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Faunal survey of the termites of the genus *Macrotermes* (Isoptera: Termitidae) of Ethiopia

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To date *Macrotermes subhyalinus* and *Macrotermes herus* are the only two species of termites of the genus *Macrotermes* recorded in Ethiopia. The description given to them in terms of distribution and their mound morphology is contrary to the literature and the species checklist is not exhaustive. This paper compares mound distribution and dimensions in Western, Central, and Southern Ethiopia and provides species checklist based on external mound morphology. Four termite hotspot districts were selected from each region as replicates and an area of 100 x 100 m was delineated. All mounds in the area were counted to determine their density. Five mounds were randomly selected and their dimensions measured. External morphology of mounds was studied to determine the species. There were significant differences (P < 0.05) in density and height among the mounds of the three regions in the order Southern > Central > Western. In Southern and western region, mound density was 16.7 ± 1.53 (mean ± standard error) and 5.3 ± 4.16, while mound height was 2.9 ± 1.69 and 0.3 ± 0.24 m, respectively. The checklist included seven species: *M. herus* from Western; *M. subhyalinus, M. natalensis* and *M. herus* from Central; *M. michaelseni*, *M. jeanneli*, *M. natalensis*, *M. falciger*, and *Macrotermes* SpA (an unidentified sp.) from Southern Ethiopia. Except *M. subhyalinus* and *M. herus,* the other species were recorded for the first time in Ethiopia to our knowledge.

Key words: Closed mounds, low mounds, *Macrotermes* termites, mound morphology, open chimney mounds.

INTRODUCTION

Globally over 3,000 species of termites are known (Munthali et al., 1999) that are grouped under seven families and 281 genera (Grohmann et al., 2010; Logan et al., 1990; Pearce, 1999). Africa is the richest continent in termite diversity, accounting for one-third of the species recorded worldwide (UNEP, 2000).

The numbers of tropical termite species are high and many of them are undescribed or poorly described because of their taxonomic difficulty and lack of sufficient termite taxonomists. Very few specialists are able to identify tropical termite species and many of the economically important groups lack proper taxonomic revision, resulting in a large number of incorrect, doubtful or incomplete identifications (UNEP, 2000). Lack of their taxonomic understanding has been a major impediment to the study and management of these termites. Identification in termites is very difficult for many reasons, and for many genera identification key has not been worked out. Termite identification is generally based on the alates' or the major soldiers' caste morphological characters. However, this conventional method is not always reliable, especially when the similarities between species are very close (Abdurahman et al., 2010).

In Ethiopia, 63 termite species belonging to 25 genera

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have been recorded representing about 6.3% of the African termite diversity, a low estimate given the vast range and the suitability of the climate. This could be due to the limited systematic studies carried out so far and the lack of national termite inventory (Debelo and Degaga, 2014). All the identification works done regarding the Ethiopian fauna were based on the fauna of other parts of Africa. The limitations clearly show some of the challenges in studying the Ethiopian termite fauna (Abdurahman et al., 2010).

A key trend in termite research is the use of molecular genetics tools to study species identification and distribution, differentiation of populations, colony social structure, and feeding behavior (Grace, 2006). Mound architecture is also useful in species identification (Dangerfield et al., 1998), especially for *Macrotermes* species which build spectacular epigeal mounds. The genus is found throughout the Afro-tropical Zoogeographic region and Indo-Malayan zoogeographical regions and so far 12 species have been described in the Afro-tropical Zoogeographic region. In Africa, they build large mounds which are a characteristic feature of many grasslands and savanna woodlands (Debelo and Degaga, 2014).

In Ethiopia, the genus *Macrotermes* is represented by two species *Macrotermes subhyalinus* (Rambur) and *M. herus* (Sjöstedt) (Abdurahman 1990; Abdurahman et al., 2010). Abdurahman (1990) stated that the mounds of *Macrotermes* termites found in western Ethiopia differ significantly in size and shape from those found in the Maki-Batu (Batu formerly Ziway) area of Central Ethiopia. In both areas, the mounds have no external openings. In Western Ethiopia, the mounds are typically dome-shaped whereas in Maki-Batu, the mounds are conical. *M. subhyalinus* is a well-described, serious pest species in Ethiopia and it builds closed, dome-shaped mounds.

According to this description, the closed dome-shaped mounds found in Western Ethiopia belong to *M. subhyalinus*. However, it is not known whether the closed conical mounds found in the Maki-Batu area of Central Ethiopia with different nest architecture belong to *M. subhyalinus* or *M. herus*. The study did not indicate whether the *M. subhyalinus* which builds dome-shaped mounds in Western Ethiopia builds conical mounds in the Maki-Batu area or whether these conical mounds belong to *M. herus*. However, many authors (Harris, 1956; Bagine et al., 1989, 1994; Turner, 2000, 2001; Abebe, 2002; Pomeroy, 2005; Brandl et al., 2007; Korb, 2011) reported that *M*. *subhyalinus* builds mounds with external openings.

The closed dome-shaped mounds of the *M*. *subhyalinus* reported earlier in Ethiopia does not agree with the wide available literatures which state that the species builds mounds with external openings. Wood (1986) reported that he collected *Macrotermes* termites from low open mounds from Batu town and 10 km south of the town but did not specify the species. Debelo and Degaga (2014) also recognized and reported the existence of two types of mound of *Macrotermes* (closed mounds and open mounds) in the area which may prove the mounds are built by two distinct species. Therefore, this calls certainly for a critical revision/taxonomic study of this genus. Thus, the aim of this study is to collect data on external morphology of mounds built by *Macrotermes* termites from the three termite hotspot regions of Ethiopia and to determine the species based on the mound architecture.

MATERIALS AND METHODS

Study areas

The external morphology of termite mounds was examined in three termite hotspot regions of Ethiopia: Western Ethiopia (Western Wallaga Zone), Central Ethiopia (Central Rift Valley - Eastern Shawa Zone), and Southern Ethiopia (Borana Zone), all found in Oromia National State (Figure 1). Four districts were selected as replicates from each area based on their accessibility and termite document (Table 1).

Western Ethiopia

In Western Ethiopia, the study was conducted in the Western Wallaga Zone of Oromia National State. Four districts, Qilxu Karra, Mana Sibu, Ayira, and Yubdo were selected from the zone. West Wallaga Zone comprises low land ranging from 1100 - 1700 m above sea level which covers 19.1%, midland ranging from 1800 - 2200 m above sea level which covers 78.4%, and highland ranging from 2300 - 2850 m above sea level, and this covers 2.5% of the zone. The major rainy season is during the months of June to September which is the case for many Ethiopian highlands. The annual rainfall in the zone varies from 1100 to 2450 mm, and the annual temperature varies from 18 to 32°C. The soil type of the region is generally nitosols (Temesgen, 2014). The vegetation of the study area falls in moist evergreen montane rainforest. The main plant species that predominates the relic forest patches are *Albizia schimperiana*, *Bersama abyssinica*, *Cordia africana*, *Croton macrostachyus*, *Syzygium guineense* and *Sapium ellipticum* (Etana Tolosa, 2007).

Central Ethiopia

The study was conducted in four districts, Dugda, Adami Tullu-Jiddo Kombolcha, Adama, and Arsi Negelle, all located in the Central Rift Valley of Ethiopia (CRVE). The first three districts are found in Eastern Shawa zone, whereas the last one is found in West Arsi zone. The area has a semi-arid and arid climate and has a bimodal rainfall patterns. Most of the rainfall occurs between July and September. There is some additional rainfall between February and the end of April, but this usually varies. The mean minimum and maximum of annual temperature recorded at Batu town (capital of Adami Tullu-Jiddo Kombolcha) are 14.0 and 27.2°C, respectively with an annual rainfall of 742.4 mm (Debelo and Degaga, 3014).

The soils of the area generally range from sandy loam, loam to sandy clay loam, with some clay loam and a few clay soils. In addition to salt crust (white and deep shiny black salt crust), the soils are characterized by numerous gray-to-gray brown termite mounds (Kefyalew et al., 2008). The vegetation in the CRVE is characterized by acacia open-woodland and savanna (Huib and Herco, 2006).

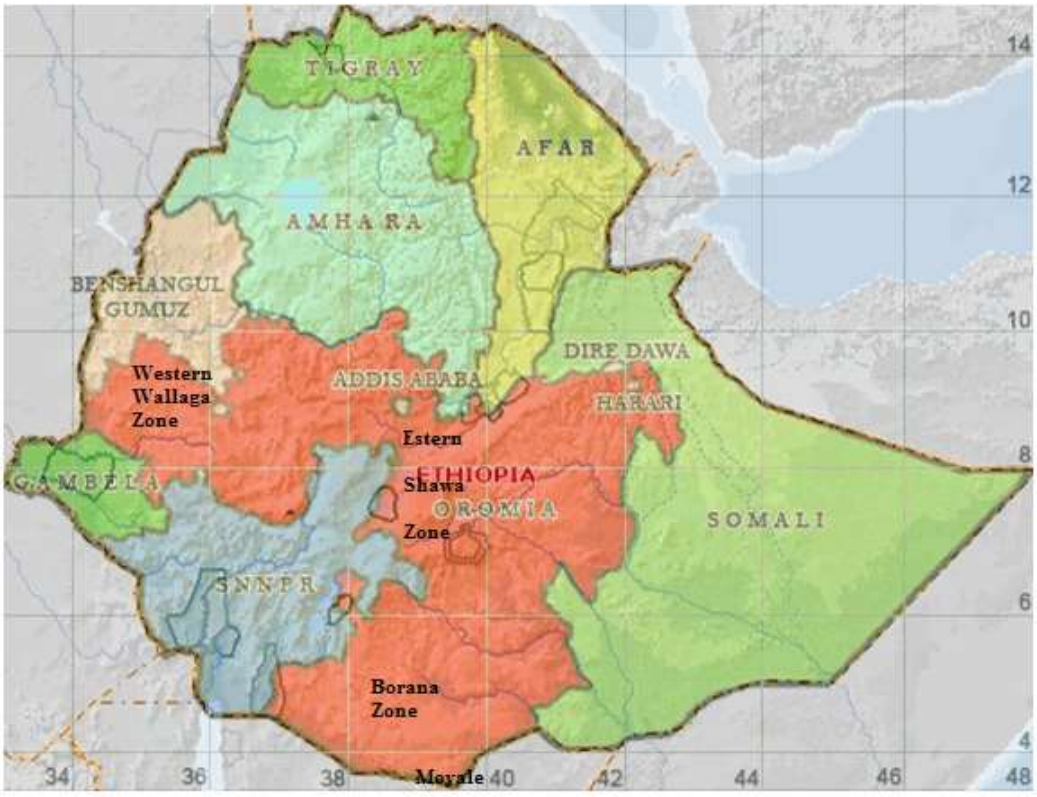


Figure 1. Map of Ethiopia showing the zones from which *Macrotermes* termite mounds were sampled.

Southern Ethiopia

Borana zone is located in Southern Ethiopia and the study sites covered four districts of the zone, Surupha, Yaballo, Mio, and Moyale. High density of tall and huge epigeal mounds of *Macrotermes* termites showing different architecture make peculiar feature of the landscape of the semi-arid of Southern Ethiopia starting from a small town known as Finchawa (capital of Dugda Dawa district, Borana Zone) extending to semi-arid areas of Guji zone, Somalia National State to the west, and Kenya to the south.
The geology of the area is composed of shales, sandstone, and limestone that largely resulted from oceanic activity. The climate is semi-arid, with an average annual rainfall ranging between 350 and 900 mm. The precipitation is bimodal with 60% occurring between March and May and 27% from September to November. Annual mean temperatures vary between 19 and 24°C. Vegetation is dominated by savannah vegetation containing a mixture of perennial herbaceous and woody plants. Physiographically, Borana zone is characterized mainly by lowlands and hills. The area is characterized by droughts, occurring every five to ten years (Tilahun et al., 2012).

Determination of mound density and dimensions

Four districts were selected from each region as replicates based on previous report as termite hotspot and accessibility. In each district, an area of 100 m x 100 m was delineated and all the mounds in the area were counted to determine mound density/ha. Five mounds were randomly selected along the diagonal of the area and their dimensions (height and basal diameter) were measured.

Examination of external mound morphology

The external morphology (shape and presence or absence of opening) of all mounds found in the area of 100 m x 100 m mentioned above were investigated, recorded, and their pictures were taken to determine the species building the mounds based on mound morphology. Mounds found outside the area were also purposively investigated to collect similar information when they were found to be different from those inside the area.

Termite identification

Identification of species based on external mound morphology was done qualitatively. The approach used was a thorough literature survey, the internet search, and termite webs.

Data analysis

Mound density and mound dimensions were analyzed by one-way analysis of variance (ANOVA) with SAS (SAS Institute Inc., 2014). Mean separation was done using Least Significant Difference test (LSD) at 5% probability level.

RESULTS

Mound density and mound dimensions

There were significant differences ($P < 0.05$) among the

Table 1. Location and elevation of the study sites.

Region	District	Elevation	Latitude	Longitude
Western Ethiopia (Western Wallaga)	Qilxu Karra	1594 m	09°41.131'N	035°16.228'E
	Manasibu	1699 m	09°42.132'N	035°06.095'E
	Ayira	1664 m	09°05.115'N	035°23.616'E
	Yubdo	1680 m	09°01.947'N	035°20.067'E
Central Ethiopia (East Shawa)	Dugda	1666 m	08°10.663'N	038°50.184'E
	Adami Tullu Jido Kombolcha	1648 m	07°52.955'N	038°41.450'E
	Arsi Negelle	1627 m	07°35.493'N	038°40.306'E
	Adama	1653 m	08°33.725'N	039°17.271'E
Southern Ethiopia (Borana)	Surupha	1738 m	05°07.408'N	038°17.176'E
	Yaballo	1710 m	04°53.378'N	038°00.059'E
	Mio	1307 m	03°53.696'N	038°34.134'E
	Moyale	1171 m	03°37.059'N	039°00.278'E

Table 2. Mound density and mound dimensions of the termite species of the genus *Macrotermes* in the three termite hot spot regions in Ethiopia.

Region	Mound density/ha	Mound height (m)	Mound basal diameter (m)
Southern Ethiopia	16.7 ± 1.53^{a}	2.9 ± 1.69^{a}	4.8 ± 2.42^{a}
Central Ethiopia	9.3 ± 14.04^{b}	1.3 ± 0.54^{b}	2.6 ± 0.56^{b}
Western Ethiopia	5.3 ± 4.16^{b}	0.3 ± 0.24^{c}	1.1 ± 0.58^{c}

Means within a column followed by the same letter do not differ significantly by Least Significant Difference (LSD) test at 5% of probability level.

mounds of the three regions in their density, height and basal diameter. The mounds in Southern Ethiopia showed the highest values in all the parameters followed by the Central while the mounds in the Western part of the country showed the least values (Table 2).

Termite species identified based on mound morphology

In total, six species and one unknown species of *Macrotermes* were recorded based on mound morphology (Table 3).

Western Ethiopia

Only one type of mounds was recorded from Western Ethiopia. They were low and had dome to more flattened shapes with no external openings (Figure 2).

Central Ethiopia

In the Central Rift Valley of Central Ethiopia, four distinct types of mound in their external morphology were recorded. Of these mounds, three were closed while one had openings on its surface. Of the closed mounds one was conical and it belongs to *M*. *natalensis* (Haviland) (Figure 3); the second type was medium dome-shaped belonging to *M. herus* (Figure 4), and the third was huge dome-shaped common in Central Ethiopia, especially in and around Adama district and these were probably built by *M. herus* and/or *M. fulcig*er or unknown species (Figure 5). The fourth type of mound was low and amorphous with a variable number of humps with openings and the mounds were built by *M. subhyalinus* (Figure 6).

Southern Ethiopia

A high density of tall mounds makes spectacular feature of the landscape of the Borana Zone and semi-arid areas of Guji Zone in Southern Ethiopia. The mounds were found in high density starting near Finchawa (a small town of the less humid of Dugda Dawa district) found at 25 km south of Bule Hora town, further south to Moyale district and then north of Kenya. Mounds were not found in the more humid of Bule Hora district and towards north

Table 3. Termite species of the *Macrotermes* genus identified in Western, Central, and Southern Ethiopia.

Region	Mound architecture	Termite species	Districts
Western Ethiopia	Low closed dome to flat mounds	*M. herus*	All districts (Qilxu Karra, Mana Sibu, Ayira and Yubdo)
Central Ethiopia	Relatively medium closed conical mounds	*M. natlensis*	Dugda, Adama, Adami Tullu Jiddo Kombolcha
	Low open mounds with turrets	*M. subhyalinus*	Arsi Negelle (mostly), Adami Tullu Jiddo Kombolcha district (some)
	Huge closed dome mounds	*M. falciger* (Gerstäcker)	Adama
	Relatively medium to high closed dome mounds	Probably *M. herus*	Adama, Dugda, Adami Tullu Jiddo Kombolcha
Southern Ethiopia	High cylindrical closed-chimney mounds	*Macrotermes* SpA	Miyo
	High closed-chimney mounds with a conical base topped by a prominent spire	*M. michaelseni* (Sjöstedt)	Miyo and Moyale
	High open-chimney mounds	*M. jeanneli* (Grasse´)	Surupha, Yaballo, Miyo, and Moyale
	Medium conical closed mounds	*M. natlensis*	Yaballo
	Huge closed dome mounds	*M. falciger*	Moyale

Figure 2. Low, flat and closed mounds of *M. herus* recorded from Western Ethiopia (A: from Qiltu Karra district; B - C: form Mandi district; D: from Yubdo district. Photo by Daniel Getahun) .

Figure 3. Closed conical mounds of *M. natalensis* recorded from a specific place called Oda Boqota, Dugda district, Central Ethiopia (Photo by Daniel Getahun).

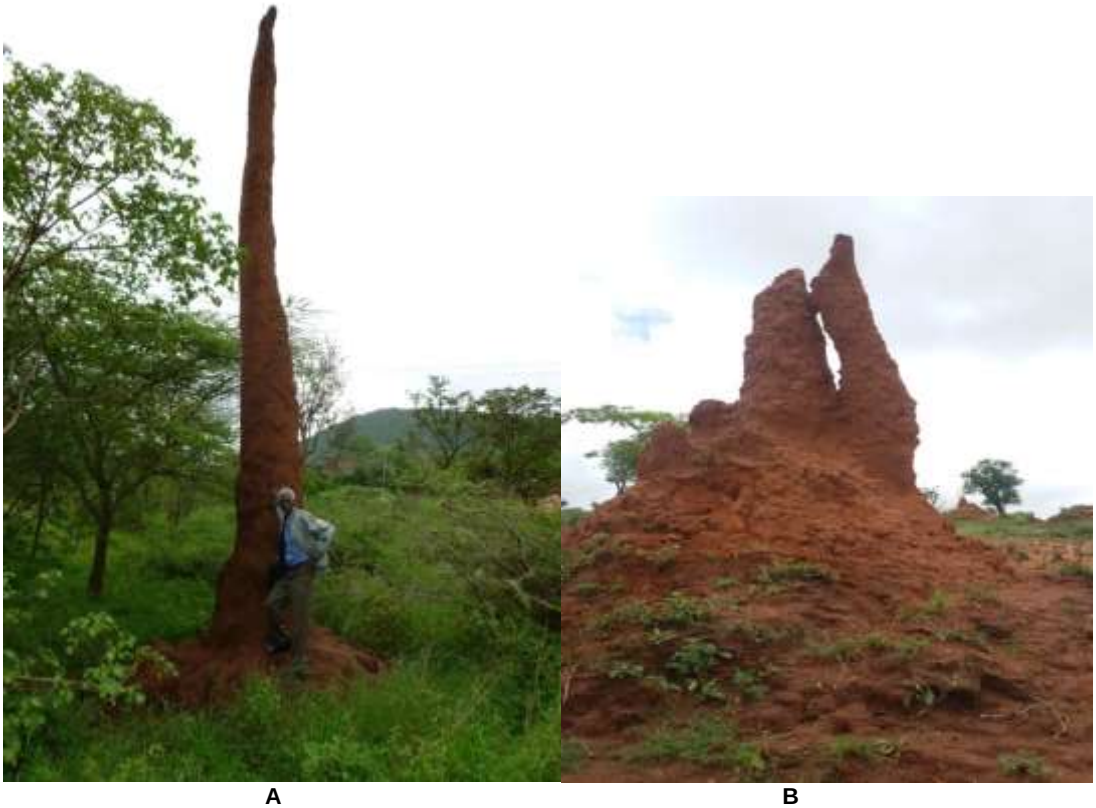
Figure 4. Closed dome-shaped of *M. herus* recorded from Adama district, Central Ethiopia (Photo by Daniel Getahun).

A **B**

Figure 5. Closed and dome-shaped live mounds recorded from Adama district, Central Ethiopia. A: from a specific place called Dhera; the hole from the front was dug to sample termites; B: from Sodere Resort (Photo by Daniel Getahun).

in Gedeo Zone. In Southern Ethiopia, mounds of variable morphology which can be divided into two categories as open and closed chimney were recorded. The open chimney mounds with only one large opening in the

Figure 6. Low and flattened mounds with a number of external openings of *M. subhyalinus* recorded from a specific place called Dada Dallo Harangama, Arsi Negelle district, Central Rift Valley of Central Ethiopia (Photo by Daniel Getahun)



A **B**

Figure 7. Mounds of *M. jeanneli* (A. mound with a single central chimney of full mature size, 8 m tall, recorded from Yaballo town; B. mound with four chimneys recorded from Surupha district, 40 km north of Yaballo town (Photo by Daniel Getahun).

chimney (pillar) belong to *Macrotermes jeanneli*. Most of *M. jeanneli* mounds had a single central chimney but occasionally two or three were observed on the same mound (Figures 7 to 9). The openings at the tip of the mounds are seen clearly from young mounds. The lip of the opening is typically asymmetrical with one edge

A B

Figure 8. Openings of mounds of *M. jeanneli* (A. Young mound of *M. jeanneli* with a prominent opening, recorded from Mio district; A typical asymmetrical mound of *M. jeanneli* with one edge raised up above the rest, recorded from Moyale district (Photo by Daniel Getahun).

Figure 9. Mound of *M. jeanneli* built on a dark red, clay-rich soil recorded from Melbana, Mio district, Borana zone. The broad base was formed from successive breaks of the vertical chimney (Photo by Daniel Getahun).

prominently raised above the rest (Figure 7) and the base is broad formed from successive breaks of the vertical chimney and outwash pediment (Figure 8).

Four different types of closed mounds built by *M. michaelseni, M. natalensis*, *M. falciger,* and other unknown species were recorded from Southern Ethiopia.

Figure 10. Typical mounds of *M. michaelseni* with a conical base topped by closed prominent spire recorded from Moyale district from specific place called Xillo Maddo, about 30 km north of Moyale town (Photo by Daniel Getahun).

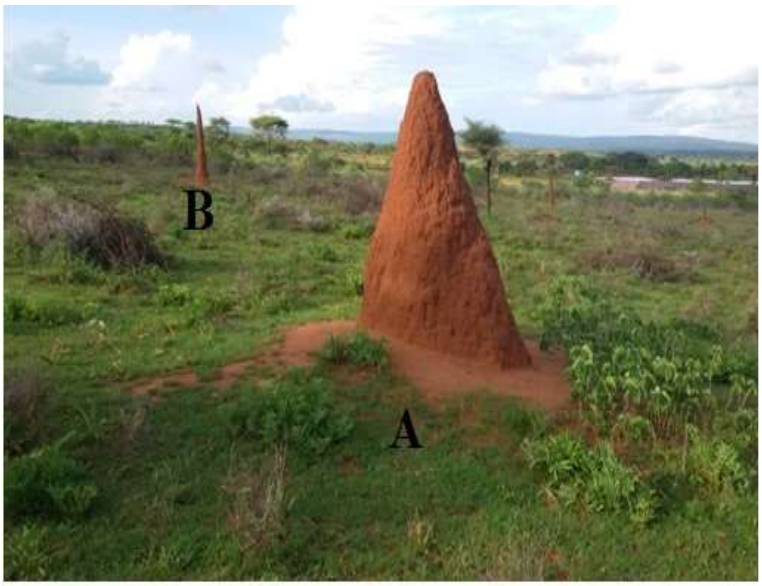


Figure 11. Mound of *M. natalensis* (A) and *M. jeanneli* mound in the background (B) at 5 km east of Yaballo town (Photo by Daniel Getahun).

The mounds of *M. michaelseni* were typically tall and they were found sparsely among mounds of *M. jeanneli*. The mounds had a conical base topped by closed prominent spire (Figure 10). Medium-sized closed steep-sided conical chimney mounds were rarely recorded and it is believed that these mounds were built by *M. natalensis* or a different species unknown (Figure 11). Huge closed conical to dome-shaped mounds were very common especially in Moyale district belonging to *M. falciger* (Figure 12A) and rarely old mounds were found colonized by other species. The spur on the mound (Figure 12B) is a young *M. jeanneli* nest. Peculiar tall and cylindrical closed chimney mounds were recorded from white soil in Melbana, Mio district (Figure 13). This type of mounds was not found on the very nearby red soil on which the typical mounds of *M. jeanneli* mounds were recorded. These mounds are believed to belong to unknown *Macrotermes* species (*Macrotermes* SpA).

A B

Figure 12. Mounds of *M. falciger* recorded from Moyale district. On top of mound (B) is a young mound of *M. jeanneli* colonizing the old mound of *M. falciger* (Photo by Daniel Getahun).

DISCUSSION

Mound density and dimension

There were significant differences ($P < 0.05$) among the mounds of the three regions in their density, height, and basal diameter in the order: Southern > Central > Western Ethiopia. The variation in height is due to the specific termite species found in each region building their own specific mound size. In Western Ethiopia, only mounds of *M. herus* were recorded. The species builds low mounds of about 50 cm high and 1 – 2 m in diameter (Darlington, 1988). In Southern Ethiopia, the mounds were giant built by species like *M. jeanneli* and *M. michaelseni*.

Of the three regions lowest mound density was recorded in Western Ethiopia and this might be attributed to the control of termites practiced by mound destruction and poisoning because of severe termite damage to crops. Huge campaigns were conducted in the 1980s by the government and NGOs by participating farmers, and currently individual subsistence farmers in the area also use mound poisoning and mound digging to control the *Macrotermes* termites. Another reason for the lowest mound density of the Western Ethiopia could be the presence of only one species, *M. herus*, unlike in the other two regions where a number of different species were recorded, particularly in Southern Ethiopia. Besides, Debelo and Degaga (2014) reported that mound density can be governed by different general factors: soil type, topography and soil's water drainage capacity, and termite distribution and abundance can be related to temperature and rainfall (these change with latitude) and salt tolerance.

Termite species identified

Western Ethiopia

Current reports by Abdurahman (1990), Abebe (2000) and Abdurahman et al. (2010) showed that there are only two species of the genus *Macrotermes*, *Macrotermes subhyalinus* and *M. herus* in Ethiopia. *M. subhyalinus* is a well-known, well described, wide spread, dominant and one of the serious termite pests in the country, particularly in Mendi area (Western Wallaga) and thus is locally known as 'Mendi termite' (Abdurahman, 1990; Abduraman et al., 2010). In western Ethiopia, the mounds of *M. subhyalinus* are typically dome-shaped without external openings (Abdurahman, 1990). Cowie and Wood (1989) also reported that *M. subhyalinus* is present almost everywhere in Western Wallaga. It is also documented that there are only two types of mound architecture of the genus *Macrotermes* in Ethiopia. *Macrotermes* mounds found in Western Ethiopia and Maki-Batu (located in Central Ethiopia) area differ significantly both in size and shape and no external openings are found on both mounds. In western Ethiopia, the mounds are typically dome-shaped whereas in Maki-Batu, the mounds are conical. According to the reports, in the former region *M. subhyalinus* builds closed and dome-shaped mounds (Abdurahman, 1990). However, they did not indicate whether the *M. subhyalinus* which builds dome-shaped mounds in Western Ethiopia builds a different mound architecture (conical mounds), which are found in the Maki-Batu area or whether these conical mounds belong to *M. herus*. Apart from its presence in Ethiopia, little description is given about *M. herus*.

However, in the current study, only short closed

Figure 13. Closed-chimney mounds built by unknown species of *Macrotermes* spA, recorded from a specific place called Melbana, Miyo district, Borana zone (Photo by Daniel Getahun).

flattened-dome mounds were recorded from Western Ethiopia. Morphological characterization of these mounds revealed that the mounds belong to *M. herus* and thus it is the only species of the *Macrotermes* found in the region and the absence of *M. subhyalinus*. *M. herus* builds mounds with circular or oval in plan with a low, rounded dome-shape with no external openings (except the flight holes built once a year to permit the nuptial flights of the alates). There is no specialized ventilation system in the mound, unlike those of other *Macrotermes* species. The mounds are about 50 cm high and 1 – 2 m in diameter and are usually kept clear of vegetation if the nest is active. There is no clear break of slope between mound and pediment. New building is applied to the surface in flat plaques, not as raised knobs (Darlington, 1988). Older surfaces are crumbly and coarse-textured, giving the mound a neglected appearance (Darlington, 2011).

Available documents (Harris, 1956; Bagine et al., 1989; Turner, 2000, 2001; Brandl et al., 2007; Korb, 2011) state that *M. subhyalinus* builds short open mounds with multi spires. This type of mounds were not recorded from Western Ethiopia in the current study and this indicated the absence of *M. subhyalinus* in this part of the country which is contrary to the existing publication on the distribution and mound morphology of the species in the country.

With further study and gain of new information, species may be re-identified and earlier name may be changed. For instance, Darlington (1982) stated that early papers published by the ICIPE termite group all used the name *M. subhayalinus* for all *Macrotermes* termites in the Kajiado district of Kenya. However, two mound types were distinguished at an early stage, and observations on the flight of alates from them indicated that where they occurred sympatrically they were reproductively isolated. Subsequently, the Kajiado termites (closed mound type) were re-identified as *M. michaelseni* (formerly *M. mossambicus*). Darlington (1984) also reported in one of her publications in 1977 that *M. michaelseni* nests were described under the name *M. subhayalinus*. Darlington (1984) also once considered that *M. subhayalinus* builds morphologically two major different types of mounds in different areas in Kenya, the Bissel type near the town of Bissel with many holes in the Kajiado District, and the Marigat type with only one large opening raised to a considerable height above the ground in the Baringo District. However, later on, the Marigat type of mound was re-identified to belong to *M. jeannelli*, not to *M. subhayalinus* (Pearce, 1999; Darlington, Personal Communication).

Central Ethiopia

Closed conical, closed dome-shaped mounds and low mounds with a variable number of external openings were recorded from the region.

Closed conical mounds: The closed conical mounds recorded during the present study from Central Ethiopia

had only a conical base without a spire; a spire on a conical base is a peculiar feature of mounds of *Macrotermes michaelseni* (earlier described). These mounds were probably built by *Macrotermes natalensis*. *M. natalensis* builds closed-mound type conical in external appearance (Harris, 1956; Korb, 2011; Turner, 2000, 2001, 2011). Meyer (2001) and Turner (2011) reported that both *M. michaelseni* and *M. natalensis* build closed-chimney mounds, in which *M. michaelseni* builds taller mounds, with a conical base topped by a prominent spire that rises 2-3 m tall, whereas *M. natalensis* mounds are shorter, typically 1- 2 m in height and usually consisting of the conical base only.

Low open mounds: In Bora, Dugda, Adami Tullu Jido Kombolcha districts and in the rest of the northern districts of East Shawa Zone, the mounds were closed, relatively medium in size with some mounds with conical shapes and others with dome-shaped. However, from west of Adami Tullu town at about 8 km south of Batu town in Adami Tullu Jiddo Kombolcha district, low mounds each with a number of external prominent open humps (multi-chimneys) appear replacing the conical and dome mounds to the south in Arsi Negelle district. These were generally the only mound type found in the semi-arid part of the Arsi Negelle district. The number of mounds decreases and finally disappears in the more humid southern part of the district. The openings of the mounds were roughly circular in cross-section leading down into the mound. Wood (1986) reported that he collected *Macrotemes* termites from low open mounds with turrets at 10 km of south of Batu town around Adami Tullu. Debelo and Degaga (2014) also reported the existence of such mounds in the area though all the authors did not specify the species which built the mounds and also the species which built the other closed conical mounds in the area. Cowie et al. (1990) reported that they observed various mound types of *Macrotemes* in Ethiopia and that they eventually to belong to different species. According to these authors, the mounds include single-chimney (perhaps belonging to *Bellicositermes jeanneli* by Grasse (1937) (only seen in southern Sidamo, a former administrative region which covers current Borana and Guji zones of Oromia National State, and Hararghe, lower, and open multi-turreted mounds (possibly *M*. *subhyalinus sensu strict*).

These newly recorded low mounds with a variable number of open humps in the current study, were found only in the two districts of the Central Rift Valley of Central Ethiopia and they were built by *M. subhyalinus*. This new record is contrary to the available documents about the species in the country which describe that it builds closed conical and dome mounds and it is widely distributed especially in western part of the country. The mound architecture of the species recorded in the current study is in agreement with the mounds of the Bissel type of *M. subhyalinus* studied by Darlington (1984) from Kenya. The species builds chimneys mounds with large diameter openings (Harris, 1956; Bagine et al., 1989; Turner, 2000, 2001; Brandl et al., 2007; Korb, 2011) with multi-spires, relatively flat hillocks with several openings or numerous ventilation shafts (Pomeroy, 2005; Korb, 2011). Ventilation shafts are numerous on large, unshaded mounds of *M. subhyalinus*, confirming the main purpose of the shafts, which may however limit the maximum size of mounds (Pomeroy, 2005).

In *M. subhyalinus,* ambient air seems to enter through peripheral, rimless, basal openings. It flows through the mound and leaves it through several exit tunnels with well-defined rims which are usually central and on top of the mound. In contrast to this, *M. jeanneli* has no openings at the peripheral nest base but has only a single central chimney, which can reach a height of several meters and through which air leaves the mound. Air probably enters the mound mainly via relatively distant foraging holes (Korb, 2011). Although, both species build open mounds, *M. jeanneli* builds tall chimney mounds while *M*. *subhyalinus* low mounds with multi spires (Darlington, 1982).

Closed dome mounds: The closed dome mounds (possibly *M. herus* or *M. falciger* or species unknown) recorded in Central Ethiopia were by far larger in size than the mounds of *M. herus* recorded in Western Ethiopia. The difference between the two mounds in the two regions may be due to species difference or the same species building different mound architecture in different environments (if the mounds belong to *M. herus*).

Differences in time of swarm of alates may also indicate species differences. *Macrotermes* termites in Western Ethiopia and Central Ethiopia showed variation in their time of swarm. In western Wallaga, swarming occurs in the evening at about 1: 00 pm and in the CRVE, it occurs in the morning at about 9:30 am which lasts for about half an hour (personal observation). This difference in time of swarm of the termites of the two areas can also be considered as evidence that these termites belong to different species.

Southern Ethiopia

Two categories of mounds, open mounds and closed mounds were recorded from Southern Ethiopia based on the presence and absence of openings on the mounds. Mound structure varies between species of *Macrotermes*, but their structures fall within two broad categories, known as open-chimney and closed-chimney mounds. In both designations, the chimney refers to the largest tunnel in an extensive reticulum of large-caliber vertically-biased tunnels that permeate the mound. In open-chimney mounds, this central tunnel opens at the top of the mound. In closed-chimney mounds, the top is capped

(Grohmann, 2010; Turner, 2011). Various mound types of *Macrotemes* in Southern Ethiopia were documented and this depicts that termite fauna of the region was more varied than the other areas. However, the closed, low flattened dome mounds of *M. herus* recorded in western Ethiopia and the lower, open multi-turreted mounds of *M. subhyalinus* and closed, domed and conical mounds of the Central Ethiopia were not observed in Southern Ethiopia. Southern Ethiopia is savanna grassland and has semi-arid climate and these might have contributed for the existence of the more species of termites than the other areas.

Open chimney mounds: These tall hollow and open cylindrical chimney mounds were built by *M. jeanneli*. In this study the tallest mound measuring 8 m high was recorded from Yaballo town, ever recorded in the country. The architecture of these mounds, including the typical asymmetrical shape at the tip of the opening is the same with those mounds of the *M. jeaneli* (the Marigat type) studied by Darlington (1984) in Kenya. However, in her study, Darlington (1984) considered the Marigat type of mounds as one type of mounds built by *M. subhyalinus*, but later on the mounds were identified to belong to *M. jeanneli*. The very distinctive mounds of *M. jeannelli* at Marigat in the Kerio valley (Kenya) are surrounded by a very tall hollow pillar which may be from 2 to 5 m or more high. There is a large opening at the tip of the pillar 10-25 cm in diameter, and no other opening anywhere on the mound. The lip of the opening is usually sharp and sometimes asymmetrical with one edge raised up to 25 cm above the rest. The vast majority of mounds have only one pillar, but very occasionally two or three may be present on the same mound (Darlington, 1984).

Cowie et al. (1990) reported the occurrence of tall chimney mounds in parts of Ethiopia adjacent to areas of northern Kenya (which is currently Borana Zone) though they could not specify the species. *M. jeaneli* is a fungus growing termite that occurs in arid regions of Eastern Africa and builds impressive mounds with only one high, towering chimney. Both *M. jeanneli* and *M. subhyalinus* build open mounds, the former builds tall chimney mounds with one opening at the tip while the later builds low mounds with multi spires with multi openings (Darlington, 1982; Leuthold et al., 2004; Brandl et al., 2007). However, Tilahun et al. (2012) considered both the open chimney mounds of *M. jeanneli* and closed chimney mounds they recorded from Derito in Yaballo district and Melbana in Miyo district (formerly part of Dire district), respectively as *M. subhyalinus*. In the current study these open and closed chimney mounds were identified to belong to *M. jeanneli* and a *Macrotermes* of an unknown species (*Macrotermes* spA), respectively.

As the *M. jeanneli* termites build their mounds to their maximum height, the pillars fall under their own weight coupled with being washed with rain and also broken by animals. Under this condition, the basal diameter of the mound increases and the termites continue rebuilding the mounds pillars. The central structures are surrounded by an outwash pediment which often has pieces of broken pillar lying on it (Darlington, 1984). Sometimes the mounds are dangerous as they fall on livestock when they scratch their bodies on them and children who look after livestock when they play by climbing on the mounds (personal communication with local people).

Closed mounds: In total, four different closed mounds were recorded in Southern Ethiopia built by four different species. Three types of mound were of chimney type and fourth type is huge closed mounds without chimney.

Closed chimney mounds: Three different types of closed chimney mounds were recorded in the area. These were mounds of *M. michaelseni*, *M. natalensis*, and an unknown species (designated as *Macrotermes* spA).

Macrotermes michaelseni* and *Macrotermes natalensis: The study recorded mounds of *M. michaelseni* and *M. natalensis* species from Southern Ethiopia and this is the first record of the species from the country. The former species was recorded from Southern Ethiopia while the latter was recorded from both Southern and in particular from Central Ethiopia. Darlington (1982) recorded mounds *M. michaelseni* from the semi-arid bushed grassland in the Kajiado area (altitude 1700 m) in the Rift Valley province of Kenya which builds a highly centralized subterranean nest with a closed system of air passages in an epigeal mound above it.

M. michaelseni occurs in East Africa and Southern Africa where it builds conspicuous closed mounds which can reach a height of several meters (Korb, 2011). *M. michaelseni* builds taller mounds, with a conical base topped by a prominent cylindrical spire that commonly rises to about twice the height of the base (2-3 m tall with a broad outwash pediment), but in contrast to the central chimney in *M. jeanneli*, the mound is closed and does not open to the outside. Internally the mound is permeated by a network of tunnels (Turner, 2000; Korb, 2011). Within this type, though, there is considerable diversity of shape. Most commonly, the variation comes in how distinct the spire is compared to the conical base. In many mounds, the spire is nearly cylindrical, and contrasts strongly with the sloping walls of the conical base. In other mounds, the base merges more or less imperceptibly into the spire, so that the mound's overall shape is that of a skewed cone (Turner, 2000).

Closed steep conical mounds without spire belonging to *M. natalensis* were also recorded from the area. *M. natalensis* builds conical closed-chimney mounds (Harris, 1956; Korb, 2011; Turner, 2000, 2001, 2011) and typically 1- 2 m in height (Meyer, 2001; Turner, 2011).

The third type of closed chimney mounds was peculiar high and cylindrical mounds recorded from white soil in

Melbana, Miyo district. This type of mounds was not found on the very nearby red soil where *M. jeanneli* and *M. michaelseni* were common. Morphologically, the mounds were quite different from those of *M. michaelseni* and *M. natalensis*. The mounds probably belong to a *Macrotermes* of an unknown species (*Macrotermes* spA). However, Darlington (*personal communication*) suggested that the mounds might be built by *M. michaelseni* or by a different species.

Huge closed non-chimney mounds

The fourth type of closed mounds in Southern Ethiopia was huge and dome-shaped recorded around Moyale town, a border town between south Ethiopia and north Kenya. These mounds were probably built by *M. falciger*. *M. falciger* builds characteristically large termitaria (Malaisse, 1978); Its mature nests are huge dome-shaped mounds; and its mounds are found in north Kenya bordering Ethiopia at low altitude (Darlington, *personal communication*).

The different types of mound belonging to different species of the *Macrotermes* recorded from Central and Southern Ethiopia were absent from Western Ethiopia. On the other hand, low closed dome to generally flattened mounds of *M. herus* were recorded only from Western Ethiopia. Mounds of *M. subhyalinus* were recorded only from Central Ethiopia, especially in Arsi Negelle district while mounds of *M. jeanneli* and *M. michaelseni* were recorded only from Southern Ethiopia. From the current study, it can be seen that the distribution of a termite species is mainly limited to a given geographical region of the country. This could be due to the geographical isolation of the three regions from each other. The Western region which is relatively lowland is isolated from the Central region (Central Rift Valley) by the highlands found between them while the Central and Southern (lowland and semi-arid) are isolated from each other by the highlands which start around north of Shashemene city and go further south to Sidama, Gedeo, and Western Guji zones. In line with this, Cowie et al. (1989) stated that the Ethiopian highlands, bisected by the Rift Valley, are surrounded by the Sahelian deserts and savannas of Sudan, Somalia and northern Kenya, and to the northeast by the Red Sea. These act as barriers to dispersal to and from the highlands; the Rift Valley may act as a partial barrier to dispersal within them. The large number of endemic and local bird species reflects this situation (Cowie et al., 1989).

Conclusion

To date, only two species of the genus *Macrotermes*, *M. subhyalinus* and *M. herus* are reported in Ethiopia. *M. subhyalinus* was earlier considered building closed conical and dome mounds. However, this study showed that the species builds low mounds with turrets and is absent in Western part of the country, but found only in Adami Tullu Jido Kombolcha district and Arsi Negelle district of the Central Rift Valley of Ethiopia. *M. herus* builds low, closed and flattened dome-shaped mounds and it was the only *Macrotermes* species recorded from Western Ethiopia in the current study.

This paper has added *M. jeanneli, M*. *michaelseni, M*. *natalensis*, *M*. *falciger*, and another unidentified species (*Macrotermes* spA) to the two existing species, *M. subhyalinus* and *M. herus*, to the checklist of the genus *Macrotermes*. Conical mounds of medium size of *M. natalensis*, relatively low closed dome mounds of *M. herus*, and huge closed and relatively dome-shaped mounds which might belong to *M. herus* or *M*. *falciger* were recorded from Central Ethiopia. Contrary to the other regions, highly diversified mounds and higher number of species were recorded from Southern Ethiopia. *M. jenneli, M. michaelseni M. falciger*, and *M*. *natalensis*, and an unidentified species (*Macrotermes* spA) were recorded from the region. The list is not definitive but merely a statement of the *status quo*. Use of molecular analysis is vital to supplement the species identification conducted using mound morphology.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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