management, School of Environment and Earth Sciences, Maseno University, Kisumu, Kenya

Email: [*]wyclifeoluoch@gmail.com

Boniface Oluoch Oindo[2]

[2] Department of Environmental Science, School of Environment and Earth Sciences, Maseno University, Kisumu, Kenya

Paul Abuom[2]

[2] Department of Environmental Science, School of Environment and Earth Sciences, Maseno University, Kisumu, Kenya

Abstract: Epigeal termitaria host richer vegetation assemblages ascribed partly to their elevated nutrients levels in savannah ecosystems. However, elaborate quantitative description of how abundance of various vegetation lifeforms (trees, shrubs, lianas and grass) vary with on-mound and off-mound locations has not been clearly studied. Therefore, the paper in hand endeavored to find out the influence of on-mound and off-mound locations on vegetation lifeforms abundance in Katolo Sub-Location of Kisumu County, Kenya. Termite mounds population in the study area was not known. Therefore, cross sectional descriptive research design was adopted. Using saturated sampling, a total of sixty accessible mounds of at least 0.11m in basal radius and corresponding off-mound plots were selected for the study. Number of trees, shrubs and lianas was arrived at by visual counting and recording while grass population was approximated by use of a quadrat. One way ANOVA was employed to determine significant difference in means of vegetation lifeforms abundance based on location on and off-mound. The results showed that location on-mound and off-mound significantly ($p \leq 0.05$) influenced all vegetation lifeforms with all except grass being more abundant on termite mounds. The study recommends conservation of termite mounds in order to boost abundance of vegetation lifeforms within the study area.

Key words: Location on-mound, off-mound, vegetation lifeforms, abundance

How to cite this paper: Oluoch, W. A., Oindo, B. O. and Abuom, P. O. (2017). Effects of Locations On- and Off- Epigeal Termitaria on Vegetation Lifeforms in Katolo Sub-Location of Kisumu County, Kenya. Scientific Research Journal, vol. V issue (XII) Page: 74-83, DOI: Scirj:10.xxxxx.

1. Introduction

On-mound locations have been documented globally to be preferentially colonized by trees over the surrounding soils in Brazil [49]. It is therefore possible that the enriched nutrient levels of the mounds positively affect the establishment of young trees on these mounds through soil disturbance [43]. They reported enriched nutrient levels in the internal chambers of *Macroterms carbonarius* mounds in comparison with adjacent open savanna soils. Later studies have revealed the positive impact of termite mounds on their surroundings, for example, [41] and [50]. However, the number of seedlings growing on termite mounds soils in an experimental study revealed that fewer seedlings grew on the mounds soils than on the surrounding savannah soils [3]. These studies have given great evidence of richness of termite mounds for woody plants establishment. However, it remains unclear how individual vegetation lifeforms such as trees, shrubs, lianas and grass would vary in abundance across locations both on-mound and off-mound. A better understanding of how individual vegetation lifeforms would vary with respect to location (on-mound or off-mound) would thus be necessary.

The preference to mound soils has been attributed to the proposition that termites contribute to the micro-topographical and nutrient heterogeneity of tropical milieu as portrayed by [4] in Malaysia. They realized that overall tree stem density was higher on the termite mounds than on the nearby surrounding plots. Moreover, it was found that location on and off-mounds significantly influenced community composition when species were quantified by basal area [3] [4] [23]. These global studies have demonstrated abundance of woody plants on termite mounds being more than off-mound plots. However, to better understand larger ecosystem functioning, it would be appropriate to look into all vegetation lifeforms abundances and compare on-mound with off-mound locations.

Within regional scale of Africa, better soil physicochemical composition on-mound as compared to off-mound sites have been demonstrated without assessing abundance of vegetation lifeforms on them [2] [13] [17]. For example, in the humid savannahs of West Africa, the density of woody species was found to be two to three times higher on *Macrotermes* mounds than in inter-mound areas [1]. Early study in West Africa showed that plants from termite mounds play a great role among all environmental and social uses and almost 70% to 80% of the world populations use those plants for their primary healthcare [10] [27] [25] with over 30 illnesses being curable in Benin by termite mound extracted herbs [14]. Termite mounds are thus shown not only to be suitable sites for plants establishment but also as sites for rich medicinal vegetation. There is, however, need to show how abundance of vegetation lifeforms on termite mounds would compare with those off-mounds.

Specific soil conditions and the modification of the habitat by termites lead to a vegetation cover on the mounds that differs in density, composition and structure from the adjacent savanna [57]. Termite mounds offer a better reservoir of soil water available for plants, especially in deeper soil horizons [35]. Mound soils have been used as fertilizers in some places such as Zambia due to their nutrient richness and physicochemical properties where they are applied once every 3 years and corresponding maize yield rise to the tune of 33% has been reported [55]. On a savanna site in northern Burkina Faso, the density of trees and shrubs was five times higher (2859 ha^{-1}) on *Macrotermes* mounds compared with the inter-mound area (527 ha^{-1}) [18]. They realized that although the mound soil covered only 2.7% of the area, it supported 8.2% of the trees on that site. This is probably because of the positive effect of mounds on woody plant establishment and recruitment through supply of more nutrients. Thus more needs to be done in order to fully understand individual vegetation lifeforms cover both on-mound and off-mound in order to quantify any existing variation.

It has also, however, been pointed out in contradicting studies that soil comprising the mounds of *Macrotermes* species contains only small amounts of nitrogen and phosphorus because they use soil from deep underground, hence, the soil of the mounds built by this genus is not suitable for plants [7] [11] [16]. On the other hand, *epigeal termitaria* are recognized as habitats for many plant species [41] [60]. Savannah termite mounds in Africa have been documented to host specialist plant species [56]. Differing vegetation cover on termite mounds might have been attributed to differing species of termites as well as soil types and climatic factors. There is therefore need to compare on-mound vegetation lifeforms abundance with off-mound in order to clearly quantify the difference.

Termite mound soils have proved to be very important in construction of houses [63] [13], consumed by some expectant women during lactation to prevent health issues [20] and are well aerated due to termite galleries and tunnels underground hence supporting better plant survival during drought [63]. Piglets with iron deficiency have also been noted to gain help when fed with red termite mound soils in Congo DRC as reported by [13]. The studies are therefore showing great evidence of relevance of termite mounds not only for plants but also suit socio-economic benefits though not fully assessed in this study.

Earlier studies on on-mound and inter-mound sites in Kenya showed significant increase of vegetation on-mound as compared to inter-mound sites [9]. A single notable study in Laikipia Kenya concluded that proximity to termite mounds, independent of herbivores and protection from ants is the strongest predictor of fruiting success for *A. drepanolobium* [6]. They also showed spatial heterogeneity that could be attributed to termite mounds. Even though the studies investigated mounds and *Acacia drepanolobium* success, there is no fully empirical investigation done on how location on and off-mound would influence vegetation lifeforms abundance. Therefore, there is a potential need for investigation of location on-mound and off-mound as a possible reason to variation in abundance of vegetation lifeforms abundance in savannah ecosystem.

Comparative corresponding off-mound plots have been identified differently by different scholars, for example, [52] decided on a distance of at least 15 m away from neighboring mound. Reference [44], on the other hand, used random distance of between 20 and 80 m away from the studied termite mound. Reference [58] sampled sites greater than 2 m away from the mounds while [26] picked sites ranging between 10 and 50 m away from nearest termite mound. Reference [17] chose corresponding off-mound sites to be areas greater than 3 m away from studied mound while [15] opted for sites between 5 and 35 m away from mounds. Recently, [24] used sites greater than 20 m away while [30] relied on sites above 10 m away. The latest study by [42] opted for 50 m away from studied mounds to be adequate for corresponding off-mound plots. In this study, therefore, a RANDBETWEEN function was invoked in Microsoft Office Excel 2010 to identify random distance between 20 and 50 m away from the nearest termite mound. In case the distance fell in an inaccessible site, another randomization was done. Humanly inaccessible sites included fenced compounds with no access permission granted and those mounds infested by bees.

2. Materials and Methods

2.1. Study Area

The study was conducted in Katolo Sub-Location (

Figure **1**) situated in the eastern end of Kisumu County of Kenya at latitude 0^0 14′S and longitude 35^0 00′ E while elevation span 1150 m to 1240 m above mean sea level in West to East direction to the border of Kericho County.

2.2. Climate, soil and vegetation of the study area

Customarily, long rains within the region peak in the month of May while the short rains come in September [46] with total annual rainfall of 1200mm [62] while mean temperature of 31°C is noted annually [45]. Poorly drained black cotton soils with low fertility characterize the area [22] classified as vertisols and normally develop cracks during dry spells while in rainy periods the area succumbs to flooding [45]. Patches of sandy loam soils of igneous rocks origin have also been reported in some parts of the study area towards the border with Kericho County [45]. The study area is situated within savanna grassland within large lowland surrounding the Winam Gulf in Kenyan Lake Victoria Basin [37]. There are scattered epigeal termitaria that appear as “topographic accidents” within the area even though the topography is predominantly flat.

2.3. Socio-economics of the study area

Poverty stricken rural population of up to 75% characterize the area, poor infrastructure conditions and the HIV menace [59] [29]. Livestock keeping (cattle, sheep and goats) and crop farming (maize, sorghum, beans and assorted local vegetables) preponderate the area [45]. Studies in the area have looked into hydrological modeling [51], erosion along river banks [37] and literacy levels [46]. However, termite nests harbor abundant assemblages of vegetation that look patchy from one mound to the other within the study area; especially during drought when they promiscuously stand out as topographic accidents yet lack in documentation so far. No prior research work had been conducted within the area on effects of location on and off *epigeal termitaria* on vegetation lifeforms abundance in the area, so far.

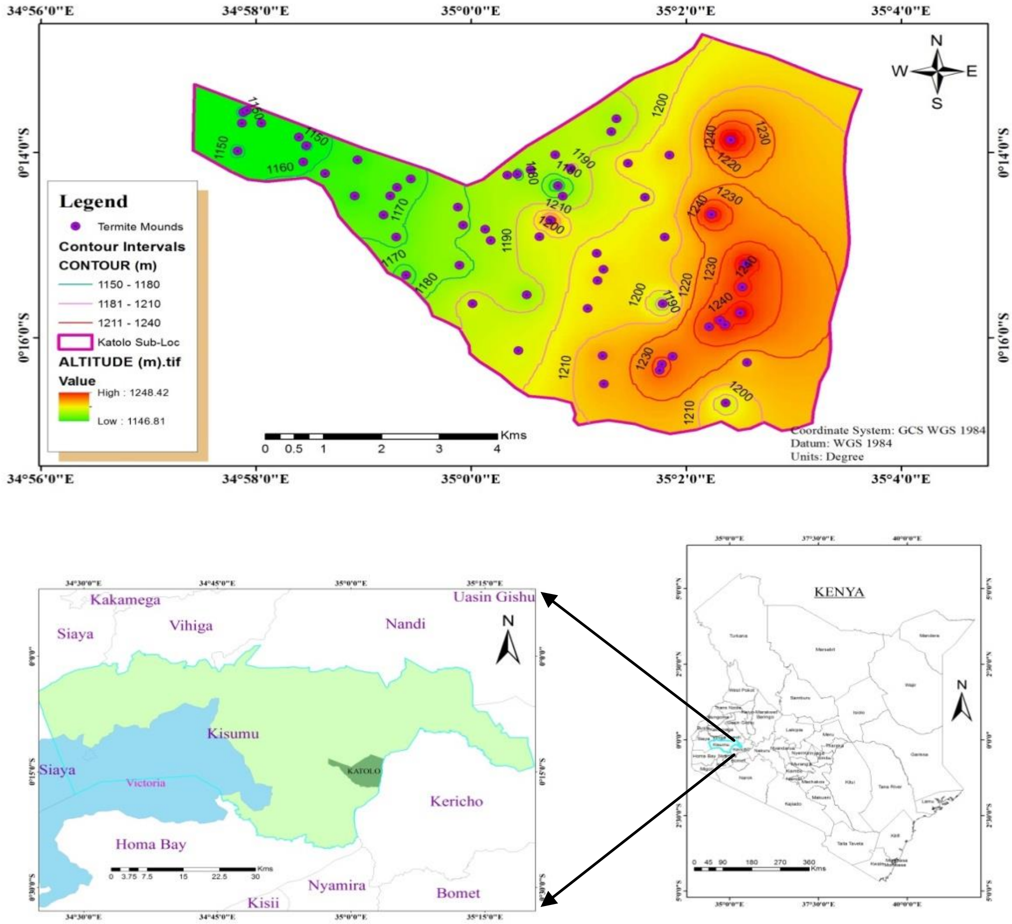

Figure 1: Study Area (Source: [47])

2.4. Research Design

Research design selected for this study was cross sectional. The research design was appropriate since it necessitated studying of the termite mounds in their current situation at the time of study. It further made it possible for future investigations on major variables studied and made possible to gathering in-depth information about the variables.

2.5 Study population and Sampling

Study population of termite mounds was unknown. Cross sectional descriptive research design was used. Saturated sampling was used to sample sixty humanly accessible termite mounds of at least 0.11m in radius and equal number of corresponding off-mound plots. Inaccessible termite mounds included those inhabited by bees and those located in homesteads or private lands with no permission granted by the owners for this study. However, their total number was less than five percent of studied mounds posing extremely minimal effect on final results. The number of studied mounds was regarded adequate following the studies of [36] that relied on 68 termite mounds, [14] who used 56 mounds and [34] who used 57 termite mounds.

In this study, a total of 60 termite mounds was used that were obtained by saturated sampling method, falling within the study area and had basal radi of greater or equal to 0.11m. The starting termite mound was selected based on its availability within the study area, being convenient to the researcher and had at least 0.11m radius [4]. Use of GPS minimized chances of repeated sampling of same mound.

2.6. Data collection methods

The study relied on data gathered between December, 2016 and March, 2017. Observation, measurement, counting and recording were used as primary data collection methods. The methods were appropriate since the data to be collected was obtainable by measurement such as radius, counting (various vegetation lifeforms) and observation (termite mounds and off-mound sites).

RANDBETWEEN function was invoked in Microsoft Office Excel 2010 to generate random bearing (1°-360°) and distance (20m – 50m) from centre of termite mounds to control off-mound plots. Whenever the corresponding off-mound plot landed in an inaccessible area, repeated randomization was done until an accessible site was found. RANDBETWEEN function eliminated subjective selection of off-mound plots. A distance of between 20 and 50 m lowered the chances of effect of termite mound on the selected off-mound site. The procedure had previously been used [44] [30] [42].

Using the radius of the termite mound, a hemispherical surface area of the mound was determined. The area was equivalent to the area of corresponding off-mound circular plot hence used to obtain the radius of the off-mound plot.

Trees number was counted by two observers and after which population was obtained by averaging the results of the observers. The same applied for shrubs and lianas. A quadrat of 0.3m square was used to determine grass population on termite mounds and corresponding off-mound plots. On every termite mound and corresponding off-mound plot, the quadrat was thrown thrice and grass population obtained after multiplying the average quadrat grass population by the area of the mound or corresponding off-mound plot and dividing by the area of the quadrat ($0.09m^2$). Adoption of quadrat method followed the works of [33] and [4].

2.7. Data analysis and Results presentation

Trees, shrubs, lianas and grass population on sixty on-mound and corresponding 60 off-mound plots were compared using one way ANOVA in MSTAT-C (Version 2.10) programme. Significant differences in means at $p \leq 0.05$ were separated using Duncan's Multiple Range Test based on the Least Significant Differences (LSD) values calculated. Results were tabulated with means presented, LSD and variance.

3. Results and Discussion

There was statistically significant ($p \leq 0.05$) difference in abundance of trees, shrubs and lianas on-mound compared to off-mound sites (Table 1). On-mound location displayed more trees, shrubs and lianas than off-mound plots. Grass abundance was however significantly more off-mound compared to on-mound plots (Table 1).

Table 1: Effects of on-mound and off-mound locations on vegetation lifeforms abundance, LSD means Least Significant Difference

Location	**Vegetation lifeforms abundance (Mean ±SD)**			
	Trees	**Shrubs**	**Lianas**	**Grass**
On-mound	15.63^{a}(±11.14)	17.67^{a}(±8.84)	10.97^{a}(±6.38)	1082.92^{a}(±673.48)
Off-mound	2.00^{b}(±1.88)	8.67^{b}(±5.80)	0.67^{b}(±1.55)	7309.37^{b}(±7652.95)

$LSD_{(p\leq0.05)}$	2.82***	2.83***	1.62***	1943.16***

*Means with the same letter down the column are not significantly different at (p≤0.05) according to Duncan's Multiple Range Test (DMRT). *** Significant at p≤0.001. ±SD is positive or negative standard deviation value from mean.*

There is evidence that trees within the study area prefer on-mound locations to off-mound locations. The finding agrees with that of [4] who found that mounds had significantly higher tree stems (>1 cm dbh) than areas immediately surrounding mounds. reference [54] further asserted that trees associated with termite mounds showed greener appearance compared to those on off-mound savannah plots during dry seasons implying availability of moisture to sustain their establishment. Establishment of large trees with taller structure on mounds have been reported elsewhere [21] [30] [60] since they create sub-canopy microclimate which enhance establishment of more woody species as was reported in preceding studies [5] [12].

Reference [6] noted that *A. drepanolobium* growing adjacent to termite mounds were significantly more likely to produce fruits than those growing farther away from mound edges: 30.7% of those trees growing adjacent to a mound produced fruits, while only 13.9% of those growing further away from a mound fruited. The presence of a termite mound therefore plays a key role in enhancing trees growth and development. Trees have been reported elsewhere to preferentially colonize termite mounds [49] [63]. Termite mounds could probably be having the best soil physical and chemical properties that ensure improved growth of trees on them.

Coupled with mineral nutrient richness [30], termite mounds would thus give denser vegetation lifeforms in the region under study. Significantly higher plant biomass on-mound than off-mound control savannah plots has also been shown by [26] and [41]. Under semi-arid conditions, [63] and [53] found out that termites often construct their mounds under trees in order to shield their nests from heat and aridity in tropical regions. Soils sampled from termite mounds supported better vegetation life forms according to study by [24]. Plants that do not send their roots beyond 0.6 m into the soil have been reported to significantly respond to termitaria moisture availability in savanna ecosystem [35]. Nitrogen, phosphorus and organic matter have been shown to be higher on-mound than off-mound locations [6] [32] that could be ensuring better performance by trees on the *epigeal termitaria*.

Increased abundance of shrubs on termite mounds mimic those by [48] who realized that termite mounds covered with and often completely hidden under dense shrub and tree vegetation occur in both dry and seasonally flooded savannahs. In both savannah types, the physical and chemical properties of the soil of the termite mounds provide more favorable growing conditions to trees and shrubs compared to the surrounding grasslands with scattered trees and shrubs [42] [44].

By constructing passages through the mounds, termites improve aeration and drainage [38]. Better aerated and well drained soils are decisive factors for tree and shrubs vegetation, and the termites themselves benefit from the resultant constant moderate moisture conditions. Reference [44] also realized stability of forbs on the mounds as compared to the adjacent savanna. This resulted after fencing off the influence of herbivores; more forbs species were noted on the termite mounds while off the mound, up to 48% forbs species disappeared. Mounds therefore are better habitats for shrubs than off-mound savannah plots.

There was over 16 times more lianas on-mound than off-mound study sites. Implication of this was that lianas tended to colonize raised grounds to reach for light as well as obtained the nutrient richness in the *epigeal termitaria* which was shown by [6]. The findings are in line with those of [34] who reported that succulents, geophytes and lianas were more on termite mounds than off-mound sites. Open savannah plots are normally rich in grass which normally have weaker stems and may not adequately support successful support to weak stemmed lianas. The lianas therefore tended to grow more on raised termite mounds where there are richer trees populations to offer adequate support to them.

Grass tended to grow in the open flat grounds to on-mound locations. Significantly (p≤0.05) higher individual grass count was recorded off-mound than on mound plots according to the findings of [26] in Namibia. The findings are in agreement with the several other works [61] [40] who reported that termites forage on tall grass layers hence minimizing the population of grass on-mound in comparison to off-mound plots. [31] [39] [28] and [8] reported nutrient contribution of eroded mound materials into the savannah to release nutrients as part of the termite mounds importance. Contradiction emanates from the works of [19] who reported complete disappearance of predominant grass following removal of subterranean termites in Chihuahuan desert following a chain of changes in soil physical properties.

Location on-mound and off-mound significantly affected population of all the vegetation lifeforms studied as had earlier been shown [14] [30] [63]. Apart from grass, all other lifeforms (trees, shrubs and lianas) were significantly higher in abundance on-mound than off-mound control plots, mimicking the findings of [56]. The implication is that mounds formed perfect niches for establishment of majority of the plant materials probably as a result of richness in highly needed nutrients.

As to the null hypothesis that there is no statistically significant difference in vegetation lifeforms abundance on-mound and off-mound locations, there is enough evidence to reject the null hypothesis. Therefore, location on and off-mound significantly ($p \leq 0.05$) influenced abundance of vegetation lifeforms with trees, shrubs and lianas being more abundant on-mound than off-mound plots.

4. Conclusion and Recommendation

On-mound sites were more suitable for three vegetation lifeforms abundance (trees, shrubs and lianas). Grass abundance was however noted to be more off-mound than on-mound. These findings imply that termite mounds are providing more suitable plant establishment sites in savannah than off-mound plots. However, for the purpose of grass establishment, off-mound plots would be referred. The study recommends more elaborate conservation of termite mounds within the study area since they are richer in various vegetation lifeforms compared to open savannah fields in the area.

Acknowledgements

I acknowledge the School of Environment and Earth Sciences of Maseno University for providing guidance throughout the execution of the project. Further gratitude goes to Mr. Harrison O. Oluoch for supporting the funding of the study.

References

[1]. Abbadie, L., Lepage, M. & Le Raux, X. (1992). Soil fauna at the forest-savanna boundary: role of termite mounds in nutrient cycling. *Nature and Dynamics of Savanna Boundaries* (P. A. Furley, J. Proctor and J. A. Ratter, Eds), Chapmann and Hall, London, pp. 473 - 484.

[2]. Abe, S. S. & Wakatsuki, T. (2010).Possible influence of termites (*Macrotermesbellicosus*) on forms and composition of free sesquioxides in tropical soils. *Pedobiologia* **53**: 301-306. http://dx.doi.org/10.1016/j.pedobi.2010.02.002

[3]. Ackerman, I. L., Wenceslau, G. T., Susan , J. R., Johannes, L. & Erick, C. M. (2007). The impact of mound-building termites on surface soil properties in a secondary forest of Central Amazonia. Cornell University, Ithaca, NY 14853, USA. http://dx.doi:10.1016/j.apsoil.2007.08.005

[4]. Beaudrot, L., Du, Y., Rahman, K. A., Rejmanek, M. & Harrison, R. D. (2011). Do Epigeal Termite Mounds Increase the Diversity of Plant Habitats in a Tropical Rain Forest in Peninsular Malaysia? *PLoS ONE* **6**(5): e19777. http://dx.doi:10.1371/journal.pone.0019777

[5]. Belsky, A. J. & Canham, C. D. (1994). Forest gaps and isolated savanna trees: an application of patch dynamics in two eco-systems. *BioScience*, **44**: 77-84.

[6]. Brody, A. K., Palmer, T. M., Fox-Dobbs, K., & Doak, D. F. (2010). Termites, vertebrate herbivores, and the fruiting success of *Acacia drepanolobium*. *Ecology,* **91**(2): 399-407.

[7]. Contour-Ansel, D., Garnier-Sillam, E. & Lachaux, M. (2000). High performance liquid chromatography studies on the polysaccharides in the walls of mounds of two species of termite in Senegal, Cubitermesoculatus and *Macrotermes subhyalinus*: Their origin and contribution to structural stability. *Biology and Fertility of Soils*, **31**: 508-516.

[8]. Coventry, R. J., Holt, J. A. & Sinclair, D. F. (1988). Nutrient Cycling by Mound-Building Termites in Low-Fertility

Soils of Semi-Arid Tropical Australia. *Australian Journal of Soil Research*, **26**: 375–390.

[9]. Cox, G. W. & Gakahu, C. G. (1985). Mima mound microtopography and vegetation pattern in Kenyan savannas. *Journal of Tropical Ecology*, **1**: 23–36.

[10]. Cunningham, A. B. (1993). African medicinal plants: Setting priorities at the interface between conservation and primary healthcare. People and Plants Working Paper 1. UNESCO, Paris. pp.50.

[11]. Danilo, L. H., Michel, B., Jean, C. F. & Michel, L. (2005). Effects of different termite feeding groups on P sorption and P availability in African and south American savannas. *Biology and Fertility of Soils*, **42**: 207-214.

[12]. Dean, W. R. J., Milton, S. J. & Jeltsch, F. (1999). Large trees, fertile islands and birds in arid savanna. *Journal of Arid Environments*, **41**: 61-78.

[13]. Deweer, E. (2014). Growth response of amaranth to admixture of termite mound material.Ph.D, Universiteit Gent, Germany.p.103.

[14]. Dossou–Yovo, H. O., Vodouhe, F. G. & Sinsin, B. (2010). Assessment of the medicinal uses of plant species found on termitaria in the Pendjari biosphere reserve in Benin. *Journal of Medicinal Plant Research*, **8**(8): 368-377.

[15]. Dowuona, G. N. N., Atwere, P., Dubbin, W., Nude, P. M., Mutala, B. E., Nartey, E. K. & Heck, R. J. (2012). Characteristics of termite mound and associated acrisols in the coastal zone of Ghana and impact on hydraulic conductivity. *Natural Science*, **4**(7): 423-437. http://dx.doi.org/10.4236/ns.2012.47058

[16]. Duponnois, R., Paugy, M., Thioulouse, J., Masse, D. & Lepage, M. (2005). Functional diversity of soil microbial community, rock phosphate dissolution and growth of *Acacia seyal* as influenced by grass, litter and soil-feeding termite nest structure amendments. *Geoderma*, **124**: 349-361.

[17]. Ekundayo, E. O. & Orhue, E. R. (2011). Physical and Chemical Properties of termite mounds and Surrounding Soil as influenced by land use in the Niger Delta region of Nigeria. *Nigerian Journal of Soil and Environmental Research*, **9**: 53-58.

[18]. Eldridge, D. J., Lepage, M., Bryannah, M. A. & Ouedraogo, P. (2001). Soil biota in banded landscapes. In: Tongway, D. J., Valentin, C. & Sergieri, J. (eds.) Banded vegetation patterning in arid and semi-arid environments: ecological processes and consequences for management. pp. 105–131. Springer-Verlag, New York, NY, US.

[19]. Elkins, N. Z. (1986). The influence of subterranean termites on hydrological characteristics of Chihuahuan Desert ecosystem. *Oecologia*, **68**: 521-528

[20]. Erens, H. (2010). Ecological significance of termite mounds in a tropical environment. A case study of Lake Victoria basin. Katholieke Universitiet Leuven, 88p.

[21]. Fleming, P. A. & Loveridge, J. P. (2003). Miombo woodland termite mounds: source islands for small vertebrates? *Journal of Zoology*, **259**: 161-168.

[22]. Food Security District Profile, (2004): Nyando District, Nyanza Province Republic of Kenya.

[23]. Gillison, A. N., Jones, D. T., Susilo, F-X. & Bignell, D. E. (2003). Vegetation indicates diversity of soil macroinvertebrates: a case study with termites along a land-use intensification gradient in lowland Sumatra. *Organisms Diversity and Evolution*, **3**: 111-126.

[24]. Gosling, C. M., Joris, P. G. M. C., Nakukhanya, M. & Han, O. (2012). Effects of erosion from mounds of different termite genera on distinct functional grassland types in an African Savannah. *Ecosystems*, **15**: 128-139.

[25]. Grace, O. M., Nigro, S. A. & Makunga, N. P. (2004). Medicinal plants at the ethnobotany-Biotechnology interface in Africa. South Africa. *Journal of Botany* **1**(70):89-96.

[26]. Grohmann, C. (2010). *Termite mediated heterogeneity of soil and vegetation patterns in a semi-arid savanna ecosystem in Namibia* (Unpublished doctoral dissertation). Julius-Maximilian University of Wüzburg, Wüzburg, Germany.122 pp.

[27]. Hamilton, A. C. (2004). Medicinal plants, conservation and livelihoods. *Biodiversity Conservation*, **13**:1477-1517.

[28]. Holt, J. A. & Coventry, R. J. (1990). Nutrient cycling in Australian savannas. *Journal of Biogeography*, **17**: 427-432.

[29]. JICA (Japan International Cooperation Agency). (2007). The development study for regional development programme in Nyando and Homa-Bay districts in the Republic of Kenya, Final Report Appendixes Vol.1/2. Tokyo: International Cooperation Agency.

[30]. Joseph, G. S., Seymour, C. L., Cumming, G. S., Cumming, D. H. M. & Mahlangu, Z. (2012). Termite mounds as islands: woody plant assemblages relative to termitarium size and soil properties. *Journal of Vegetation Science*. http://dx.doi:10.1111/j.1654-1103.2012.01489.x

[31]. Jouquet, P., Tavernier, V., Abbadie, L. & Lepage, M. (2005). Nests of subterranean fungus-growing termites (Isoptera,

Macrotermitinae) as nutrient patches for grasses in savanna ecosystems. *African Journal of Ecology*, **43**: 191–196.

[32]. Kaschuk, G., Cesar, J. P. S., Almeida, J. A., Sinhorati, D. C. & Berton-Junior, F. J. (2006). Termite activity in relation to grassland soil attributes. *Sci. Agric. (Piracicaba, Braz.)*, **63** (6):583-588

[33]. Kaspari, M., Clay, N. A., Donoso, D. A. & Yanoviak, S. P. (2014). Sodium fertilization increases termites and enhances decomposition in Amazonian forest. *Ecology*, **95**(4): 795-800.

[34]. Kirchmair, I., Schmidt, M., Zizka, G., Erpenbach, A. & Hahn, K. (2012). Biodiversity Islands in the Savanna – Analysis of the Phytodiversity on Termite Mounds in Northern Benin. *Flora et Vegetatio Sudano-Sambesica*, **15**: 3-14.

[35]. Konaté, S., Le Roux, X., Tessier, D. & Lepage, M. (1999). Influence of large termitaria on soil characteristics, soil water regime, and tree leaf shedding pattern in a West African savanna. *Plant and Soil*, **206**: 47–60.

[36]. Korb, J. & Linsenmair, K. E. (1999). Ventilation of termite mounds: new results require a new model. *Behavioral Ecology*, Canberra Australia pp. 486-494.

[37]. KSS (Kenya Soil Survey), (1990) The Environment and Soil profiles characterization of some gully sites within Winam Gulf soil and water conservation project area (Kisumu District); Republic of Kenya.

[38]. Lal, R. (1987c). Managing soils of sub-Saharan Africa. *Science*, **236**: 1069-1076.

[39]. Lavelle, P. (1997). Soil function in a changing world: the role of invertebrate ecosystem engineers. *European Journal of Soil Biology*, **33**: 159-193.

[40]. Lobry de Bruyn, L. A. & Conacher, A. J. (1990). The role of termites and ants in soil modification: a review. *Australian Journal of Soil Research*, **28**:55-93.

[41]. Loveridge, J. & Moe, S. (2004). Termitaria as browsing hotspots for African megaherbivores in miombo woodland. *Journal of Tropical Ecology*, **20**: 337–343.

[42]. Mbah, N. C., Ukpa, C., Nwali, E., Attoe, E. E., Ojikpong, O. T. & Idike, I. F. (2014). Physicochemical properties and heavy metal content of termite mound in relation to non-mound and its implication in agriculture. *European Journal of Academic Essays*, **1**(9): 24-29.

[43]. McComie, L. D. & Dhanarajan, G. (1993). The physical and chemical composition of mounds of *Macrotermes carbonarius* (Hagen) (Termitidae, Macrotermitinae), in Penang, Malaysia. *Journal of Soil Science* **44**.

[44]. Moe, S. R., Mobæk, R. & Narmo, A. K. (2009). Mound building termites contribute to savanna vegetation heterogeneity. *Plant Ecology*, **202**: 31–40.

[45]. Nyasimi, M., Butler, L. M., Burras, L., Ilahiane, H., Schultz, R. & Flora, J. (2007). Differentiating livelihood strategies among the Luo and Kipsigis People in Western Kenya. *Agrarian/non-Agrarian livelihood continuum*, **11**: 43-57.

[46]. Okuom, H. A., Simatwa, E. M. W., Olel, M. A. & Wichenje, M. K. (2012). Assessment of factors that contribute to repetition and dropout of pupils in primary schools in Flood Prone Areas of Nyando District, Kenya, *International Research Journals* 3(2) 190-201 ISSN: 2141-5151. http://www.interesjournals.org/ER

[47]. Oluoch, W. A., Oindo, B. O. & Abuom, P. (2017). Modeling of Vegetation Lifeforms Abundance based on *Epigeal Termitaria* Physiography and Altitude in Tropical Savannah of Katolo Sub-Location, Kisumu County. *Journal of Geoscience and Environment Protection*, 5, 22-31. https://doi.org/10.4236/gep.2017.510003

[48]. Pomeroy, D. E. (1976). Some effects of mound-building termites on soils in Uganda. *Journal of Soil Science*, **27**: 377-394.

[49]. Ponce, V. T. & Cunha, C. N. D. (1993). Vegetated earth mounds in tropical savannas of Central Brazil: a synthesis. *Journal of Biogeography*, **20**: 219–225.

[50]. Ragnhild, M., Anne, K.N. & Moe, S. R. (2005). Termitaria are focal feeding sites for large ungulates in Lake Mburo National Park, Uganda. *Journal of Zoological Society*, **267**:97-102.

[51]. Rwigi, S. K., Opere, A. O. & Mutua, F.M. (2010). Comparative case study of rainfall-runoff models over the Nyando River Basin, Department of Meteorology, The University of Nairobi, Nairobi Kenya.

[52]. Scott, T. J. & Soar, R. C. (2008). *Beyond biomimicry: What termites can tell us about realizing the living building*. Paper presented at First International Conference on Industrialized, Intelligent Construction (I3CON) Loughborough University, Leicester, UK, 14-16 May, 2008.

[53]. Scott, T. J. (2000). Architecture and morphogenesis in the mound of *Macrotermesnichaelseni* (Sjostedt) (Isoptera: Termitidae, Macrotermitinae) in northern Namibia. *Cimbebasia*, **16**: 143-175.

[54]. Scott, T. J. (2006). "Termites as mediators of the water economy of the arid savanna ecosystems", in Dryland Ecohydrology, Porporato, A. and D'Odorico, P., Eds., ed Berlin Springer Science and Business Media, 303-313.

[55]. Siame, J. A. (2005). Termite mounds as fertilizer. *LEISA Magazine*, **21**(2), p.29.

[56]. Sileshi, G. W., Arshad, M. A., Konate, S. & Nkunika, P. O. Y. (2010). Termite-induced heterogeneity in African savanna vegetation: mechanisms and patterns. *Journal of Vegetation Science*, **21:** 923–937.

[57]. Smith, F. R. & Yeaton, R. I. (1998). Disturbance by the mound building termite, *Trinervitermes trinervoides*, and vegetation patch dynamics in a semi–arid, southern African grassland. *Plant Ecology*, **137**: 41–53.

[58]. Susumu, S. A., Sadahiro, Y. & Toshiyuki, W. (2009). Physicochemical and morphological properties of termite (*Macrotermesbellicosus*) mounds and surrounding pedons on a toposequence of an inland valley in the southern Guines savanna zone of Nigeria. *Social Science and Plant Nutrition*, **55**: 514-522.

[59]. Swallow B., Onyango, L. & Meinzen-Dick, R. (2005). Catchment property rights and the case of Kenya's Nyando basin. (In Swallow, B., Okono, N., Achouri, M. and Tennyson, L., eds. Preparing for the next generation of watershed management programmes and projects. Proceedings of the African Workshop, Nairobi, 8-10 October 2003. Watershed management and sustainable mountain development working paper no. 8. Rome: FAO).

[60]. Traore´, S., Tigabu, M., Oue´draogo, S. G., Boussim, J. I., Guinko, S. & Lepage, M. G. (2008). Macrotermes mounds as sites for tree regeneration in a Sudanian woodland (Burkina Faso). *Plant Ecology*, **198**: 285–295.

[61]. Uys, V. (2002). A guide to the termite genera of southern Africa. Plant Protection Research Institute Handbook No. 15. Pretoria: Agricultural Research Council.

[62]. Yamane, Y., Asanuma, S. & Umenaura, K. (2015). Influence of livestock farming on vegetation in a degraded soil area on the East Coast of Lake Victoria in Western Kenya: A case study of Jimo East Sub-Location in Nyando Sub-County. *Journal of Environmental Protection*, **6**: 824-836.

[63]. Yamashina, (2010). Interactions between Termite Mounds, Trees, and the Zemba people in the Mopane Savanna in Northwestern Namibia. *African Study Monographs*, Suppl.**40**: 115-128.