Telling Time with Termite Mounds:
Termite mound declination, azimuth, and structure in Tarangire National Park

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Macrotermes michaelseni *termites are found in savannah habitats throughout sub-Saharan Africa. Macrotermes michaelseni differ from other species of termites in that they construct chimney-shaped mounds in order to house their colonies (Turner 2001). These mounds are complex structures which utilize the sun as a tool for thermoregulation. By building their mounds at an angle,* Macrotermes michaelseni *are able to control air flow and regulate temperature within the inner chambers of their mounds. This study examined the zenith (heading on the horizon to which the mound points) and azimuth (the angle of tilt from vertical) of* Macrotermes michaelseni *termite mounds in Northern Tanzania. A total of 62 termite mounds were studied in and around Tarangire National Park during the month of October. Overall, the average zenith of* Macrotermes michaelseni *mounds was found to be 29.4°, however, average angle decreased as termite mound height increased. Of the 62 mounds studied, 59 faced northwest, with an average azimuth of 61.7° west of north. These results suggest that one can indeed use a termite mound in order to tell time. We tested this idea by constructing a sundial which mimicked the average angle and direction of the* Macrotermes michaelseni *termite mounds. We recorded the shadow cast by the mound for every hour of daylight and ultimately produced a chart which can be used to determine time using a* Macrotermes michaelseni *termite mound. Overall, termites provide vital ecosystem services for the surrounding environment. Understanding termite behavior and termite mound structure can provide vital information for agriculturalists, ecologists, and researchers worldwide.*

Introduction

Termites are found worldwide in a variety of climates including grasslands, savannahs, and forests. Termites belong to the order *Isoptera* and include any social, cellulose-eating insects that are soft-bodied and wingless (Termites 2011). Although termites are found worldwide, Africa is the richest continent in terms of termite diversity, containing over 660 species of termites (Eggleton 2002). These species are divided into 7 families: *Rhinotermitidae, Mastotermitidae, Termitidae, Termopsidae, Serritermidae, Hodotermitidae,* and *Kalotermitidae* (Isoptera 2003). Of these families, the *Termitidae* family contains over 60% of termites worldwide and is the most prominent subgroup in Africa (Jones 1990).

This study examines *Macrotermes michaelsenis* termites which belong to the *Termitidae* family, and more specifically, to the *Macrotermitinae* subfamily. *Macrotermitinae* differ from other species of termites in that they cultivate fungus in combs within their nests. These fungi function to break down the complex polysaccharides in plant materials and increase the amount of available nitrogen in the soil (Collins 1982). Additionally, the termites of the *Macrotermitinae* family are hypogeal and feed on dead wood and litter (Jones 1990). They are able to break down lignin and cellulose through the use of gut symbionts and potent digestive enzymes (Stanton 1988). As a result, *Macrotermitinae* termites are some of the main decomposers of litter and animal dung in warm grasslands (Stanton 1988). This decomposition ultimately affects the physical and chemical properties of the surrounding land. Some studies have shown that through plant digestion, termites increase the amount of free calcium ions in the soil (Bagine 1984). Additionally, termite tunnels facilitate water movement and decrease soil bulk density, thus improving the quality of the land (Schabel 2006). As a result, termites have been proposed as ecosystem engineers as well as potential solutions to land degradation (Dangerfield 1998).

The mounds of *Macrotermes michaelsenis* are typically built above ground and are completely enclosed. Each mound consists of three parts and includes a columnar spire, a conical base, and a broad outwash pediment consisting of eroded soil. However, the overall shape of the mound varies, as some mounds have a very distinct spire while others appear more as a tilted cone (Turner 2000). These mounds exist not only above ground, but extend below the ground's surface in a series of tunnels and corridors (Schabel 2006). The corridors are formed via soil translocation which results in the movement of soil from within the colony to the top of the mound (Turner 2000). These corridors capture energy from colonial metabolism and utilize it in order to drive circulatory air flow within the mound (Turner 2001). The thermosiphon model proposed by Luscher explains this airflow, indicating that colonial metabolism heats and humidifies the nest air, reducing its density, and causing it to flow upward (Luscher 1961, Turner 2001). As a result, the air within termite mound is usually warmer and more humid than the surrounding air (Turner 2001). Since the introduction of the thermosiphon model, some have argued that a model based on tidal ventilation is more appropriate. Proponents of the tidal ventilation model argue that air flow relies not only on colonial metabolism, but also on temporal variation in the speed and direction of the wind (Turner 2001). However, regardless of the model proposed, most scientists agree that the structure of *Macrotermes michaelsenis* mounds plays a key role in thermoregulation. The mounds are typically built in a cathedral shape, in order to equalize the distributions of temperature around the spire (Turner 2000). This temperature equalization is achieved when the spire points towards the sun's average zenith. By constructing the mounds so that the largest surface points north, the termites are able to keep all sides of the mound heated equally (Turner 2001). One study found that when termite mounds were rotated 180 degrees so that the spire faced southward, the termites then began to rebuild the spire so that it pointed north (Turner 2001). Overall, the azimuth and zenith of the termite mound are essential to termite survival as these two factors help maintain ideal temperatures for fungal colonization and termite growth (Collins 1982).

This study aims to identify the average azimuth and zenith of *Macrotermes michaelsenis* mounds in Tarangire National Park. We hypothesize that the majority of the termite mounds will face north in order to equalize temperature distribution and sun exposure. In addition, we predict that the average zenith of the termite mounds will be close to the sun's average zenith in Tarangire National Park. This hypothesis is based on a study by Scott Turner which found that *Macrotermes michaelseni* mounds in Namibia pointed at an angle similar to the sun's average zenith (Turner 2000).

Field Site & Data Collection

Data collection took place during the month of October in Tarangire National Park, Tanzania (S 03° 44.294 E 035° 58.191, elevation 1021.0m). Termite mounds of the species *Macrotermes michaelseni* were identified and recorded using a GPS locator. All of the mounds studied had angled spires. A protractor was used to measure the angle of the termite mound while standing approximately 20m away from the mound. The angle was recorded as the deviation from 90 degrees (fig. 1). Angle measurements were taken by two different individuals and then averaged. Additionally, spire direction was recorded using a compass. Compass readings were taken by standing directly in front of the longest face of the termite mound and recording the direction towards the midpoint of the spire. Shade and vegetation surrounding the termite mound were also recorded. A sundial was constructed using the mean angle and direction of the termite mounds. The position of the shadow on the sundial was recorded every hour.

Results

A total of 62 *Macrotermes michaelseni* mounds were surveyed in and around Tarangire National Park. Of these 62 mounds, 31 were in full or partial shade while the remaining 31 mounds were in full sun. The average height of the termite mounds was 2.25m. The average angle of the termite mounds was

29.4°, but, the average angle decreased as height increased (fig. 2). Short termite mounds (less than 1.5m) had an average angle that was 7.3° greater than medium termite mounds (1.5-2.5m) and 12.8° greater than large termite mounds (greater than 2.5m) (p=0.0001). The mean angle for short termite mounds was 35.9° while the mean angles for medium and large termite mounds were 30.4° and 23.1°, respectively (fig. 3 & 4). In terms of direction, mound azimuth pointed almost exclusively northwest, however, we did find mounds facing west, southeast, and southwest. A total of 59 out of the 62 mounds faced northwest, and the mean direction of the northwest facing mounds was 61.7° (±17.7°) west of north (fig. 5).

Discussion

Consistent with our hypotheses, we found that *Macrotermes michaelseni* mounds point in a northward direction and at an angle similar to that of the sun's average zenith in Tanzania. In terms of azimuth, we found that the average heading on the horizon to which the mounds face is 61.7° west of north. This is consistent with a study conducted by Scott Turner which found that *Macrotermes michaelseni* termite mounds in Namibia point north in order to equalize the temperature within the mounds (Turner 2000). Due to the tilt of the earth's axis, the sun does not pass directly above in the southern hemisphere, and instead passes in an arc closer to the northern horizon. As a result, the northern side of the termite mound is warmed more by the sun than the south surface. The termites use this temperature difference to aid in the construction of their mounds: by translocating soil to the warmer side of the mound, they effectively build a spire which points in a northerly direction. The mound continues to grow towards the north until it points towards the sun's average zenith, at which point the mound is warmed evenly on both sides (Turner 2007).

We found that *Macrotermes michaelseni* mounds in Tarangire Park have an average zenith of 29.4°. In a similar study in Southern Namibia, researchers found that the average zenith of *Macrotermes michaelseni* mounds was 18.2°, similar to the sun's average zenith in Namibia of 19.98° (Turner 2000). The sun's zenith indicates how high the sun is in the sky. At an average zenith of 0°, the sun is directly overhead. In Tanzania, the sun's average zenith is estimated to be between 25° and 32° (Near Real Time Map of Solar Zenith Angles 2011). In our study, we found the mounds to have an angle of 29.4° which is consistent with the sun's average zenith in Tanzania of 25° - 32°. Therefore, we suggest that termite mounds are built at an angle similar to the sun's average zenith in order to equalize sun exposure on both sides of the mound (Turner 2007). However, not all of the mounds in our study pointed at angle of exactly 29.4°. In fact, we found that average angle decreased as height increased. While short termite mounds had an angle outside of the solar zenith range for Tanzania, medium and large mounds had average angles well within Tanzania's solar zenith range of 25° to 30°. We suggest that younger, more immature termite colonies have not yet translocated enough soil to the northern side of the mound in order to equalize the temperature within the mound. Therefore, younger termite mounds are shorter and have a larger tilt from 90°. However, as the mound grows, more soil is moved upward and towards the northern surface, thus causing the angle to lessen. Therefore, more mature termite mounds have an angle closer to the sun's average zenith.

Overall, external environment and habitat location have a profound impact on termite mound construction. By using the sun as a guide, termites are able to effectively build a home in which they and their fungal counterparts can thrive.

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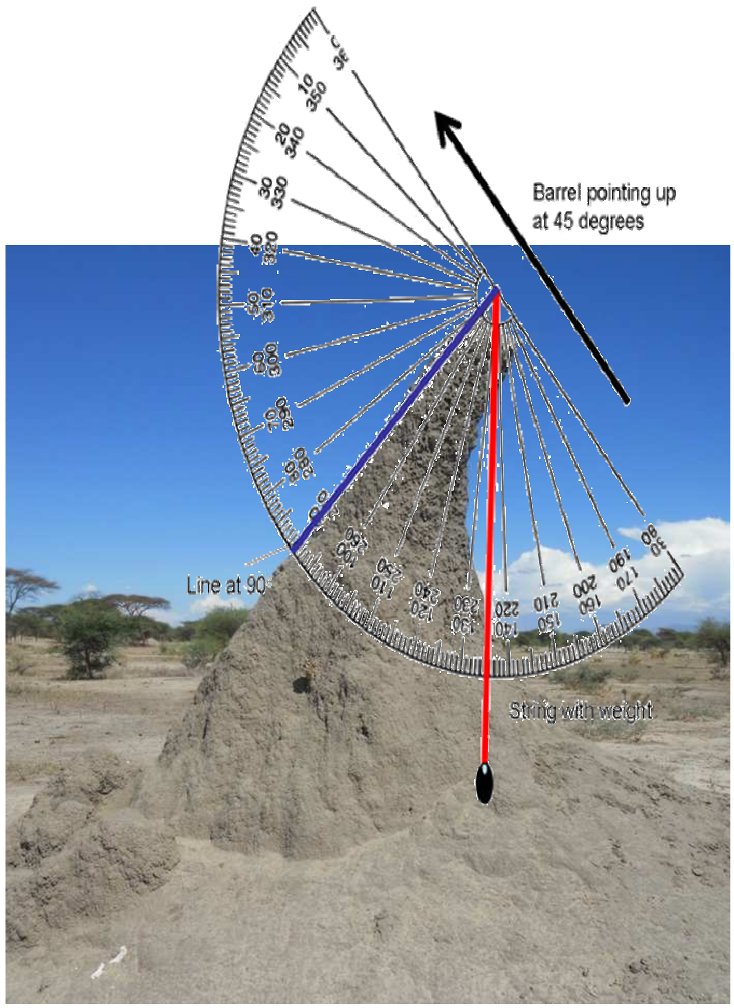

Figure 1. Measurement of termite mound zenith. A protractor with a weighted string was used to calculate the angle of the termite mound. The weighted string hung perpendicular to the ground while the protractor was positioned so that the 90 degrees lined up with the longest edge of the termite mound. The angle at which the weighted string hung was recorded.

Figure 2. A comparison of zenith between a short mound (left) and a tall mound (right). Notice that the short mound has a larger zenith angle than that of the tall mound.

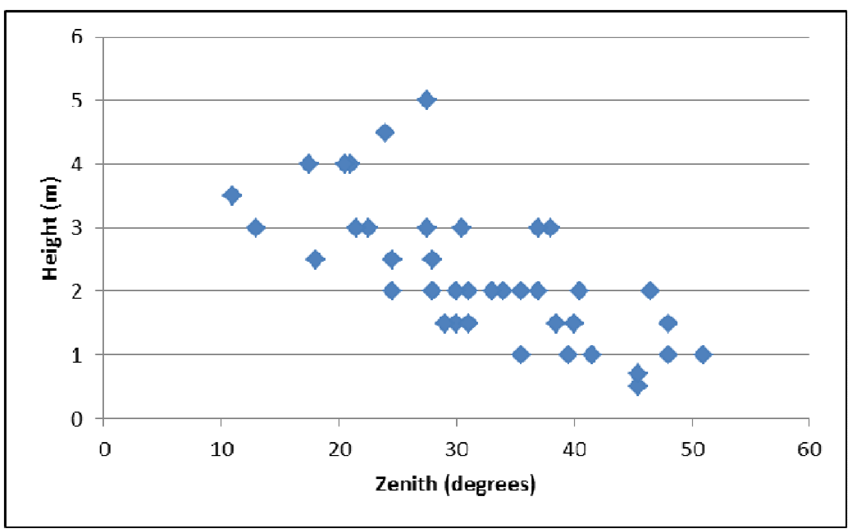

Figure 3. Termite mound zenith in relation to termite mound height.

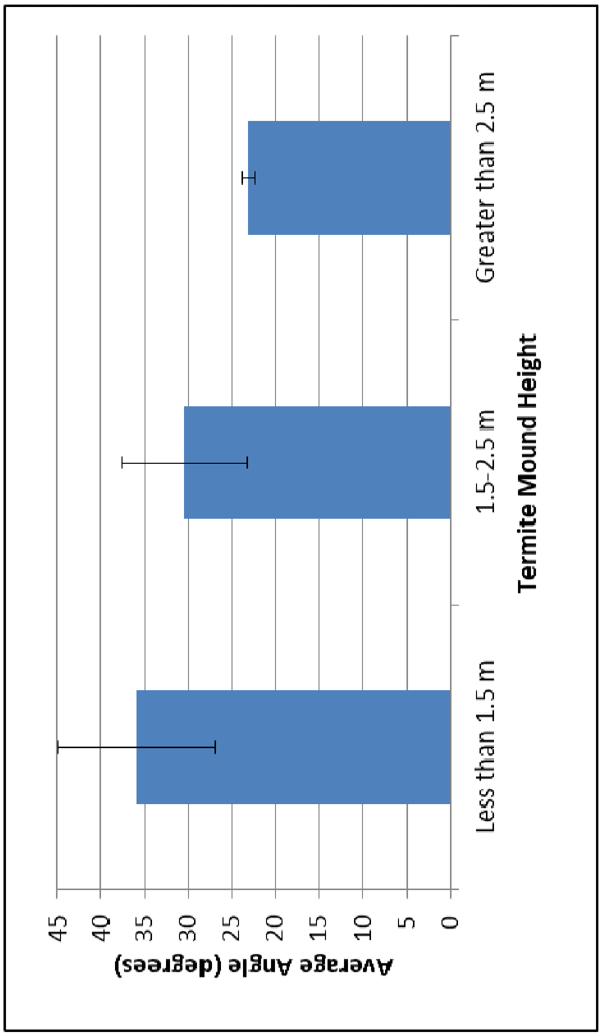

Figure 4. Termite mound height in relation to zenith.

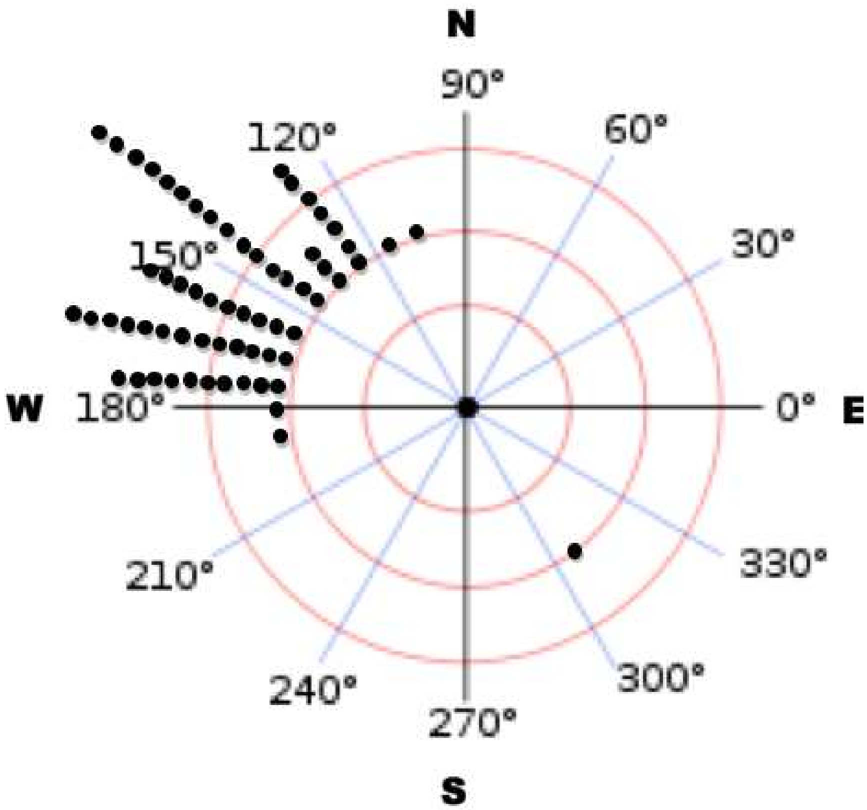

Figure 5. Compass plot representing termite mound azimuth for the 62 mounds studied. Termite mounds were treated categorically, with each category representing a ten degree range of azimuth. Average azimuth was 61° west of north.