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Influence of Activities of Termites on Some Physical and Chemical Properties of Soils under Different Land Use Patterns: A Review

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Abstract: This study revealed that termites are found all over the world with numerous species that have existed on this earth in the past million of years. The most prominent among these various species under different land use patterns is the Isoptera. Generally, termite activities in the soil affect the nutrient and organic matter dynamics, productivity of the ecosystem via carbon sequestration, nutrient recycling as well as some physical properties of the soil.

Key words: Nutrients, dynamics, physical, chemical, termites, mounds influence, activities

INTRODUCTION

Termite is an endogenic exopterygotous insect which belongs to the order Isoptera and it is one of the numerous organisms that inhabit the soil. The abundance, composition and hence their impact on soil processes vary greatly depending on vegetation and land use (Ayuke *et al.*, 2004). The management practices such as continuous land preparation can cause alteration in the population structure, elimination and reduction of key species (Dangerfield, 1993). In terms of number, termites and ants predominate under agro-ecosystem (Bruno *et al.*, 2001) and in terms of diversity termite group are in abundance in natural sites than the cultivated sites (Abe and Matsumoto, 1979; Collins 1979; Kondoh *et al.*, 1980; Leaky and Proctor, 1987; Atkin and Proctor, 1988; Lavelle and Pashanarv, 1989; Fragoso and Lavelle, 1992; Dangerfield, 1993; Frageria and Baliga, 2004).

Generally, termite thrives by consuming detritus material and building mounds in which they control their environment. Depending on the species of termites and the surrounding environment, the mounds take on a variety of shapes and sizes. These mounds illustrate how termites are well suited for the environment. Construction of mounds from soil or mixture of soil and other material or within soil horizons must affect the physical and chemical characteristics of both the soil used for construction and the soil of the surrounding areas from which the materials are derived (Lee and Wood, 1971). During the period of occupation of the mound, organic debris or living plant tissue is collected, often over extensive foraging areas, transported to mounds and subjected to intense degradation when it is digested by termite. Plant nutrients and organic matter that they contain are withheld from circulation in the plant-soil system until they finally decay. Termite activities in the soil therefore affect the nutrient and organic matter dynamics and structure of soil. Such changes in soil properties have profound influence on the productivity of the ecosystem via carbon sequestration, nutrient cycling and soil texture.

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Within the savanna and rainforest ecosystem, termites bring about an important change on the soil environment and can occupy a large portion of the land (Leed and Wood, 1971). Knowledge about the impact of termites on soil fertility is not only important for understanding the ecology of tropical system but also for evaluating the potential constraints for agricultural production in our fields (Bruno *et al.*, 2001).

Some results of the research work carried out on physical and chemical changes in soil due to termite activity are difficult to relate to soils in our environment under different land use pattern. The elements estimated vary from one investigation to another and some of the studies lack the identification of the termites responsible for the mound structures. Therefore, this review will enable us understand the activities of termite in our soil as it affects both physical and chemical components of the mounds, the surrounding soils as well as nutrient dynamics in termite infested soils under different land use systems.

TERMITE BACKGROUND

Malaka (1996) reported that there are about 2100 species of termite while Kambhampati and Eggleton, (2000) noted that there are close to 3000 species of termite in the order of Isoptera that are phylogenetically separated into lower and higher termites. These orders according to Kambhampati and Eggleton include lower termite such as Mastotermitidae, Kalotermitidae, Hodotermitidae, Termopsidae, Rhinotermitidae and Serritermitidae while the Termitidae is the higher family of termite. Termites are further divided into either wood-dwelling or soil dwelling and the majority of the soil dwelling termites construct either above nests or dig underground galleries while the wood-dwelling termites do not create nests but live in excavated galleries in the hollow of trees (Ratcliffe *et al.*, 1952; Malaka, 1996). Lee and Wood (1971) and Malaka (1996) reported that it is the Termitidae family that makes up the mound forming termite.

The sub family of Termitidae according to Pearce (1997) includes Macrotermitinae, Apicoternutinae, Termitinae and Nasutitermitinae while the species associated with these subfamilies are shown in Table 1.

According to Ratcliffe *et al.* (1952), Krishna and Weesmer *et al.* (1969) and Kambhampati and Eggleton (2000) all known species of termite live in colonies that are compose of distinct caste namely the workers, soldiers, nymphs, larvae and reproductive (King and Queen). Each caste according to Kambhampati and Eggleton (2000) has a specific role that contributes to the productivity of the colony. The workers represent the majority of termite in a colony; they build the nest or mound, take care of the eggs and the young ones and gather food while the soldiers protect the community from predators. The nymphs are immature ones that may develop into adults whereas the larvae are the immature ones of the reproductive and the reproductives are the actively reproducing males and females.

Table 1: Species associated with various termitinae subfamily

	Macrotermitinae	Apicoternutinae Subfamilies	Termitinae	Nasutitermitinae
Species	<i>Ancistrotermes</i>	<i>Anoploterma</i>	<i>Anitermes</i>	<i>Hospitalitermes</i>
	<i>Allodotermites</i>		<i>Eremotermites</i>	<i>Nasutitermes</i>
	<i>Macrotermes</i>		<i>Globitermes</i>	<i>Procoruitermes</i>
	<i>Pseudacanthotermites</i>		<i>Microcerotermites</i>	<i>Syntermites</i>
			<i>Termes</i>	<i>Trinervitermes</i>
				<i>Volocitermes</i>

Source: Pearce (1997)

GEOGRAPHICAL DISTRIBUTION OF TERMITES

According to Tsukamoto and Sabang (2005), climate and zoogeography are the major determinant of termite distribution at global level. The great majority of termites live in tropical and subtropical regions but they extend into the temperate zone to about 45°N (Harris, 1970) or 48°N (Emerson, 1955) and about 45°S (Araujo, 1970). Termite distribution can be related to temperature and rainfall. The distribution changes with latitude and the limits of survival are between latitude 45 and 50° north and south (Pearce, 1997).

Within the tropics, many species in Africa and South America are found in rainforests (Lee and Wood, 1971), whereas in Australia only four species are known to be restricted to tropical rainforest and the majorities are found in the sclerophyll forest, woodland and savanna (Gray and Calaby, 1970). Termites are also known to have reached Hamburg, Germany (Pearce, 1997) and in Southern portion of Canada (Grace, 1989, 1990). Some of the genera with old origin such as *Zootermopsis* according to Pearce (1997) are in British Columbia, *Porotermes* at tip of Chile, Tasmania and South East Australia and the *Archotermopsis* in Himalaya, *Mastotermes* in Australia and Papua New Guinea, *Heterotermes* in the hotter regions of South Western USA, Central America, Caribbean, India while the *Reticulitermes* are common in Canada, Middle East, Japan, China, *Coptotermes* are common in tropical America, Africa, Far East, Pacific Island and Japan; the lower termites are common in palearctic, nearctic and Australia south of the tropic of Capricorn. Pearce reported further that the higher termite family of Termitidae occurs mainly in tropical latitude with the fungus growers and humus soil-feeders found in Ethiopia and oriental regions. The macrotermitinae are mainly found in Africa, Middle East and Asia.

Malaka (1996) while citing Harris (1970) reported that harvester termites are common throughout subtropical dry grassland areas where they compete with man's flock for the sparse grazing. Abe and Matsumoto (1979), Kondoh *et al.* (1980) and Lavelle and Pashanan (1989) recorded that abundance of termites is common to tropical lowland forests. In Africa, termites are widespread, restricted mainly by desert areas and lower temperature found at higher altitude. Lee and Wood (1971) while citing Grasse (1950) noted that fungus feeding termite were rare or absent from dry areas of West Africa and that their preferred habitat being humid savanna and forest. Kemp (1955) reported a similar distribution in East Africa where the humid woodland near the coast supported many more species and greater proportion of mound builders than the dry inland areas. In Nigeria as in other parts of West Africa termite representatives of only three family according to Sands (1965a), Malaka (1973, 1983) include Kalotermitidae, Rhinotermitidae and Termitidae. In the mangrove and freshwater swamp of Nigeria, *Ancistrotermes*, *Cryptotermes*, *Marotermes subhejahnus*, *Odontotermes*, *Microcarotermes* and *Armitermes evuncifer* have been reported to be common Malaka (1977a, b) whereas in the rainforest area. Malaka (1996) reported that there are more diverse species of termites in the zone as a result of favourable climate and vegetation. In the savanna as well as Sahel zones according to Malaka termite species identified include *Macrotermes bellicosus*, *Mmacrotermes subhuyallinus*, *Trinervitermes* species.

COMPONENTS OF CONSTRUCTED TERMITE MOUNDS

According to Wood and Sands (1978), termite nest systems may be arboreal, either within or attached to the outside of the vegetation epigeal or subterranean. Depending upon the species and location (Ratcliffe *et al.*, 1952; Abensperg Traun and Perry, 1998) and moisture availability and environmental conditions (Pearce, 1997) termite mound can take a variety of forms and that in colder regions mounds may be underground and in arid regions, the mound may become smaller to reduce water loss. Pearce observed further that *Armitermes evuncifer* species in West African can be

subterranean in dry areas and above ground in wet regions. The nests or mounds according to Malaka (1996) and Lee and Wood (1971) consist of four main types of structures based on material from which mounds are composed and they include

- Fabric dominated by re-packed orally transported soil particles without admixture of excreta such as large mound of *Macrotermitidae*.
- Fabric dominated by re-packed orally transported soil particles with admixture of excreta constructed by *Coptotermes* species and *Trinervitermes* species.
- Fabric dominated with excreta consisting of soil mixed orally with transported soil as seen in the mounds of *Odontotermes* species.
- Fabric dominated by excreta consisting of organic matter derived from ingesting of plant materials as seen in *Amitermes* species and *Nasutitermes* species.

Malaka (1996) reported that the construction of these mounds result in the transport of soil from either deep or shallows horizons or both to the soil surface where it is formed into mounds and covered runways on the soil surface and over or within vegetation on which the termites are feeding. Pearce (1997) reported that mounds are usually made after colony developed below the ground and that *Amitermes*, *Cubitermes* and *Proculitermes* are often mushroom shape with dry tips to help remove rain quickly while the mound of *Cubitermes* species often do not have this umbrella cap.

In Nigeria according to Collins (1979) the *Macrotermes* may have two kinds of mounds in similar conditions. One has a spiral plate supported by a central pillar; the other does not have this arrangement and the spiral plate has downward directing vanes that are covered in salt deposits. The magnetic mounds of *Amitermes* in Australia according to Pearce (1997) are wedge shaped and reach 5.5 m in height with a width of only 0.9-1.2 m whereas the *Macrotermes goliath* can attain a width of 12 m at least 4.8 m high and can number as many as 17 ha⁻¹. *Odontotermes* mounds are larger in India than in Africa and species differences also occur between mounds in India: *Odontotermes Obesus* mounds are conical while *Odontotermes wallanensis* are dome-shaped (Pearce, 1997).

Lee and Wood (1971) recorded that the termite mounds range in size from small domed to conical structures, only a few centimeters in height and diameter to the colossal mounds built by some species of African *Macrotermes* which reach 9 m or more in height and 20-30 m in diameter at the base. Harris (1955) recorded a mound of *Macrotermes* species in Ethiopia of approximately 9 m in height and that of *Nasutitermes triodiac* in Australia to be above a height of 8 m. Merdraci and Leppage (2001) reported *Odontotermes* in Lampto Savanna to be the main contributor in building large mounds of varied sizes 2-20 m in diameter with 10 cm-2 m in height. In terms of space occupied and amount of soil deposited on the surface, the species of Macrotermitinae reported by Meyer (1960) in Congo and that of *Macrotermes bellicosus* (Nye, 1955) were 240,000 and 306000 kg ha⁻¹, respectively. According to Lee and Wood (1971), the weight of mounds and area of ground covered by termite mound varies with species and localities and that the space occupied by these mounds has significant effect on the landscape, vegetation and local agricultural practices.

The mounds in various ecosystems according to Lee and Wood (1971) however are not static objects but are continually being eroded by rainfall and occupied mounds are repaired, enlarged by the termites while abandoned mounds are gradually eroded away.

TERMITE ABUNDANCE BASED ON LAND USE PATTERNS

The presence of termite in a place depends on various factors such as soil, vegetation type as well as climatic features (Pearce, 1997). It is often not possible to say which factor is most important on basis of observational evidence alone (Lee and Wood, 1971). Tsukamoto and Sabang (2005) reported that at local level, the interrelated two factors, soil condition and litter quality, are most important and

that land use practices disturb both levels of regulation. At the initial stage of the conversion practice of natural forest to tree plantations, clear felling, site preparations, introduction of seedlings from outside seriously damage the indigenous soil biota. Such perturbation and/ or the establishment of herbaceous stratum could provide niches that allow some exotic species to colonize (Fragoso *et al.*, 1999; Pellens and Garay, 1999; Muys *et al.*, 1992; Yeates, 1988). Termite mounds are relatively easy to count and the densities of the large mounds of Macrotermitinae in Africa and of *Nasutitermes triodiae* in northern Australia which support colonies of several million individuals are usually less than 10/ha while densities of the smaller mounds which support colonies of several thousand individuals may approach 1000 ha⁻¹. High densities of the large mounds are reached only in Savanna or sparsely timbered shrub or tree savanna while smaller mounds can be extremely abundant in both savanna and dense forest and there are few estimates of the abundance of mounds of all species in selected habitat (Lee and Wood, 1971). Sands (1965) observed that the number of mounds may approach or even exceed 1000 ha⁻¹ in the rain forest areas of West Africa. Glover *et al.* (1964) reported an average of 5-7 ha⁻¹ in Kenya savanna while Bouillon and Kidieri (1964) reported 2-3 ha⁻¹ in Congo savanna of both *Odontotermes* species and *Macrotermes bellicosus*. In the tropical rain forest of Congo Maldegue (1964) reported 875 ha⁻¹ of *Cubitermes fungiflabe* species mounds.

Parkr *et al.* (1994) noted that the Woodoo Woodland appeared to be more optimal for *Drepanotermes tamminensis* species than the casuarinas shrubland in Western Australia Wheatbelt. In agro forestry, in Tororo District of Uganda, Nyeko and Olubayo (2005) reported abundance of *Macrotermes bellicosus* and *Macrotermes sabhyalumus*. In a survey conducted in Nakasongola District of Uganda and Central Uganda, Sekamate (2001) recorded *Ancistrotermes*, *Allodontotermes*, *Armitermes*, *Cubitermes hodotermes*, *Macrotermes*, *Microtermes*, *Odontotermes* and *Pseudocasthotermes* as most abundant species.

Nel and Malan (1974) noted that mounds of *Trinervitermes trinervoides* were not randomly distributed over the veld in South Africa but tended to aggregate in certain area, while Nyeko and Olubayo (2005) observed that *Macrotermes bellicosus* were rare in valley in the agroforest in Tororo District of Uganda. Cowie *et al.* (1989) and Sands (1998) recorded that *Macrotermes*, *Odontotermes* mounds were associated with land cultivated with wide range of field crops and trees. Pearce *et al.* (1995), Sands (1998) and Sekamate (2001) discovered the *Pseudocanthotermes* termite mounds to be found in various field crops and nursery plot or newly transplanted tree seedlings. *Amitermes evuncifer* termite mounds have been found to be commonly seen in field of root crops such as yam, cassava and some tree crops (Sand, 1998).

According to Sands (1998) *Trinervitermes* species have been reported to be common in cotton field, grass crops including sugar cane, upland rice and wheat whereas *Trinervitermes trinervoides* mounds were reported to be common in pastures in South Africa. Tsukamoto and Sabang (2005) reported that termite mounds were significantly lower in *Acacia mangrum* plantation than the primary forest. Lee and Wood (1971) showed that in Frankenwald, South Africa, the abundance of termite mounds increased as secondary plant succession advanced from two year fallow to undisturbed veld. Ekundayo and Aghatise (1997), Brouwer *et al.* (1991), Dangerfield (1990), Lal (1998) and Lobry de Bruyn and Conacher (1990) reported that the number of termite mounds were greater in order of fallow greater than residential greater than cropping while on the other hand Ekundayo and Orhue (2002) found that the number of termite mound per unit area increased from cropping through the riparian forest and the palm plantation to residential area.

Soil feeders have been reported by Pearce (1997) to be abundant in humid forest of Africa and South America. According to Pearce, as areas of low, open vegetation give way to dense forest, the species of Macrotermitinae increased.

In the lowland forest in Sarawak, high numbers of soil feeding termite mounds were seen while in the continuous forest of Amazonia, greater species richness was found than the scattered forest

(Martins, 1994). The removal of trees and bushes followed by cultivation resulted in loss of *Macrotermes*, *cubitermes*, *trinervitermes* and shallow mound of *Coptotermes* in Nigeria (Pearce, 1997), Black and Wood (1989) reported that some subterranean species such as *Microtermes* increased in numbers as they could move down into the soil to avoid the effect of surface disturbances. The clearing of primary rainforest in Malaysia and Indonesia for cultivation allowed termites such as *Coptotermes* to survive where tree stumps remains (Eggleton *et al.*, 1995).

Sands (1965b) in his study of distribution and abundance of termite mound in Northern Nigeria reported high densities of termite mound in an area with about 90% exposure. Kemp (1955) found that in the dry thickets of inland Tanzania, termite mounds only occurred in shaded tree sites. In semi-desert where little vegetation is present, *Psammotermes* is often found underneath small rocks (Pearce, 1997). Bodot (1964, 1967) who studied the interaction of various factors observed that there were more termite mounds in area with more clay and low water holding capacity than area with high water holding capacity. Soils with seasonal cracking as noted by Ratcliffe *et al.* (1952) do not accommodate termite mounds. Meyer (1960) in Congo recorded much termite mound in soils with high clay content while Lee and Wood (1971) reported high termite mounds in soil with higher depth compared to shallow soil in Australia in savanna woodland. In sandy soil few mounds according to Pearce (1997) were present especially of humus-feeding termites and that of desert of Hodotermitidae which have mound than other regions. Jones (1988), Nutting and Jones (1990) and Grace (1992) recorded that true desert dwelling termites such as some *Armitermes* and *Psammotermes* species are found in sandy and gravelly soils whereas *Trinervitermes* species are absent in extremely dry arid conditions but commonly seen in semi-arid and wet open areas.

Where there is a rich well drained grassland such as in Ivory Coast, Pearce (1997) reported that humivorous and fungus-growing termites are common while in poor drainage areas grass-feeders such as *Trinervitermes* and *Macrotermes* species are common.

Lee and wood (1971) while citing Williams (1966) reported that in Africa species of *Cubitermes* were abundant in regions of heavy to moderate rainfall, rare in regions of light or more season rainfall and absent from regions with annual rainfall of less than 250 cm. The effect of a relatively rapid change in climate over a short distances can be seen in reduced population of the termite fauna with increasing attitude as illustrated in Kemp (1955) study in Tanzania where *Coptotermes lacteus* - a common mound-building species in Woodland and sclerophyll forest on the eastern plateau, rarely occurs above 1200 m and the even more abundant *Nasutitermes exitiosus* rarely occurs above 900 m. Termites of different genera or different species of same genus can have its differing temperature tolerance as discovered in the behaviour of *Coptotermes formosanus* that have higher temperature tolerance (Sponsle and Appel, 1991).

CHEMICAL AND PHYSICAL PROPERTIES OF TERMITE MOUNDS

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 (Malaka, 1977a). The significance of physical disturbance of soil profile depends partly on the nature of the soil brought to the surface by the termites and partly by the physical and chemical changes in the soil due to the activities of the termites. Chemical changes are brought about by the incorporation of organic matter while physical changes appear to be due to selection and sorting of certain particles resulting in a change of structure and particle size distribution (Malaka, 1977a, b). The changes in texture brought about by redistribution of mounds and other structures in the surface is likely to be accompanied by changes in physical properties such as structural stability, bulk density, infiltration rate, permeability and water holding capacity

(Wood and Sands, 1978). Studies by Pomeroy (1983), Arshad *et al.* (1982), Wood *et al.* (1983), Menant *et al.* (1985) and Abhadie and Lepage (1989) showed that termite play a major role in both physical and chemical properties of soil as well as nutrient cycling and soil metabolism.

PHYSICAL CHANGES AND TERMITES MOUNDS

According to Lee and Wood (1971), the particle size of soil from various termite mounds when compared with adjacent soil showed that some degree of selection of particular size fraction is general and that few termite species consistently select material within a precise range of particle size.

Nye (1955), Harris (1956), Stoop (1964) and Grasse (1984) noted that particle size of mounds of *Macrotermes* species in Africa showed that their composition is close to that of subsoil, but there is some selection in favour of fine size fraction in soils that are not rich in clay or against the finer fraction in soils rich in clay at Arush, Tanzania. The changes in *Macrotermes* mound shape in Eastern Africa were related to the ratio of sand to clay in mounds and the subsoil from which materials were obtained (Hesse, 1955). Hesse (1955) reported further that tall, thin mounds had sand to clay ratios of 1:1 to 3:1 while larger, domed-shaped mounds had ratios of 2:1 to 18:1. According to Kemp (1955), *Cubitermes* species mounds had 67.2% clay and 26.5% sand compared with 30.8% clay and 63.0% sand for the surrounding soils. Stoop (1964) recorded that the mounds of *Cubitermes scinteuensis* had low proportion of 100-500 μ particle size and higher proportion of less than 100 μ particle size of soil compared to surrounding soil with higher values.

Pathak and Lehri (1959) found that in the termite mound soil, 67.7% of clay aggregates had particle size greater than 2 μ compared with 48.1% in undisturbed soil and 19.2% of silt size particles were incorporated in aggregates in the mound soil while 5.6% were aggregates in undisturbed soil. Watson (1962) reported that the termite mound had 94% fine material (clay + silt) compared to 52% clay and silt in adjacent soil in West Africa. When the physical properties of termite modified soil by *Drepanotermes tammunensis*, *Amitermes obenntis* and *Amitermes neogermans* were examined; Debruyne and Conacher (1987) found that the mounds had significantly higher clay content than the surface surrounding soil. Kang (1978), Lal (1988), Breuwer *et al.* (1991), Malaka (1977), Ekundayo and Aghatise (1997) and Ekundayo and Orhue (2002) observed that the various termite mound soil had higher values of silt and clay and lower values of sand in relation to bulk surrounding soil from which the mounds were constructed. Ghilarov (1962) describe the termite mound of *Anacanthotermes* species to be strongly cemented with clays while Greaves (1962) observed the termite mound of *Soptotermes brunneus* to consist of compact red sandy soil in Western Australia. In a comparison of granulometry between mound and the surrounding soil Merdraci and Lepage (2001) reported higher increase of finer soil particles (clay + silt) than the surrounding soil in Lamto Savanna. Lobry de Bruyn and Conacher (1990) however observed that variation in particle size was due to variation in site characteristics, termite species and genera, land use at the sampling site.

Ghilarov (1962) reported the bulk density of termitaria to be 1.112 g cm⁻² compared with 1.225 g cm⁻³ for surrounding soils. Malaka (1977), Ekundayo and Aghatise (1997), Ekundayo and Orhue (2002) and Reddy and Rapu (2005) reported that the bulk density of surface mound were higher than that of the surrounding soils. Malaka (1977b) however reported that the mound soil of three species of *Cubitermes*, *Macrotermes*, *Trinerviterma germinatus* which do not support vegetation had an average bulk density of 1.80 g cm⁻³ or greater with accompanying porosity less than 33% while mound material of *Amitermes evuncifer* which commonly support vegetation had an average bulk density of 1.33 g cm⁻³ and a porosity of 48%.

Pathak and Lehri (1959) reported that mounds of *Odontotermes obscuriceps* in India had a water-holding capacity about five times than that of adjacent soil. It was reported by Elkins and Sabadol (1986) and Jaean and Valentin (1987) that the surrounding soil had less water-holding capacity

relative to the various termite mounds examined. Kemp (1955) have earlier reported a small increase in water holding capacity in mounds of *Cubitermes umbratus* in Africa compared to the adjacent soil. Ghilarov (1962) reported a fall in water-holding capacity of about 8% in mounds of *Anacanthotermes* species relative to surrounding soils in central Asia while Goodland (1965) found a reduced water holding capacity in an unidentified termite mound compared with the surrounding soil in Rupunmu savanna. Lal (1988) found low water infiltration in mound soil in relation to bulk surrounding soil. Arshad (1982) reported favourable water availability together with good drainage in termite mound soil compared to the surrounding soil.

CHEMICAL CHANGES AND TERMITES MOUNDS

Lal (1988) and Brouwer *et al.* (1991) reported that mound soil of various termite species can have either higher or lower values of organic carbon total nitrogen, available phosphorus, exchangeable calcium, magnesium and potassium, effective cation exchange capacity in relation to surrounding soils. It has been described by Lavelle *et al.* (1994) that pedogenesis, organic matter decomposition and nutrient cycling are highly influenced by termites.

Ekundayo and Aghatise (1997), recorded a higher organic carbon, C/N ratio, Ca, Mg, K, P in mounds of *Macrotermes* and *Odontotermes* species than the surrounding soils in Nigeria. Also Reddy and Rapu (2005) recorded increased organic matter in termite mound compared to adjacent soil of Podili and Talupula in India. Frageria and Baligar (2005) reported that termite activities significantly increased exchangeable cations, micro-nutrients, organic matter content and the pH of the mound soil while the soil acidity in terms of Al was decreased in an oxisol of cerrado region of Brazil. Lobry de Bruyn and Conacher (1990), Debruyn and Conacher (1987) and Duponnois *et al.* (2005) found that the termite mounds of *Cubitermes* and *Trinervitermes* have higher carbon and N, CEC, NH₄ and P while *Macrotermes subhyalinus* mound however have lower NO₃ and carbon content compared to the surrounding soil in Burkina Faso.

Malaka (1997a) however, recorded low organic carbon content but high Ca, K and Mg in Macrotermitanae as compared to their surrounding soils. In the Cerrado, Brazil soil carbon stabilization was higher in termite mound as demonstrated by higher carbon content in silt size separates (Zech *et al.*, 1997). Hesse (1955) found low C/N ratio in the termite mound in comparison to adjacent soils. Kemp (1955) using *Cubitermes* mound and Stoop (1964) using *Macrotermes* mound recorded higher organic matter content, P, cations, pH in both mounds, low pH in *Macrotermes*. Lee and Wood (1971) found that the organic carbon content of mounds and other structures parallel the organic matter content that is it is generally higher and occasionally lower than that of adjacent soil. Similarly, nitrogen content according to Lee and Wood (1971) was roughly parallel to organic matter content but not necessarily in the same proportion as carbon content. Lee and Wood (1971) in their investigation in Australia found that exchangeable Ca, Mg, K were generally high in termite modified soils than unmodified samples. Lee and Wood reported further that CaCO₃ were occasionally found usually in a band near the base of the mound and sometimes the quantity may be sufficient that the mound may be used as a fertilizer in the initial agricultural system. Holt and Lepage (2005) and Marisa (2005) reported increase in carbon and nitrogen content of various termite mounds as compared to the surrounding soils. In the analysis of *Anacanthotermes* mound in Central Asia Kozlova (1951) reported 0.85% NO₃ in the mound compared to adjacent soil with 0.022% NO₃ and 47 kg ha⁻¹ readily available nitrogen.

Jones (1973) and Cabrera (1993) recorded the lowest carbon content and lowest C/N ratio in the soil of *Macrotermes* and *Odontotermes* mounds. Bruno *et al.* (2001) however found that the largest increase of mineralize carbon took place but with lower pH in the soil of termite mound of *Macrotermes* in Northern Tanzania. Duponnois *et al.* (2005) while citing Ndiaye *et al.* (2003) reported

that termite mound exhibited higher %C and K content in Burkina Faso. Among the African species, Boyer (1956) found that *Amitermes* species had a C/N ratio of 18.7-18.82 accompanied with high pH compared with C/N ratio of 8.26-10.31 for surrounding soil while Maldugue (1959) reported that the mound of *Thoracotermes brevinatus* had C/N ratio of 12 compared with 15.0 in the adjacent soil. Bernhard-Reverret (1982) found lower N content in the mounds of *Macrotermes* and *Odontotermes* species than the surrounding soil. Of the 46 samples consisting mainly of soil taken from mounds of 13 species only 2 samples had C/N ratio lower than the soils from which they were derived, while the remaining samples consisting of carbon or containing high proportion of carbon had C/N ratio much higher than the surrounding soils.

It has been reported by Pearce (1997) that *Trinervitermes*, *Hodotermes* species mound had great levels of N, Silica, Ca, Al, Fe, Mg, Cr, while the *Odontotermes* species had higher ferric and aluminum oxide, CaCO₃ than the adjacent soils. Pearce also reported further that the Russian *Anacanthotermes ahalgerianus* had higher water soluble salts, phosphorus and potassium salts while in Okarago Delta, various termite mounds have been discovered to be rich in calcite crystals.

Watson (1962) found high concentration of Ca and high pH in un-identified species of African Macrotermitidae. Goodland (1965) found high Ca and Mg concentration in termitaria with Ca concentration averaging more than three times and sometimes up to seven times than those in the surrounding soil in the Repununi Savannah lands of Guyana. Gokhale *et al.* (1958), Pathak and Lehri (1959) reported high concentration of Ca, Mg, P in *Odontotermes* species and *Microcerotermes* species mounds respectively but Pathak and Lehri (1959) however recorded low K content in *Odontotermes* species mound. Ellis (2001) also found high content of Ca, high pH and P as well as high content of CaCO₃ in the termite mound of *Microhodotermes viator* in South Africa.

The abundance of the CaCO₃ according to Ellis (2001) has equally led to the presence of petrocalcic horizon in the soil profile. Donova *et al.* (2001) discovered high content of Kaolinite and higher pH and a decrease relative amount of quartz in the termite mound of *Cubitermes fungifaber* in humid forest of Southern Cameroon. Siame (2005) concluded in his investigation that termite mounds have high levels of Ca, P, K as well as higher amount of organic matter which contribute to better crop development. In the examination of mounds of species in northern Tanzania, Bruno *et al.* (2001) reported that the termite mound had low Zn but higher Na and Cu contents than the native and degraded savanna soils with higher basic cations than the termite mounds.

CONCLUSION

From the review, termites have been known to exist for several years and its study only known within past century. Termites are known all over the world and several families and species exist. The most prominent among these termites is the Isoptera. Generally, termites are the principal decomposer of organic materials thereby helping to recycle nutrient in our soils. Their role as nutrient recycler in our environment helps to balance nutrients in the soil. The particle size selection aids the re-arrangement of soil which brings about an improvement in some physical properties.

REFERENCES

- Abe, T. and T. Mastumoto, 1979. Studies on destruction and ecological role of termites in lowland rainforest of West Malaysia, distribution and abundance of termites in Pasoh forest reserve. Japan J. Ecol., 29: 337-351.
- Abensperg-Traun, M. and D.H. Perry, 1998. Distribution and characteristics of mound-building termites (Isoptera) in Western Australia. J. Royal Soc. Western Australia, 81: 191-200.

- Abhadie, L. and M. Lepage, 1989. The role of subterranean fungus comb chambers (Isoptera Macrotermitidae) in soil nitrogen cycling in pre-forest savanna (Cote de Ivoire). *Soil Biochem.*, 21: 1067-1071.
- Araujo, R.L., 1970. Termites of Neotropical Region. In: *Biology of Termites*. Krishna, K. and F.M. Weesner (Eds.), Vol. 2. Academic Press. N.Y., pp: 527- 576 .
- Arshad, M.A., 1982. Influence of *Macrotermes michadson* (sjost) on soil Fertility and vegetation in a semi arid savanna. *Agro-Ecosystem*, 8: 47-58.
- Arshad, M.A., N.K. Mureria and S.O. Keya, 1982. Effect of termite activities on the soil micro flora. *Pedobiologia*, 24: 161-167.
- Atkin, L. and J. Proctor, 1988. Invertebrate in the litter and soil in Volcan Barva, Costa Rica. *J. Trop. Ecol.*, 4: 307-310.
- Ayuke, F.O., M.R. Raam, M.J. Swilt and M.L. Oponda-Mbai, 2004. Assessment of Biomass Transfer from Green Manure to Soil Macrofauna in Agro-ecosystem Soil. *Macrofauna Biomass In: Managing Nutrient Cycles to Sustain Soil Fertility in Sub-sahara African*. Andre, B. (Ed.), Academy of Science, Nairobi, pp: 411-422.
- Bernhard-Reversat, F., 1982. Biogeo-chemical cycle of nitrogen in a semi-arid savanna. *OIKOS*, 38: 321-333.
- Black, H.I. and T.C. Wood, 1989. Effect of cultivation on vertical distribution of *Microtermes* sp. (Isoptera Termitidae; Macro- termitinae) in soil at Mokwa, Nigeria. *Sociobiology*, 15: 133-138.
- Bodot, P., 1962. Etudes ecologique des termites de Base. Cote de Ivoire. *Insectes Sociateux*, 14: 229-258.
- Bodot, P., 1984. Etudes ecologiques of biologie des termiles dans les savanas de Besse Cote de Ivoire. In: *Etudes sur les Termites Africaens*. Bouillon, A. (Ed.), Leopoldville University, Leopoldville pp: 251-262.
- Bouillon, A. and S. Kidieire, 1964. Repartition Des Termitieres De *Bellicositermes bellicosus* Nex Grasse et Noisof Dans l'ubange D'pre's Les Photos Aerienues Correlations Ecologiques Qu'elles R'ev'ele. In: *Efudes Surles Termites Africans*. Bouillon, A. (Ed.), Leopoldville University Leopoldville, pp: 373-376.
- Boyer, P., 1956. Relation entre la flore intestinate de *Bellicositermes natulensis* et celle do sol. *Proceeding of 6th International Soil Science Congress Paris*, 3: 111-113.
- Brouwer, J., S.C. Geiger and R. Vandenbelot, 1991. Likely positive effects of termites on soil fertility and tree and crops growth near Niamey, Niger. Would tillage reduce these? In: *Abstract of 12th International conference of International soil tillage research organization.*, 8-12th July, 1991 Ibadan, Nigeria. OHSU Press, Columbia, pp: 82.
- Bruno, G., L. Johannes and F. Maike, 2001. Carbon and nitrogen mineralization in cultivated and natural savanna soils of Northern Tanzania. *Biol. Fertility Ssoil*, 33: 301-309.
- Cabrera, M.L., 1993. Modeling the flush of nitrogen mineralization caused by drying and riveting soils. *Soil Sci. Soc. Am. J.*, 57: 63-66.
- Collins, N.M., 1979. The nest of *Macrotermes bellicosus* (Smeathman) from Mokwa, Nigeria. *Insectes Sociateux*, 26: 240-246.
- Cowie, R.A., J.W.M. Logan and T.G. Wiod, 1989. Termite (Isoptera) damage and control in tropical forestry with special reference to Africa and Indo- Malaysia. *Entomol. Res.*, 79: 175-184.
- Dangerfield, J.M., 1990. Abundance, biomass and diversity of soil macrofauna in savanna and associated managed habitats. *Pedobiologia*, 34: 141-150.
- Dangerfield, J.M., 1993. Characterization of Soil Fauna Communities In: *Report on Characterization of an Experimental Field in KMRL Farm*. Rao, M.R. and R.J. Scholar (Eds.), Muguga, Kenya. ICRAF. Nairobi, pp: 51-67.
- Debruyyn, L.A.L. and A.L. Conacher, 1987. Soil modification by termites in the central wheat belt of Western Australia. *Australia J. Soil Res.*, 33: 179-193.

- Donovan, S.E., P. Eggleton, W.E. Dubbin, M. Batch and L. Dibog, 2001. The effect of a soil-feeding termite *Cubitermes fungifaber* (Isoptera: Termitidae) on soil properties: Termites may be an important source of soil microhabitat heterogeneity in tropical forest. *Pedobiologia*, 45: 1-11.
- Dupponois, R., M. Peougy, J. Thwuou, D. Masse and M. Lepage, 2005. Functional diversity of soil microbial community, rock phosphate dissolution and growth of *Acacia seyal* as influenced by of grass-litter and soil-feeding termite nest structures amendments. *Geoderma*, 12: 349-356.
- Eggleton, P., D.E. Bignell, W.A. Sands, B. Waiter, T.C. Wood and J.H. Lawson, 1995. The species of richness of termites (Isoptera) under different levels of forest disturbances in the Mbalaiyo forest Reserve, Southern Cameroon. *J. Trop. Ecol.*, 11: 88-98.
- Ekundayo, E.O. and V.O. Aghatise, 1997. Soil properties of termite mounds under different land use types in a Type paleudult of Midwestern Nigeria. *Environ. Monit. Assess.*, 45: 1-7.
- Ekundayo, E.O. and E.R. Orhue, 2002. Properties of termite mounds soil in the Niger Delta region of Southern Nigeria. *J. Sci. Technol. Res.*, 14: 15-21.
- Elkin, N.Z. and V.S. Sabadol, 1986. The influence of subterranean termites on the hydrological characteristics of chihuahuan desert ecosystem. *Oecologia*, pp: 1-8.
- Ellis, P., 2001. Contribution of termite to the formation of hardpans in soils of arid and semi arid regions of South Africa. A paper presented at a symposium No. 20 at Department of soil science, University of Stellenbosch, South Africa. Paper No. 572, pp: 1-9.
- Frageria, N.K. and V.C. Baligar, 2004. Properties of termite mound soils and responses of rice and bean to N.P. and K fertilization on such soil. *Communi. Soil Sci. Plant Analy.*, 35: 15-16.
- Fragoso, C. and P. Lavelle, 1992. Earthworm communities of tropical rainforest. *Soil Biol. Biochem.*, 24: 1397-1408.
- Fragoso, C., I. Lavelle, E. Blanchart, R.K. Senapati, J.J. Jimenez, M.A. Martinez, T. Decaens and J. Tondoh, 1999. Earthworm communities of tropical agro ecosystems origin, structure and influence of management practices In: *Earthworm, management in tropical Agro ecosystems*. Lavelle, P., L. Brussaard and P. Hendrix (Eds.), CABI publishing Oxon, pp: 27-55.
- Ghilarov, M.S., 1962. Termites of the USSR, their Distribution and Important. In: *Termites in the Humid Tropic*. New Delhi Symposium, UNESCO, Paris, pp: 131-135.
- Glover, P.E., E.C. Trump and L.E.D. Wateridge, 1964. Termitaria and vegetation patterns on the Loita plains of Kenya. *J. Ecol.*, 52: 365-377.
- Gokhale, N.G., S.N. Sarma, N.G. Bhattacharyya and J.S. Dutta, 1958. Effect of termite activity in the chemical properties of tea soils. *Sci. Cultivation*, 24: 229.
- Goodland, R.S.A., 1965. On termitaria in a savanna ecosystem. *Can. J. Zool.*, 43: 641-650.
- Grace, J.K., 1989. Northern subterranean termites. *Pest Manage.*, 8: 14-16.
- Grace, J.K., 1990. Termites in Eastern Canada: An updated review and bibliography. The International Research Group on wood preservation. Stockholm, Sweden IIoc IRG/WP/ 1431, pp: 6.
- Grace, J.K., 1992. Termite distribution, colony size and potential for damage. *Proceedings of the National Conference on Urban Entomology*, pp: 67-76.
- Gray, F.J. and J.H. Calaby, 1970. Termite from Australian Region. In: *Biology of Termites*. Krishna, K. and F.M. Weesner (Eds.), Academic Press N.Y. London, 2: 393-449.
- Grasse, P.P., 1984. *Termitologia foundation de la societee et construction*. Tome 11: Masson, pp: 613.
- Greaves, T., 1962. Studies of the foraging galleries and the invasion of living trees by *C. ocinaciformis* and *C. brunneus* (Isoptera). *Aust. J. Zool.*, 10: 630-651.
- Harris, W.V., 1955. Termites and the Soils. In: *Soil Zoology*. Miekevan, D.K. (Ed.), Butter Worth, London, pp: 12-72.
- Harris, W.V., 1956. Termite Mound Building. *Insectes Sociatus*, 3: 261-265.
- Harris, W.V., 1970. Termites of the Palaearctic Region. In: *Biology of Termites*. Krishna, K. and F.M. Weesner (Eds.), Academic Press. New York, 11: 295-315.

- Hesse, P.R., 1955. A chemical and physical study of the soils of termite. Mounds in East Africa. *J. Ecol.*, 43: 449-461.
- Holt, J.A. and M. Lepage, 2000. Termite and Soil Properties, Termites. Evolution, Sociality, Symbiosis and Ecology. In: Abe, T. (Ed.), Kluwer Academic Publisher, pp: 389-407.
- Jauean, J.L. and N. Valentin, 1987. Relations entre les termitieres *Trinervitermes* sp. et la surface du sol reorganization, ruissellement et erosion. *Ecol. Biol. Soils*, 24: 637-647.
- Jones, M.J., 1973. The organic matter content of the savanna soils of West Africa. *J. Soil Sci.*, 24: 42-53.
- Jones, S.E., 1988. Foraging and distribution of subterranean termites. Proceedings of the National Conference on Urban Entomology, pp: 23-32.
- Kambhampati, S. and P. Eggleton, 2000. Taxonomy and Phylogeny of Termites. In: Termites Evolution, Sociality, Symbiosis, Biology. Abe, T., D.E. Bigness and M. Hu (Eds.), Kluwer Academic Publisher, Netherlands, pp: 1-23.
- Kang, B.T., 1988. Effect of some biological factors on soil variability in the tropics 111. Effect of the *Macrotermes* mounds. *Plants and Soil*, 50: 241-251.
- Kemp, P.B., 1955. The termites of North-eastern Tanganyika: Their distribution and biology. *Bull. Entomolog. Res.*, 46: 133-135.
- Kondoh, M., H. Watanabe, S. Chiba, T. Abe, M. Shiba and S. Saito, 1980. Studies on the productivity of soil animals in Pasoh Forest Reserve, West Malaysia. Seasonal change in the density and biomass of soil. Macrofauna Oligochaeta, Hirudinea and Arthropoda. Memo graph of Shiranme Grakuen College, 16: 1-26.
- Kozlova, A.V., 1951. Accumulation of nitrates in termite mounds in Turkmenia. *Pochvovedeuie*, 10: 626-631.
- Krishna, K. and F.M. Weesmer, 1969. Biology of termites. Volume II. Academic Press, New York.
- Lal, R., 1988. Effect of macro fauna on soil properties in tropical ecosystem. *Agric. Ecosyst. Environ.*, 24: 101-106.
- Lavelle, P. and B. Pashanasi, 1989. Soil macro fauna and management in Peruvian Amazonia (Yurimagnas Loreto). *Pedobiologia*, 33: 283-291.
- Lavelle, P., M. Dangerfield, D. Eschenbrunner Lopez-Hernandez, B. Pashanasi and L. Brusaad, 1994. The Relationship Between Macro Fauna and Tropical Soil Fertility. In: Wooner, P.L. and M.J. Swift (Eds.), *The Biological Management of Tropical Soil Fertility* Wiley, New York, pp: 157-169.
- Leaky, R.J. and J. Proctor, 1987. Invertebrates in the litter and soil at a range of altitude on Gunung Silam, a small ultrabasic mountain in sabah. *J. Trop. Ecol.*, pp: 119-129.
- Lee, K.E. and T.G. Wood, 1971. Termites and Soils. Academic Press, New York, pp: 251.
- Lobry de Bruyns, L.A. and A.J. Conacher, 1990. The role of termites and ants in soil modification A review. *Aust. J. Soil Res.*, 28: 55-93.
- Malaka, S.L.O., 1973. Observation on termites in Nigeria. *The Nigerian Fields*, 38: 24-40.
- Malaka, S.L.O., 1977a. A study of the chemistry and hydraulic conductivity of mounds materials and soils from different habitants of some Nigerian termites. *Aust. J. Soil Res.*, 15: 87-92.
- Malaka, S.L.O., 1977b. A note on bulk density of Termite mounds. *Aust. J. Soil Res.*, 15: 93-94.
- Malaka, S.L.O., 1983. Economic importance of termite: Six case studies in Nigeria and Ghana. *Nigerian Fields*, 47: 222-230.
- Malaka, S.L.O., 1996. Termites in West Africa. Publisher University of Lagos Press, pp: 165.
- Maldague, M.E., 1959. Analyse sde sols et materiaux de termiterees du Congo Belge. *Insect Sociateux*, 6: 343-359.
- Maldague, M.E., 1964. Importance des populations de termites dans les sol equatoriaux. Trans 8th International Soil Science Congress, Bucharest 1964, pp: 743-751.

- Marisa, A., 2005. Australian termites and nutrient recycling. *Biology*, 394: 1-12.
- Martins, C., 1994. Diversity and ecology of termites in Amazonian forests. *Pedobiologica*, 38: 407-428.
- Menaut, J.C., R. Barhault, P. Lavelle and M. Lepage, 1985. African Savannas Biological Systems of Humification and Mineralization. In: *Ecology and Management of the World's Savannas Australia*. Mott, J.T.J. (Ed.), Academy of Science Canberra, pp: 14-33.
- Merdraci, K. and M. Lepage, 2005. Effect of termitaria on spatio-temporal variation of soil water in tropical savanna. *Enregistrenment Scientique*, 1229: 1-6.
- Meyer, J.A., 1960. Resultants agronomiques d'un essai de nivellement des termitieres realize dans la cuvelte centraie congolaise. *Bulletin of Agriculture in Congo Belgs*, 51: 1047-1059.
- Muys, B., N. Lust and P.H. Granval, 1992. Effects of grassland afforestation with different tree species on earthworm communities, litter decomposition and nutrient status. *Soil Biol. Biochem.*, 24: 1459-1466.
- Nel, J.J.C. and E.M. Malan, 1970. The distribution of mounds of *Trinervitermes trivernoides* in the central orange tree state. *J. Entomolog. Soc. South Africa*, 37: 257-256.
- Nutting, W.L. and S.C. Jones, 1990. Methods for studying the ecology of subterranean termites. *Sociobiology*, 17: 167-189.
- Nye, P.H., 1955. Some soil forming processes in the humid tropics. A field study of a catena in West African forest. *J. Soil Sci.*, 5: 7-21.
- Nyeko, P. and F.M. Olubayo, 2005. Participatory assessment at farmers experience of termiteproblems is Agro forestry in sources District. Uganda. Network Paper No. 143: 1-15.
- Park, H.C., J.D. Mayer and R.J. Hobbs, 1994. Influence of vegetation and soil types on the wheat belt termite, *Drepanotermes tamminenses* (hill), in the Western Australia wheat belt. *Ecol. Res.*, 9: 157-158.
- Pathak, A.N. and L.K. Lehri, 1959. Studies on termite nests I: Chemical, physical and biological characteristics of a termitarium in relation to its surrounding. *J. Indians Soc. Soil Sci.*, 7: 87-90.
- Pearce, M.J., J.W.M. Logan and A. Tiben, 1995. Termites (Isoptera) from Durfur region of the Sudan with comments on their pest status. *J. Arid Environ.*, 30: 197-206.
- Pearce, M.J., 1997. *Termites, Biology and Pest Management*. CAB International, Willing Ford UK., pp: 172.
- Pellen, R. and L. Garay, 1999. Edaphic macro arthropod communities in fast growing plantations of *Eucalyptus grandis* Hill ex maid (Myrtaceae and *Acacias mangium* wild (Leguminosae) in Brazil. *Eur. J. Soil Biol.*, 35: 77-89.
- Pomeroy, D.E., 1983. Some effects of mound-building termites on the soils of a semi arid area of Kenya. *J. Soil Sci.*, 34: 555-570.
- Ratcliffe, P.N., F.J. Gay and T. Greaves, 1952. *Australian Termites*. Commonwealth Scientific and Industrial Research Organization. Melbourne, Australia.
- Reddy, K.S. and A.N. Raju, 2005. The physical and textural characteristic of termite mounds from podili and Talupula Areas, Andhra Pradesh WWW.bestindia.com/ygsi/sinu.
- Sands, W.A., 1965a. Termite distribution in man-modified habitat in West Africa with special reference to species segregation in the genus *Trinervitermes* (Isoptera, Termitidae, Nasutitermitinae). *J. Annim. Ecol.*, 34: 557-571.
- Sands, W.A., 1965b. Mound population movements and fluctuation in *Trinervitermes ebeneriamis* Sjostedf (Isoptera, Termitidae, Nasutitermitidae). *Insectes Societeaux*, 12: 49-58.
- Sands, W.A., 1998. *The Identification of Worker Caste of Termite Genera from Soil of Africa and the Middle East* Willing Ford,UK. CAB International.
- Sekamate, M.B., 2001. Termites situation on crops and range lands in Nakasongola District. A Report Submitted to the Environmental protection and Economic Development (EPED) Project, Kampala, Uganda.

- Siame, A.J., 2005. Termite mound as fertilizer. *Low external input and sustainable Agriculture*, 21: 29.
- Sponsler, R.C. and A.G. Appel, 1991. Temperature tolerance of formosa and eastern subterranean termites. *J. Thermo Biol.*, 16: 41-44.
- Stoops, G., 1964. Application of Some Pedological Methods to the Analysis of Termite Mounds In: *Etudes Sur Les Termite Africains*. Bouillon, A. (Ed.), University of Leopoldville, Leopoldville, pp: 379-398 .
- Tsukamoto, J. and J. Sabang, 2005. Soil macro-fauna in an *Acacia mangium* plantation in comparison to that in a primary mixed dipterocarp forest in the lowlands of Savawala, Malaysia. *Pedobiologia*, 49: 69-80.
- Wood, T.G. and W.A. Sand, 1978. The Role of Termites in Ecosystems In: *Production Ecology of Ants and Termites*. Brian, M.W. (Ed.), International Biological Program 13. Cambridge University Press, pp: 245-392 .
- Wood, T.G., R.A. Johnson and J.M. Anderson, 1983. Modification of the soil in Nigerian savanna by soil-feeding *Cubitermes* (Isoptera Termitidae). *Soil Biol. Biochem.*, 15: 575-579.
- Watson, J.P., 1962. The soil below a termite mound. *J. Soil Sci.*, 13: 46-51.
- Yeates, G.W., 1988. Earthworm and enchytraeid populations in a 13-year- old agro forestry system. *New Zealand J. Forest Sci.*, 13: 304-310.
- Zech, W., W. Amelung and H. Neufeldt, 1997. Organic Matter in Termite Mounds of Corados, Brazil. In: *The Role of Humic Substances in the Ecosystem and in Environmental Protection*, Drozd, S., S.S. Gonet, N. Senesi and J. Weber (Eds.), PT SH, Wroclaw, pp: 263-268.