



The Impacts of Mound-Building Termites on Micronutrients and Soil Hydraulic Properties in Parts of Borana Lowlands Southern Ethiopia

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Abstract: This study was focuses on the impact of mound- building termite on micronutrients and soil hydraulic properties in three districts of Borana zone. The condition of soil is in unfavorable condition when its physical, chemical and biological features have negative impact on environment. Knowledge on soil hydraulic properties and micro nutrient content for soils affected by termite mound and adjacent unaffected soil will give a clue on the impact of mound building termite for plant establishment. Infiltration rate for adjacent soil profile 106.47 mm/hr (Moderately rapid) and for termite mound profile 142.13 mm/hr (rapid) infiltration rate has been observed while the packing density up to 1.80 t m^{-3} (high) for external part of termite mound which is greater than 1.75 t m^{-3} and 1.36 t m^{-3} (low) for adjacent soil profile less than 1.40 t m^{-3} . There is also higher concentration of manganese (Mn) and zinc (Zn) content on external part of termite mound for fine textured soil and no difference in copper (Cu) and Iron (Fe) content between termite mound material and adjacent soil. Generally, the termite mound has positive impact on soil hydraulic properties of soil and micronutrients in order to support plant establishments.

Keywords: Termite Mound, Hydraulic Properties, Micronutrients

1. Introduction

In Borana lowland, both mound building and mound less termites are abundant and widely distributed [3]. Termite mound materials can be differentiated from the adjacent soil by its different physico-chemical properties that impact some soil processes. Usually high concentration of organic matter and mineral nutrients are found in termite mound than in the surrounding soils. Consequently, subsistence farmers in Africa commonly spread termite mound materials in their fields to improve soil conditions and increase plant nutrient availability [18]. They also promote nutrient availability, nutrient cycling and soil physical properties [2].

However, Amsalu [1] reviewed that, research on termite in Ethiopia has been concentrated on only the pest management aspects. Amsalu [1] studied the effects of mound-building termites on macronutrients and some physical properties and found that termite biogenic structure are rich in macronutrients specifically in available phosphorus and basic

cations. In spite of relatively rich in macronutrients, highly visible in many of the Borana rangelands mounds are bare of vegetation, creating a marked visual patchiness to the landscape (personal observation). What properties of the mounds at our study site constrain vegetation establishment instead? Only a handful of studies exist describing macronutrients properties of termite mounds in Yabello and Dire Districts of Borana zone [1]. No studies on the hydraulic and micronutrients properties of termite mounds were found for Borana zone. The main objective of this paper is to determine the impact of termite mounds on micronutrients and soil hydraulic properties.

2. Materials and Methods

2.1. General Description of the Study Area

The study was conducted in Borana zone of Southern Oromia Regional state, 577 km away from Addis Ababa.

According to the newly organizational structure of Oromia, Borana zone has thirteen districts, with its capital Yabello town. The Borana rangelands are characterized by arid and semi-arid climate, with pockets of sub humid land. The vegetation is patchy, due to widely varying soils, temporally and spatially variable rainfalls and differences in the land use history. The plateau is divided into four major seasons. These include: (1) – Ganna(March-May), the long rainy season; (2)-

Adolessa(June-August), the cool dry season; (3)- Hagayya(September-November), the short rainy season; and (4) - Bona (December-February) [4]. The average annual rainfall ranges between 350 and 900 mm, with a considerable inter-annual variability of 21% to 68% [6]. Rainfall is bimodal, 60% of the rainfall occurs between March and May (main rainy season) followed by a minor peak between September and November (short rainy season) [4].

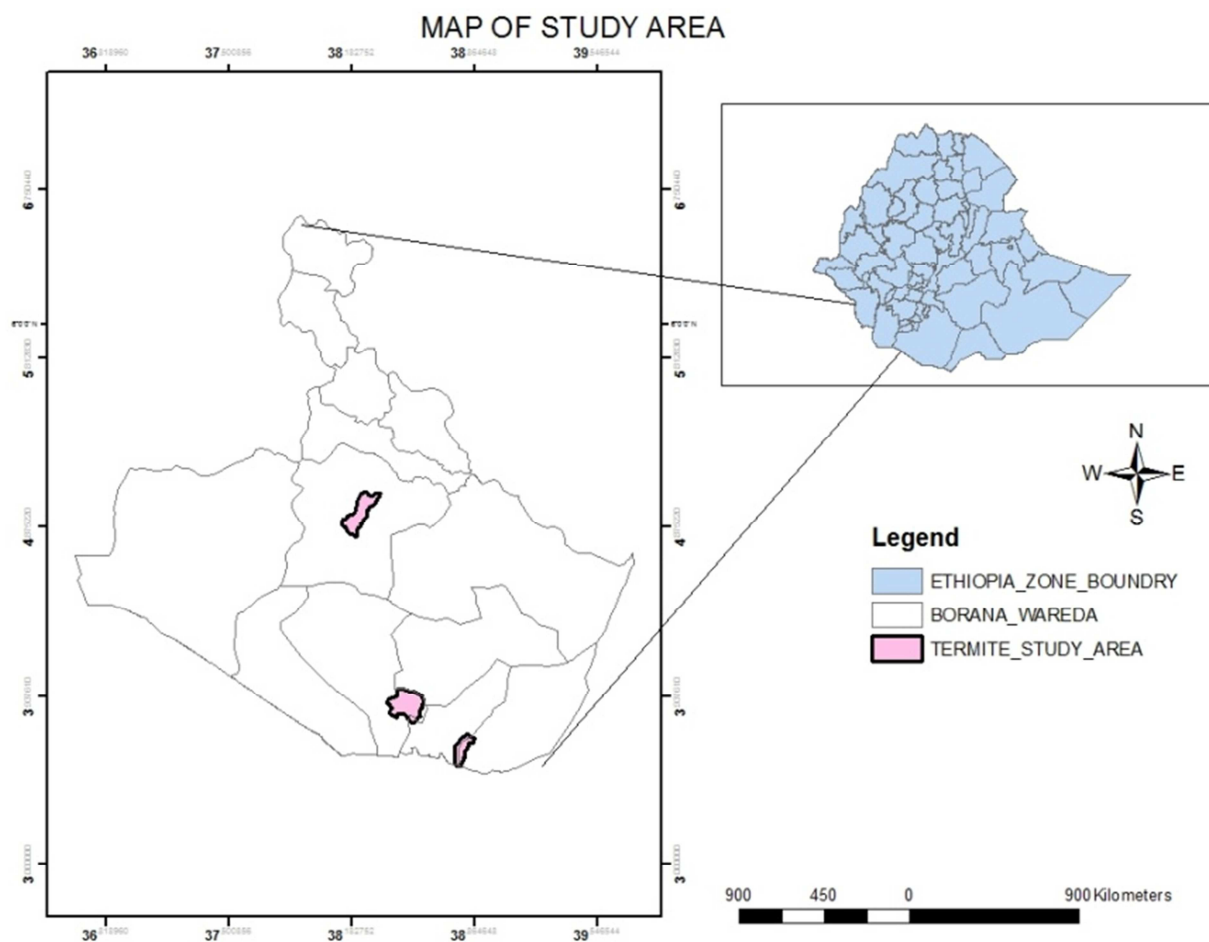


Figure 1. Study area map.

2.2. Site Selection and Sampling of Soils and Mound Materials

The study was conducted in three districts of Borana zone. Specific districts and sites were selected considering the widespread of termite mounds and agricultural expansion. In each location, replications of three termite mounds were purposively selected on a uniform slope. To test whether high concentration of nutrients are found where new building materials are deposited such that at the top of the mounds and termite mound materials has been collected from the top and bottom parts of mounds. Samples were collected after scratching and removing the outer surface of mound materials.

Besides, in order to evaluate micronutrients composition of termite mounds in relation to the surrounding soils, a total of six soil profiles were sampled for this study. The profiles have been opened in a relatively unaffected area by termite

mound at reasonable distance from mounds and considered to be the reference soils without significant termite activity not meaning necessarily that termite activity never occurred in it. Termite mound and its corresponding soil profile were located on comparative slope gradients in order to avoid further differences that can be introduced due to topographic effects. Under this condition, any difference in soil micronutrients properties between termite mound materials and adjacent soil profile can be attributed to the effects of mound-building termites.

Before collecting soil samples, all soil profiles were described in accordance with the [5] guidelines for Soil profile description. In all cases depth of sampling and number of sample per profile/pit was depends on soil depth and their horizons formations. For bulk density determination, mound materials and adjacent soil profile samples were collected using core sampler.

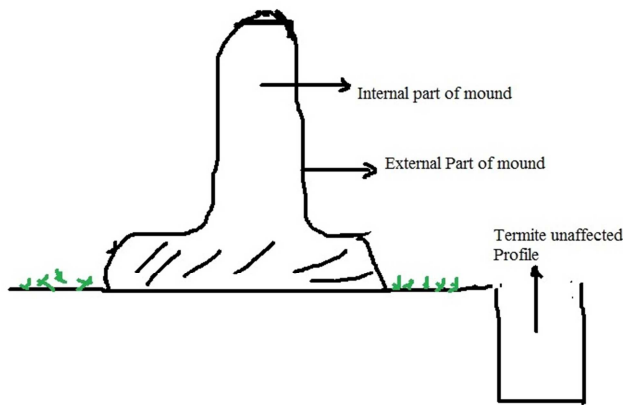


Figure 2. Tentative sampling protocol from termite mound, termite unmodified soil profile.

2.3. Physico-chemical Analysis of Soils and Mound Materials

The soil samples were air dried ground, mixed well and passed through a 2 mm sieve for analysis. Parameters was analyzed following standard procedures as described in [12] at J. J. soil laboratory and Holetaagricultural research center soil laboratory and soil compaction was measured using bulk density. Available micronutrients (Fe, Mn, Zn, and Cu) were extracted with DTPA as described by [9]. Infiltration rate was determined in the field using ring infiltrometer. R-commander statistical package software version 2.15.5 was used to analyze the data.

3. Soil Hydraulic Property

The condition of soil is in unfavorable condition when its physical, chemical and biological features have negative impact on environment. Information on soil hydraulic properties is very crucial in understanding plant- water relationship in the soil. Several hydraulic parameters are used under different circumstances for water management

activities. Different hydraulic properties are commonly selected than the others depending on difference on application of water management or water movement in soil. Soil hydraulic properties can be obtained directly from laboratory or field measurement.

3.1. Selection of Soil Hydraulic Properties

Soil under termite mound and adjacent soil profile were sampled to determine critical soil hydraulic properties which are selected for measurement based on environmental soil condition assessment criteria under this activity. Soil infiltration rate indicates the movement of water into and through the soil profile and soil compaction which is a mechanical stress of soil destroying the soil structure, reducing or eliminating its permeability to water, heat and air.

3.2. Selected Soil Hydraulic Properties

3.2.1. Infiltration Rate

Infiltration is the downward entry of water in to the soil. Infiltration rate is the velocity at which waters enters to the soil i.e., the volume of water passing through a unit cross sectional area per unit time. In relation to soil function, infiltration is the pointer of soil's ability to allow water movement through and into soil profile such as storage, plant growth and habitat as function of soil. Infiltration rate is affected by inherent properties of soil such as soil texture (percentage of sand, silt and clay) and clay mineralogy as well as the dynamic properties like a reflection of climate, landscape position, management practice and initial water content of soil affect the additional intake of water in it [15].

A ring infiltrometer of 30 cm diameter was used to measure final infiltration rate. To protect the disturbance of soil surface and soil structure the ring infiltrometer has been inserted in a depth of about 10cm. The ring was filled with water at the depth of about 12-16 cm water level and manually measured for 150 min using T-ruler in both termite mound and adjacent soil.

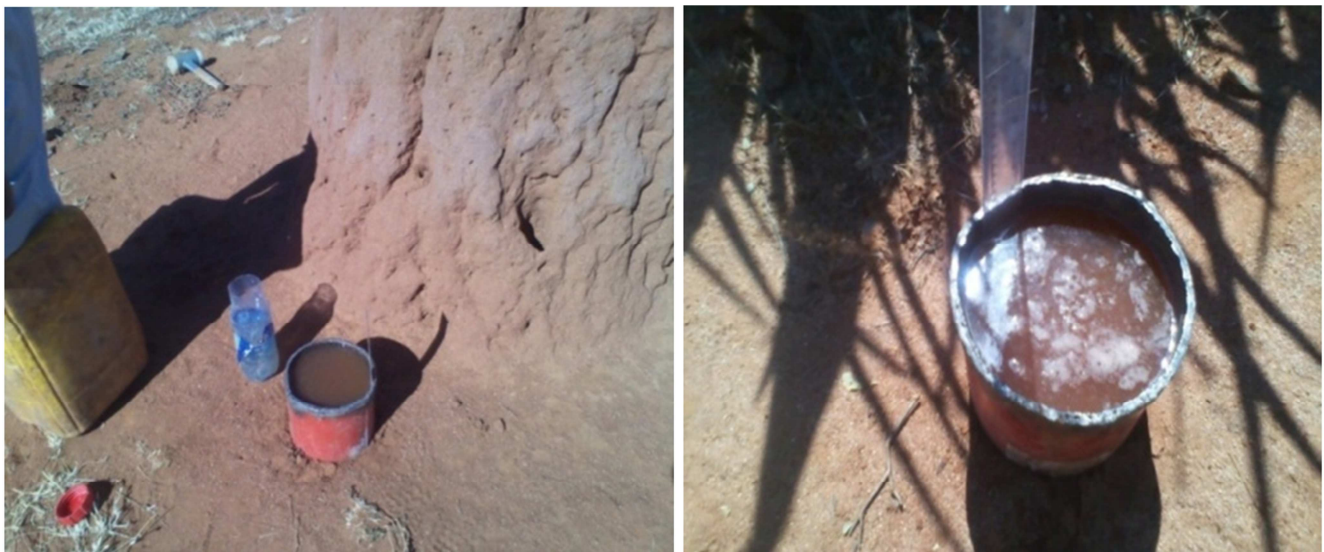


Photo 1. Soil infiltration rate measurement.

As different soil has different infiltration rate it is important to classify infiltration rate in to different classes Panda [14].

Table 1. Classification of infiltration rates (source: panda, 2007).

Class	Rate (cm/hr)
Very rapid	>25.4
Rapid	12.7-25.4
Moderately rapid	6.3-12.7
Moderate	2.0-6.3
Moderately slow	0.5-2.0
Slow	0.1-0.5
Very slow	<0.1

3.2.2. Soil Compaction

Bulk density is an indicator of soil compaction and soil health which influence key soil processes and productivity by affects infiltration, rooting depth/restrictions, available water capacity, soil porosity, plant nutrient availability, and soil microorganism activity. Soil bulk density (Db) is the ratio of mass of dry solids to bulk volume of soil. An increase in Db indicates that movement of air and water within the soil has been reduced, and that the soil may be less favorable for plant growth or be more likely to erode [11].

Soil bulk density affected by inherent soil properties such as soil texture which cannot be changed and also it is dependent on soil organic matter, the density of soil mineral (sand, silt, and clay) and their packing arrangement.

By integrating the bulk density, structure, organic matter content of mineral fraction and clay content [16], to find packing density in order to provide a single measure of soil compactness which is defined as

$$PD = Db + 0.009C \quad (1)$$

Where, PD= packing density in $t\ m^{-3}$; Db= actual bulk density in $t\ m^{-3}$; C is clay content (%). There are three classes of packing density are recognized; low: $<1.40\ t\ m^{-3}$, medium $1.40 - 1.75\ t\ m^{-3}$, and high: $> 1.75\ t\ m^{-3}$. The packing density can be determined in situation where the actual bulk density is known by incorporating the clay% which is a useful parameter for spatial interpretations that require a measure of the compacted state of soil.

4. Result and Discussion

4.1. Infiltration Rate

Figure 3 and 4 show the infiltration curves for both site separately and figure 5 show the combined average infiltration curves of both site in order to evaluate the total difference of infiltration rate of termite profile Vs adjacent soil profile. The infiltration curve for termite profile had high starting value and gradually decreased while for adjacent soil profile the curve had high initial values with gradually decrease value until it attained a constant value.

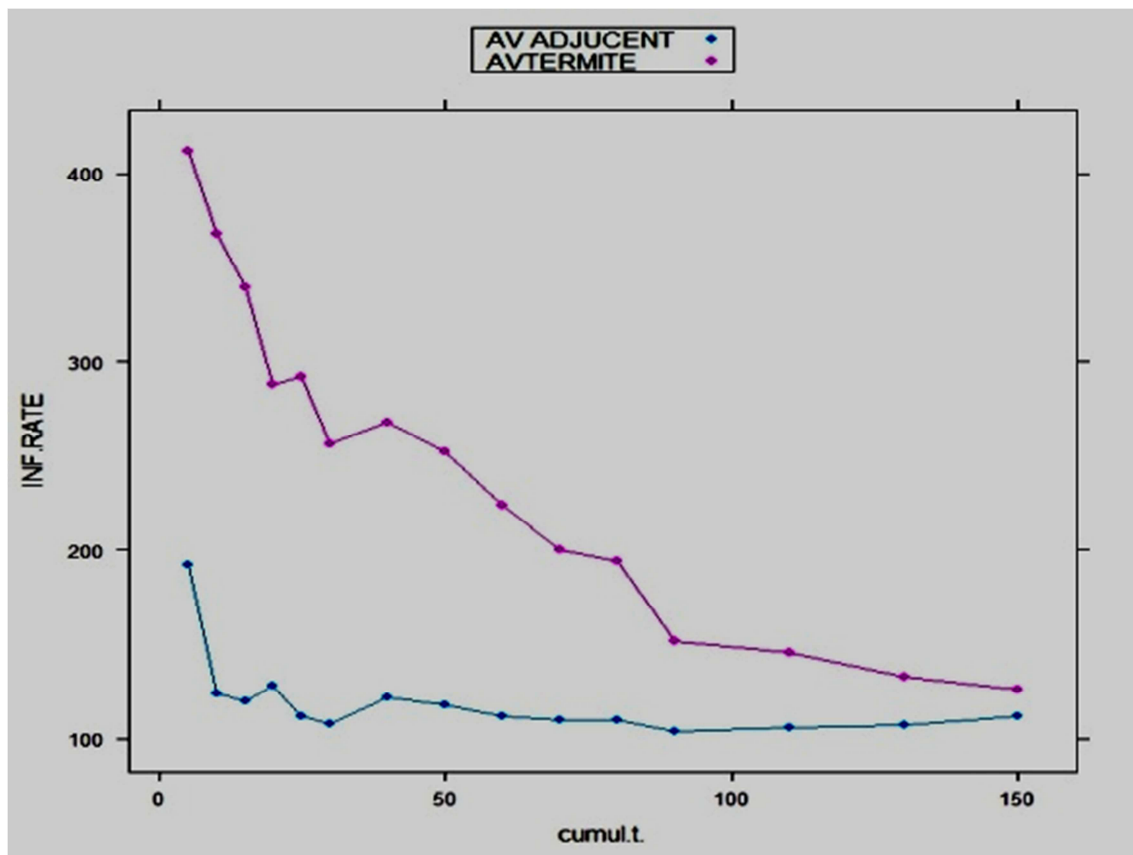


Figure 3. Measured infiltration rate for Tilomaddo site (a).

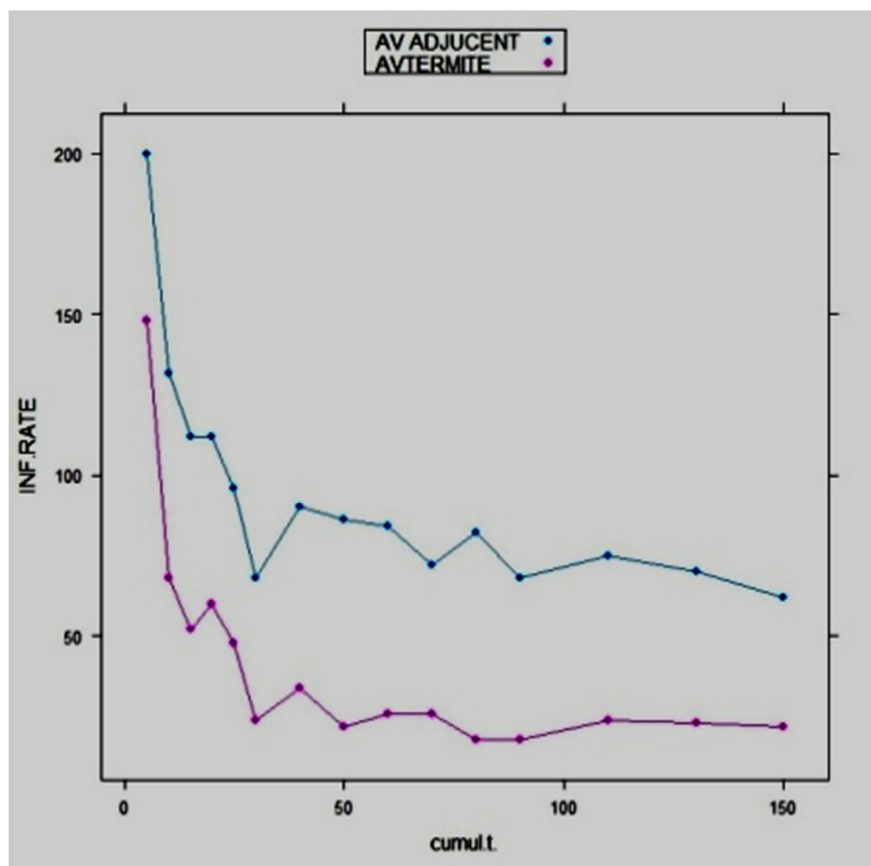


Figure 4. Measured infiltration rate for Bokuluboma site (b).

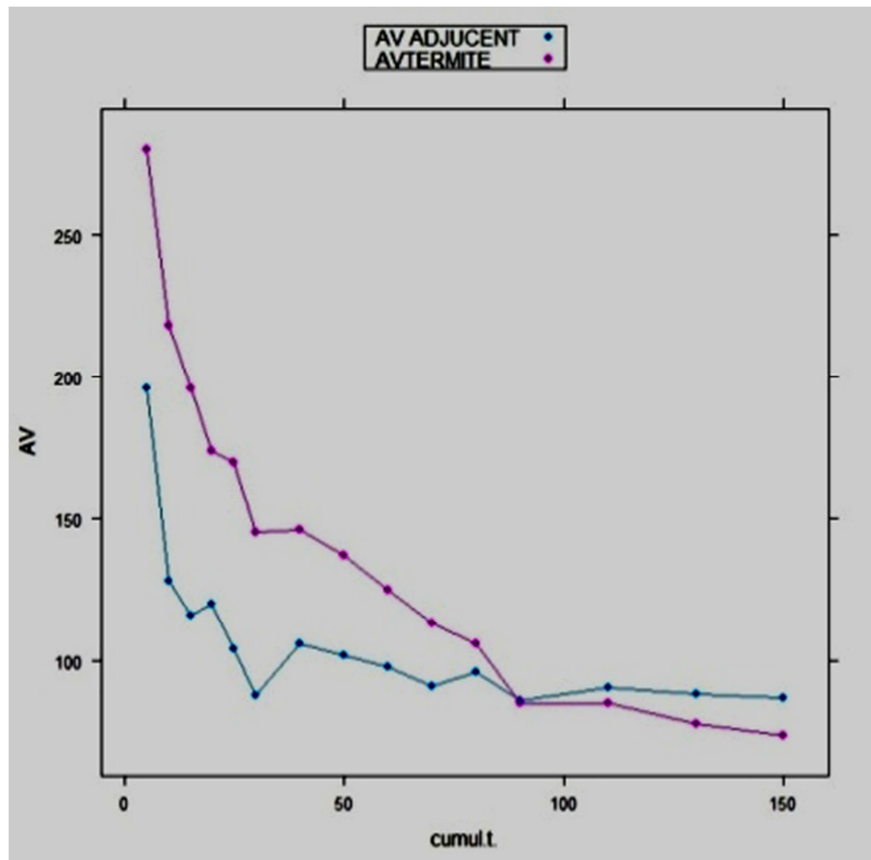


Figure 5. Measured average infiltration rate of both site.

Generally, using the R commander statistical package independent sample t-test (Welch Two Sample t-test), there was significant difference between the two means of infiltration rate at the bottom of termite mound and adjacent soil profiles at significance level of 95%. The p-value = 0.044 with the mean for adjacent soil profile 106.47 mm/hr (Moderately rapid) and at bottom of termite mound 142.13 mm/hr (rapid) infiltration rate have been observed. Due to the heterogeneity of soil the highest infiltration rate 412 mm/hr (very rapid) in Tilomaddo site and 18 mm/hr (Moderately slow) for Boku Luboma sites were registered. The activities of termite created tunnels and galleries at the beneath of termite mound could be the reason for higher infiltration than that of adjacent soil profile [10]. From model that quantifies the relationship between overland flow and macro pore infiltration in vadose zone which was developed by [13]. Concluded infiltration is highly sensitive to macro porosity, or the number of macro pores, suggesting that increased macro porosity caused by termites will increase infiltration. Léonard and Rajot [8] also indicate that the increase of

infiltration as runoff interception process, where by an increased number of macro pores intercepting runoff which resulted from termite activities leads to increase in infiltration. The influence of different termite species activity and its variation over time and space for particular site is important to consider as different species have different surface macro pores diameter which correspond to infiltration [8].

4.2. Compaction Rate

Although it seems as though different species of termites do not have specific particle size requirements for the construction of their mound, most termites preferentially select clay and silt sized particles. An investigation of soil under termite mounds led to the conclusion that in general termites have the potential to modify soil morphology up to 6.1 m below mounds not including potentially greater depths away from these mounds [17].

Table 2. Textural class of soil sample from external part of mound and adjacent soil profile.

Bokuluboma site					Did -Yabello site				
Field no	%clay	%silt	%sand	Textural class	Field no	%clay	%silt	%sand	Textural class
MBM1Ext	40	30	30	clay loam	DYM1Exit	18.75	21.25	60	sandy loam
MBM2Exit	41.25	31.25	27.5	clay	DYM2Exit	28.75	1.25	70	sandy clay loam
MBM2Exit	40	27.5	32.5	Clay	DYM3Exit	21.25	12.5	66.25	sandy clay loam
MBP1A	20	32.5	47.5	loam	DYP1A	15	7.5	77.5	sandy loam
MBP2A	21.25	31.25	47.5	loam	DYP2A	11.25	6.25	82.5	loamy sand
MBP3A	23.75	31.25	45	loam	DYP3A	13.75	6.25	80	sandy loam

As cohesive soils have lower bulk density than non-cohesive soil, soil samples taken from Did-Yabello site exhibited higher dry density than Bokuluboma site which is the result of inherited soil properties. However, the textural class between adjacent soil profile (Horizon A) and Mound external part was significantly different. This is the result of soil used to built termite mound are fine textured than the top soil profile horizon of adjacent soil.

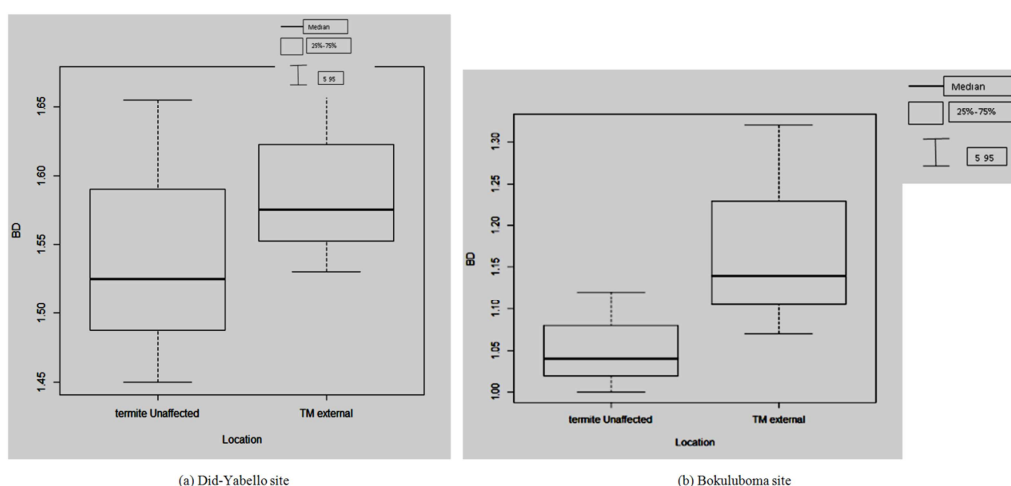


Figure 6. Bulk density comparison between External part of termite mound and adjacent soil profile (horizon A).

The bulk density was no significant at 95% confidence interval with p-value= 0.547, p-value = 0.24 for both sites and an average value or mean of 1.54 g/cm³ and 1.59 g/cm³, 1.05 g/cm³ and 1.17 g/cm³ for adjacent soil profile A horizon and termite external mound part in both Did-yabello and Bokuluboma sites respectively. However, for plant establishment the bulk density which also indicate the porosity of soil have favorable condition, since the average values are less than 1.6 g/cm³ and porosity become also greater than 40%.

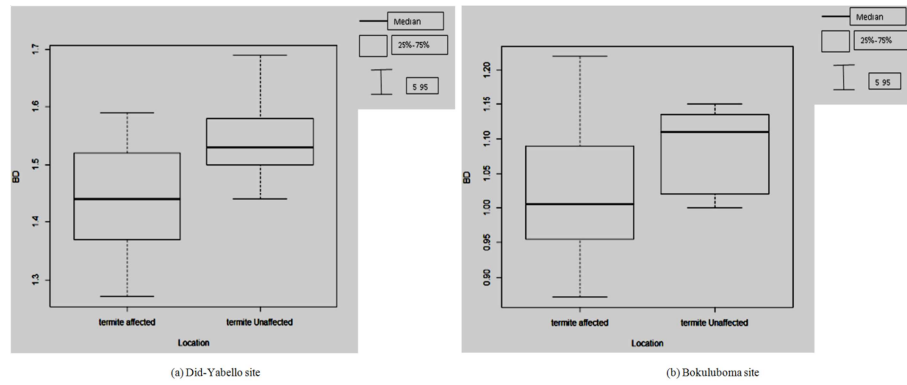


Figure 7. Bulk density of termite mound profile and adjacent soil profile.

In case of total termite mound profile and adjacent soil profile, the bulk density was significantly different for Did-yabello site at 95 percent confidence interval with p -value = 0.034 and 1.44 g/cm^3 , 1.54 g/cm^3 mean value respectively. For Bokuluboma site, there was no significant difference at 95 percent confidence interval with p -value = 0.233 and 1.02 g/cm^3 , 1.08 g/cm^3 mean value respectively using independent sample t-test mean comparison. This difference could be attributed to heterogeneity of soil and the textural class for Bokuluboma site, which had relatively fine textured soil. On other hand the low bulk density of termite mound affected profile is that it is the activity of termite tunneling on their movement.

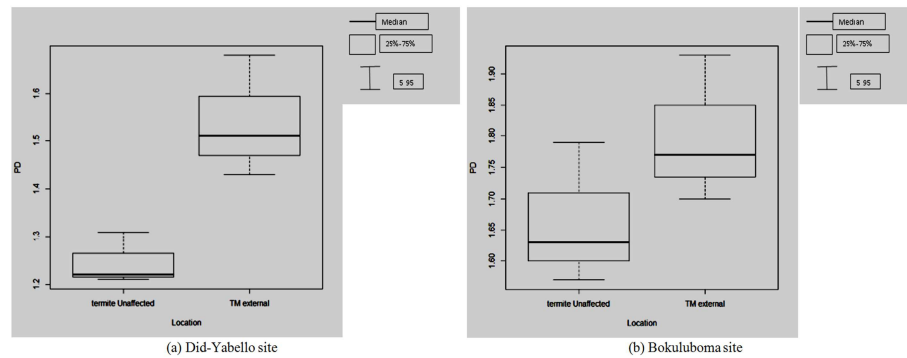


Figure 8. Packing density of External part of mound Vs adjacent soil profile.

Packing density(PD) of termite mound external part was not significantly different with A horizon of adjacent soil profile at 95 percent confidence interval with p -value = 0.222 for Did-Yabello site while the packing density for Bokuluboma site was significantly different at 95 percent confidence interval with p -value = 0.042. This difference could arise from the clay content of termite mound that created by termite selection of fine textured soil in their construction. The external part of the mound was compacted than the top horizon of adjacent soil

profile according to the range given by Van RANST, et al., [16], the mean for Did yabello site 1.66 t m^{-3} (medium) and 1.80 t m^{-3} (high) packing density even if there is no difference statistically speaking. However, for the fine textured Bokuluboma site, the mean of PD for external part of the mound 1.540 t m^{-3} (medium range) and for adjacent soil profile 1.246 t m^{-3} (low) and it has significant different. Those results indicate that the external part of termite mound re more compacted than that of normal adjacent soil.

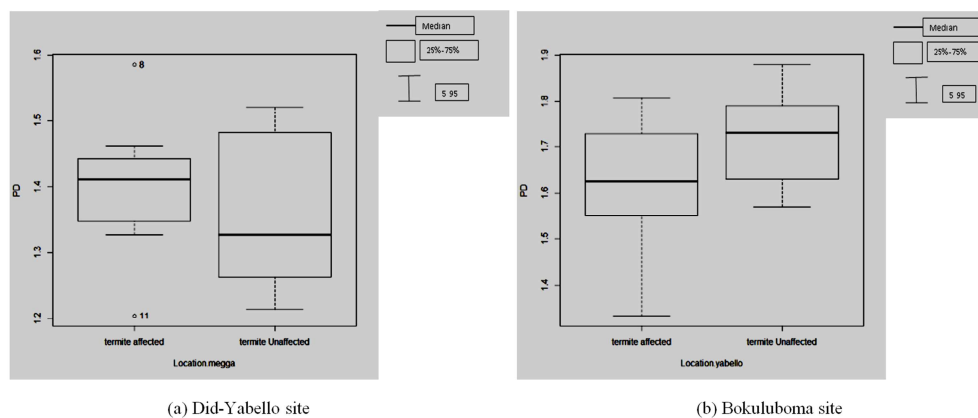


Figure 9. PD of adjacent soil profile and termite mound affected profile.

In comparison of the profile that are affected by termite and not affected adjacent soil profile, for packing density there is no significant difference at 95 percent confidence interval with p-value = 0.1505, p-value = 0.6297 for Did-yabello site and Bokuluboma site respectively. Mean packing density of 1.629 t/m^3 (medium), 1.72 t/m^3 (medium) in Did-Yabellosite and 1.39 t/m^3 (low), 1.36 t/m^3 (low) for Bokuluboma site termite affected profile and adjacent soil profile respectively.

4.3. Micro Nutrients

ANOVA-Tukey Contrasts result of Multiple Comparisons of mean show that there was no significant difference between means of internal part of termite mound, external

part of termite mound and adjacent top layer of profile (A horizon) in copper (Cu), Iron (Fe), Manganese (Mn) and Zinc (Zn) content with $\text{Pr}(> F)$ - value = 0.483, $\text{Pr}(> F)$ - value = 0.143, $\text{Pr}(> F)$ - value = 0.51 and $\text{Pr}(> F)$ - value = 0.432 respectively at 95% family-wise confidence level for Did-Yabello site. From Bartlett test of homogeneity of variances, result indicated that there was significant difference in SD between internal part of termite mound, external part of termite mound and adjacent top layer of profile (A horizon) with p-value = 0.002686, p-value = 1.146×10^{-8} for Iron (Fe) and Zinc (Zn) content respectively while there was no significant difference in copper (Cu) and Manganese (Mn) content with p-value = 0.07123, p-value = 0.1796 at 95 percent confidence interval respectively for this site.

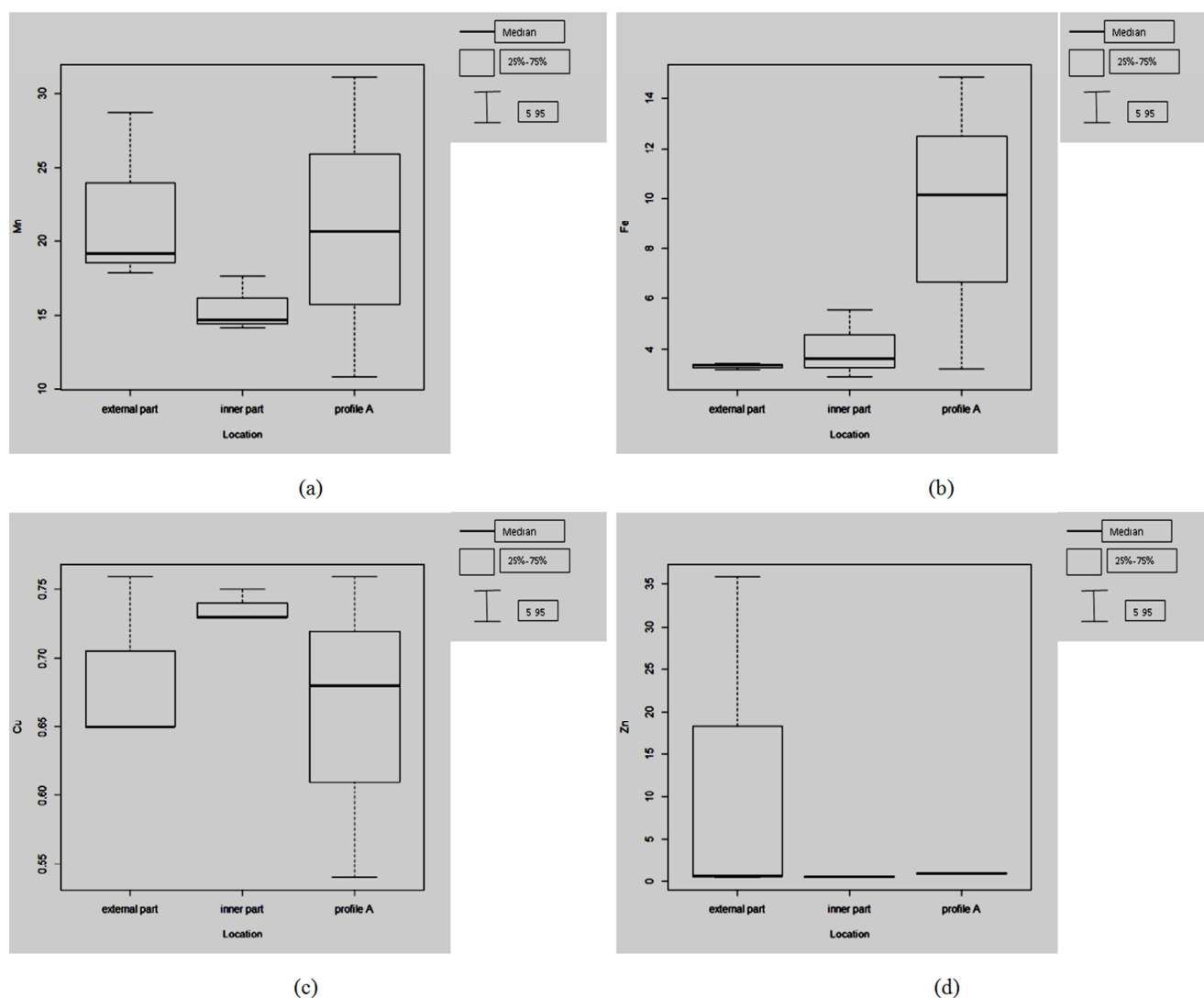


Figure 10. Box plot for Did-Yabello site Mn (a), Cu(b), Fe (c) and Zn (d) to compare the micro-nutrient content of internal, external part of mound and adjacent soil profile.

For Bokuluboma site, using one-way ANOVA-Tukey Contrasts of Multiple Comparisons of Mean, copper (Cu) and Iron (Fe) content were not significantly different at 95% family-wise confidence level with $\text{Pr}(> F)$ - value = 0.426, $\text{Pr}(> F)$ - value = 0.451, respectively while the manganese (Mn) and zinc (Zn) content the mean shows that there was significant difference at 95% family-wise confidence level with $\text{Pr}(> F)$ - value = 0.0246, $\text{Pr}(> F)$ - value = 0.0221, respectively for between internal part of termite mound, external part of termite mound and adjacent top layer of profile (A horizon). By using Bartlett test of

homogeneity of variances, there is no significant variation in SD because the P-value = 0.2727 for manganese (Mn) and p-value = 0.5751 for zinc (Zn) content while for copper (Cu) and Iron(Fe) content there was significant variation in SD with p-value = 1.599e-07, p-value = 0.005858 respectively at 95 percent confidence interval for Bokuluboma site.

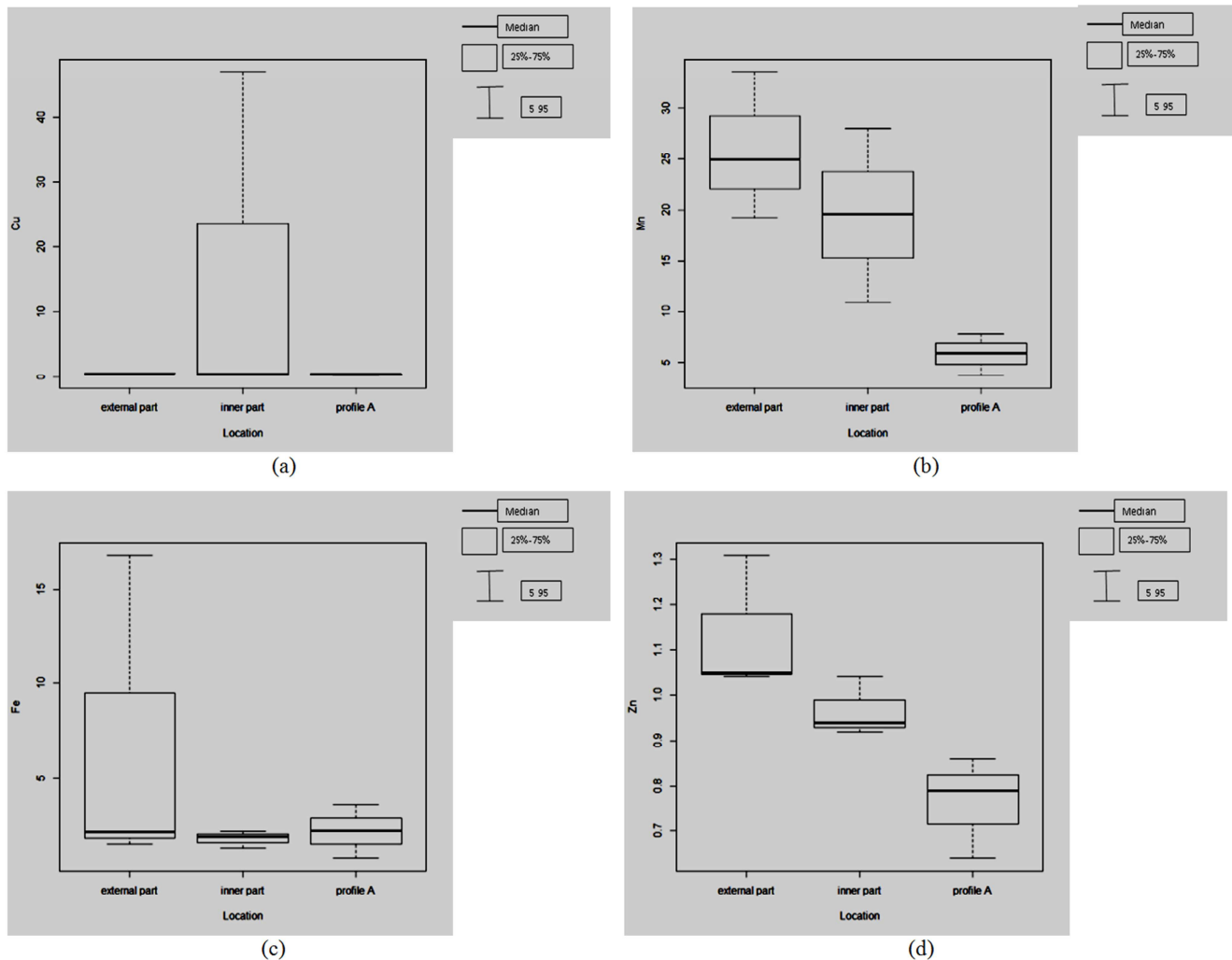


Figure 11. Box plot of Cu (a), Mn (b), Fe (c) and Zn (d) to compare the micro-nutrient content of internal, external part of mound and adjacent soil profile for Bokuluboma site.

5. Conclusion and Recommendation

The information on soil hydraulic properties is crucial in understanding the soil-plant-water relationship. The infiltration rate due to biological activities of termite, there was rapid rate than the adjacent termite unaffected soil profile which is moderately rapid. This indicate that as a result of preferential flow of water in fine textured soil from which the termite mound is built offer higher moisture retention capacity than that of adjacent soil for the establishment of plant.

In relation to soil compaction rate, the external termite mound is less workable than that of termite unaffected adjacent soil profile due to its high packing density even if the rate of compactness depend on soil inherent properties and selection of soil by termite to build the mound. While in comparison of total profile depth under termite mound and adjacent termite unaffected soil, there was no difference in

compactness. Generally, the termite mound has positive impact on soil hydraulic properties of soil in order to support plant establishments.

Micro nutrients also depend on soil heterogeneity nature. Soil with sandy to medium textured soil, there was no change in micro nutrient content between internal part of termite mound, external part of termite mound and adjacent top layer of profile (A horizon) for copper(Cu), Iron (Fe), Manganese(Mn) and Zinc (Zn) availability (Did-Yabello site). For fine textured soil (Bokuluboma site), copper (Cu) and Iron(Fe) content show no difference in content while manganese (Mn) and zinc (Zn) content high in external part than that of internal and termite unaffected top horizon (A).

It is important that identifying the termite species in order to investigate further ecological function of termite that are abundant to the study area. Additionally it is important to study best agronomic management practice to use the positive impact of termite mound hydraulic properties.

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References

- [1] Amsalu T. 2009. Mound-Building Termites (*Macrotermes subhyalinus*) Effects on Soil Chemical Fertility in Yabello and Dirre Districts of Borana Zone, Southern Ethiopia. MSc Thesis, Mekelle University.
- [2] Anderson, J. M., 1994. Functional attributes of biodiversity in land use systems. In: Soil Resilience and Sustainable Land Use, Greenland, D. J., and Szablocs, I. (Editors), CAB International, Wallingford, pp. 267-290.
- [3] Barnett E. A, Cowie, R. H., Sands, W. A. and Wood., J. G., 1987. Identification of termites collected in Ethiopia. Report No. C0696. Tropical research institute, London.
- [4] Coppock, D. L., 1994. The Borana Plateau of Southern Ethiopia: Synthesis of pastoral research, development and change, 1980-91. ILCA (International Livestock Center for Africa), Addis Ababa Ethiopia. 418p.
- [5] FAO (Food and Agricultural Organizations of the United Nations), 2006. Guidelines for soil description, 4th edition
- [6] Kamara, A. B., 2001. Property rights, risk and livestock development in Southern Ethiopia. PhD dissertation, *Georg-August-University Gottingen*, Waldweg 26 D-37073
- [7] Lavelle, P. M., Dangerfield, C. Fragoso V. Eschnebrenner, D. L. Hernandez, B. Pashanari, and Brussaard, L., 1994. The relationship between soil macrofauna and tropical soil fertility. In Woomer P. L. and Swift M. J. (eds). The biological management of tropical soil fertility. pp.136-169. A Wiley-Sayce publication
- [8] Leonard J., Rajot J. L. (2001): Influence of termites on runoff and infiltration: quantification and analysis. *Geoderma*, 104:17-40.
- [9] Lindsay, W. L. 1979. Chemical Equilibria in Soils. Wiley-Interscience. John Wiley & Sons, New York. 449 p. Lee, K. E. and Wood, T. G. (1971) Termites and Soils, Cornell University: Academic Press Léonard, J. and Rajot, J. L. (2001) Influence of termites on runoff and infiltration: Quantification and analysis, *Geoderma*, Vol. 104, pp. 17-40.
- [10] Mando, A., Stroosnijder, L. and Brussaard, L. (1996) Effects of termites on infiltration into crusted soil, *Geoderma*, Vol. 74, pp. 107-113.
- [11] Miller, R. E., Hazard, J., and Howes, S., 2001. precision, accuracy, and efficiency of four tools for measuring soil bulk density or strength. Res. paper PNW-RP532:U.S. Department of Agriculture, Forest service, Pacific Northwest Research Station, Portland, OR.
- [12] MoNRDEP (Ministry of Natural Resource Development and Environmental Protection). 1990. Soil analysis in the laboratory manual. Ministry of Natural resource development and environmental protection, Addis Ababa, Ethiopia.
- [13] Ruan, H. and Illangasekare, T. H. (1998) A model to couple overland flow and infiltration into macroporous, *Journal of Hydrology*, Vol. 210, pp. 116-127.
- [14] Panda S. C., 2007. Soilwater conservation and dry farming. agrobios, India, pp. 111-115.
- [15] USDA NRCS (Natural Resources Conservation Service), 2008. Soil Quality Indicators
- [16] Van RANST, 1995. Non parametric techniques for predicting soil bulk density of tropical rainforest top soils in Rwanda. *Soil science society of America Journal*
- [17] Watson, J. P. (1962) The soil below a termite mound, *European Journal of Soil Science*, Vol. 13(1), pp. 46-59.
- [18] Watson, J. P., 1997. The use of mounds of the termite *Macrotermes falciger* (Gerstaecker) as a soil amendment. *Journal of Soil Science* 28, pp 664-672.