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# Preliminary Survey on The Termite Mounds, Their Interior Geometrics and The Termite Prevention from Infrastructural Construction at New Site of Ndola International Airport in Zambia

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**Abstract:**

An ecological study was conducted on termites located at the new site of Ndola International Airport in Zambia. The aim of this study was: (a) to assess the distribution pattern of different sizes of termite mounds located at the site, (b) to investigate the interior geometrics of termite mounds, (c) to determine the colony sizes of termites per each mound found at the site and (d) to provide technical expertise on the different termite preventive methods used on new buildings.

**Methods:** Using an aero-drone fitted with a camera, aerial surveys were conducted to capture and evaluate the spread of differently sized mounds at the site. Mathematical models were used to calculate the volume and number of nests contained in each mound. The colony sizes were captured and recorded per each mound. **Analysis:** Multivariate statistical analyses were performed using SPSS, to compute a two way ANOVA table for comparison of *p*-values involving the colony sizes and the volumes of nests for small and big mounds. The ratios affecting these volumes were also calculated.

**Results:** The total of 1,880 termite mounds was captured spreading at an average of 14 mounds/ $1km^2$. Results further showed that 65% of total mounds were actively housing termites while 32% were virtually deserted. The 3% balance of mounds were occupied by rodents, ants and snakes, respectively. Progression on the volume of nests in bigger and smaller mounds, significantly tallied with the size of mound at $p < 0.0121$ and $p < 0.0346$, respectively. Similarly, the colony size of termites in small and larger mounds was also significant at $p < 0.002$ and $p < 0.001$, respectively. The nest volume ratios of small, medium and larger mounds were also markedly increasing with the size of mound at 1:8.7-small, 1:32.8 medium and 1:1, 098.6-large, respectively.

**Conclusion:** Not every existing termite mound is occupied by termites; the size of nest was directly related to the size of mound; the size of colony concurrently increased with that of the volume of nest. This study unravels some intriguing and conflicting suggestions that smaller mounds can still have larger colonies underground and vice versa. Furthermore, this study is the first in Zambia to combine the concepts of termite habitat geometrics and infrastructural protection.

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## Introduction

In the Agricultural industry, termites are regarded essential insects in fixing the soil ecosystems by improving the soil pH, organic carbon content, water content and porosity [1,2,3]. However, termites are also known in causing detrimental effects in agriculture by destroying a number of food crops like maize cassava etc. [4,5,6,7]. Furthermore, termite activities can still be a menace in the urban set up where they are associated with destroying a variety of components from unprotected buildings [8,9,10,11]. These damages caused by termites on buildings are of great economic importance for home owners because the integrity of infested buildings get compromised, resulting into their loss in value [12,13,14,15]. To date, it is estimated that billions of dollars are spent annually on the control of termites worldwide [16,17,18].

In Australia and China, termite infestations are widespread, with an estimation of 20% of Australian homes and up to 90% of Chinese homes, south of the Yangtze River being affected by termite damage [19,20,21]. Termite infestation is also a major problem to urban buildings in many tropical countries including Malaysia [22]. In particular, the termite damage to buildings in tropical countries is of serious concern, with losses sometimes approximated to 100% [23]. However, there is paucity of data documented on the termite damage to buildings in the sub-Saharan countries [14]. Of late, the available anecdotal data in Zambia, attest to a wide spread of termite infestations recorded on buildings including: houses, offices, libraries, gymnasium, warehouses, Bank, Universities and some Airports. Despite the alarming incidences on termite damage to infrastructure in Zambia, there is very little knowledge on the preventive measures to both the general communities and the building constructors. In most cases, no one seems bothered, even when severe termite damages are observed on important buildings in the country.

Until recently, chemical control methods, including organochlorines (OC) and organophosphates (OP) have been world-widely used on termite attacks during the past 30-35 years, with the OP subsequently replacing the OC [24,25]. Essentially, organochloride pesticides i.e. dieldrin, dichlorodiphenyltrichlothane (DDT), aldrin, endrin, lindane, heptachlor, etc. were used as pesticides in Australia and many countries for a number of decades but were later deregistered when they were observed to be persistent organic pollutants (POPs) [26,27]. In 2001, the USA manufactured organophosphates (OP) pesticides i.e. parathion, malathion, diazinon, fethion, diclorvos, etc. were also banned by the Environmental Protection Agency (EPA) due to similar reasons of POPs [26,14]. In recent years, the enhanced manufacturing of pyrethroid pesticides i.e. thiodicarb, fipronil, thiamethoxam, tebufenozide, methomyl, lambda, etc. which are more specific in action and friendly to human and environment [28]. Among the over 700 banned or deregistered OC and OP pesticides, few are still being used in sub-Saharan Africa, Asia and USA, on special order and closely monitored in use by regulatory bodies [29]. Ratios for water to chemical concentration of these pesticides vary and are always provided by the company manufacturing the chemical brand. To achieve better results, instructions on chemical to water ratios should be followed accordingly. While most of chemicals can be used in contact treatment, others may also be used in fumigation methods [28]. However, the physical control method might not always be used as conventional treatment but rather as an auxiliary method for partial processing [27].

Due to concerns with the environmental pollution however, more and more attention on termite control are being concentrated on various biological control technologies. Despite some degree of safety recorded on pyrethroids, chemical use is always regarded dangerous because after continuous use, users might eventually experience some detrimental effects on health [26]. The biological control methods, may be done by introducing parasitic nematodes, biological control agents such as disease causing fungi and bacteria such as *Bascillus thuringiensis* is also used [28]. In some cases, these agents are released into the soil or injected into the above ground termite galleries [14,30]. With the new and safer methods of termite control being introduced, more research is needed in order to compare and determine advantages and limitations [18].

Recently, several research techniques have also been developed on the use of Integrated Pest Management (IPM) to avoid the use of chemicals [5,6,25]. Mostly, the liquid termiticides have negatively impacted on both the human health and the environment. This coupled with existing limitations recorded on both the non-repellant termiticides and pyrethroids, there is need for use of other IPM methods as an alternative control of subterranean termites [31]. The IPM or rather natural methods are less harmful to both the environment and humans and are thereby widely used both in structural environments and agriculture [7,32,33,34,35].

The aim of this study was to conduct a preliminary survey, to assess the [i] distribution pattern of different sizes of termite mounds located at the new site of Ndola International Airport, [ii] geometric parameters affecting the size of each mound and nest habitat of termites, [iii] colony sizes of termites per each nest located at the site, and [iv] provision of technical expertise, involving different and safer preventive measures of termites from buildings that are under construction.

## Materials and Methods

### *Study Site*

New site of Ndola International Airport is located 17km to the South of the City of Ndola. Using the Android Smart phone- SAMSUNG S4 Mini, the new site was identified on the Global Positioning System (GPS) coordinates of **Latitude:** 12° 57′43.6″S and **Longitude:** 28° 30′ 53.5″ E while its **Altitude:** 1,314m above sea level. It is allocated on a total landscape area of 137.4km$^2$ which was of Savannah type, being rich with alluvium soils, as shown on Google Earth boundary (Fig 1). The area was conspicuously spread out with a variety of mounds which were classified; small, medium and large. Clearing and uprooting of trees at the site started early this year after Government compensated indigenous settlers to move out of the area. From the natural thicket of a Savannah forest environment, trees were first cleared and this exposed a series of mushrooming termitaria of different types. To prevent further termite infestation or attacks at the Airport grounds, all trees found at the site, big or small were completely uprooted, using heavy earthmoving machines, without leaving any stumps underground. The stumps once left would later attract mound-less termites to settle and start making nests under them since wood cellulose is potential food for termites [14,30]. A google

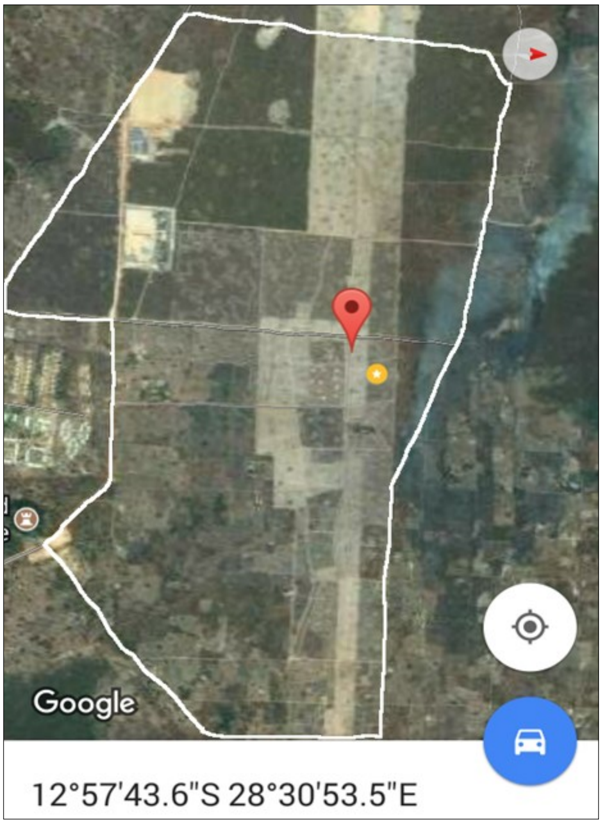



Fig. 1. Google earth boundary of new Ndola Airport site

earth picture is given below to show the boundary of the study site (Fig. 1).

URL:[New Ndola Airport Site]

*Aerial Surveys*

From July to October 2017, a number of surveys were conducted, using an aero-drone fitted with a camera, and operated with a high-tech remote control system from the ground surface (Fig. 2). Aerial surveys were constantly conducted along the 30m width, at the lower altitudes ranging from 45-55m above the ground, in order to clearly capture different mounds (Fig. 2 & 3). To enable better assessment of geometrics, mounds were also classified into small, medium and larger (Fig. 4). The average number of mounds per 1 $km^2$ were calculated.

Fig. 2. An aero-drone fitted with camera taking photos of mounds in flight mode at the site.


Fig 3. Aerial view assessment of mounds spreading over the construction site

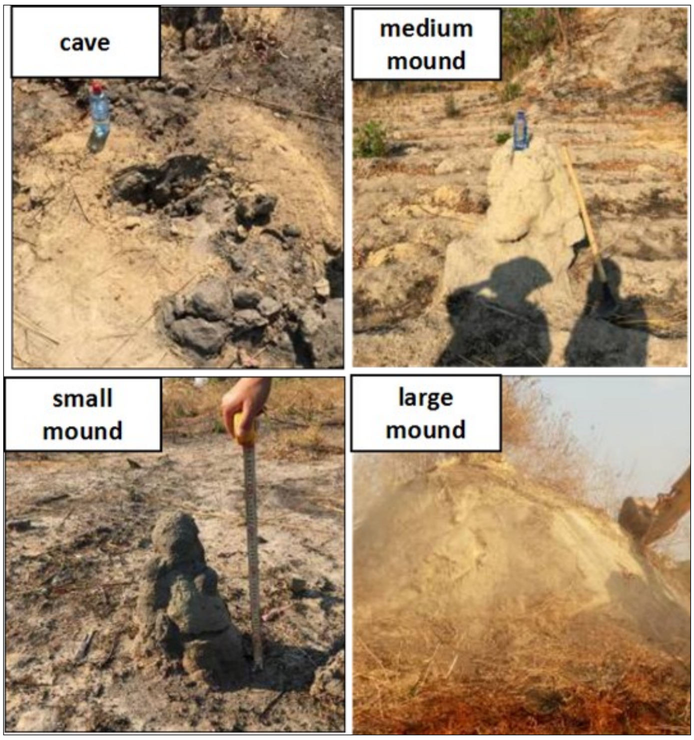



Fig. 4. Classifying mounds of different sizes at the site


Fig.5. HC-01 visual termite detector fitted with a microwave sounder" used on site

*Testing the Efficacy of Fipronil Termiticide on Termite Mounds Located at the Site:*

Using an HC-01 visual termite detector, fitted with a microwave sounder all the mounds were tested whether they were housing termites or not (Fig.5). Per every 1km$^2$, three mounds: small, medium and large, which were detected with termites were reserved for determination of sample size, collection of termite samples and for testing the efficacy of fipronil termiticide. Using the pick for small mounds and a bulldozer for larger mounds, the rest of mounds were destroyed and leveled to the ground (Fig. 6). The trial on the efficacy of chemical was carried out from July to August, 2017. Out of the three mounds reserved per 1 km$^2$, each mound was opened up with a pick or bulldozer and the spot application of fipronil (5% SC), with chemical formula of $CH_{12}H_4C_{12}F_6N_4OS$ - dust, was made. The soil was then buried back and the monitoring on the efficacy of the chemical for eliminating termites was done at 5, 10 and 15 days respectively. Where some termites were still alive after 5 days, some more chemical was injected into the mound using a Duster and shot ball chemical sprayer (Fig. 7). Assessing the chemical potential in controlling termites was concluded within 15 days. The smaller mounds were assessed in July, while the medium and larger ones were assessed in August and September, respectively.

After verifying the effectiveness of chemical, a general application of chemical was done on the broader spectrum, to prevent the future termite attack from the construction site. This also included the prevention of subterranean termites which are hardly seen on surface unless they are detected on a mission tunneling on buildings and plantations. To this effect therefore, 30-40cm of top soil, with lesser binding capacity was cleared, using earthmoving equipment. Depending on how high the surface area was, only 30cm was cleared from the zero filling area and 40cm from areas that were higher than zero filling. According to the compact design required, the paving thickness which is about 1m meter deep was filled in at 35cm layer by layer, with the compaction done at each layer. The mixture of chemical in the tanker is then sprayed evenly across the section (Fig. 8). All these treatments were to ensure that the

Fig.6. Termite mounds before leveling them and their demolition in action at the site

Fig. 7. Duster and shot ball chemical sprayer used at site.

Fig. 8. The mixing of chemicals and spraying with a tanker at site

Airport area remained free from termite attack for about 50 years. Thereafter, regular inspections can be carried out with subsequent treatment.

Ecologically, termites often clean each-others' bodies, especially if a foreign particle or feces were detected on them. Consequently, termites continued distributing the sprayed chemical to the entire colony members until they all died including queens and kings. Apart from being used on termites, fipronil can also kill a number of other insects once ingested. It kills the insect by disrupting their central nervous system. Characteristically, fipronil is much more toxic to insects than to humans and animals. The liquid form was better used in tankers to spray a wider area while the dust was more of spot application. The dosage in terms of ratio of concentrations between chemical: water were followed according to instructions provided by the company that produced chemicals.

*Geometric Calculations, Colony Size Assessment and Sample Collection*

The mounds were carefully opened up so as not to disturb the set-up and arrangement of nests and tunnels leading to the nest. Parameters of width and height of mound were recorded. The number of tunnels were counted so that their width and depth in cm up to the nest was recorded. The width and height of nest were also recorded. These dimensions were eventually used to calculate the volume of each nest and mound at the site (Fig. 9). The colony size was also assessed for each nest. Samples of termites were collected from each nest for further identification (Fig. 10). The manually calculated volumes and colony sizes were also initially verified using the HC-01 visual termite detector.

*Termite Treatment and their Ecological Tenacity in Securing Passage*

The existence of both the mound building and the mound-less subterranean termites has enabled civil engineers to come up with new and more sophisticated methods for both identifying nests and in preventing termites from entry into buildings. In most cases, engineers have partnered with entomologists so as to jointly address the termite situation at the construction site, especially for bigger projects like constructing the International Airport. According to Peterson [36], the best time to prevent termite problems on the property is at the construction stage. While the nests for most mound building termites are located within mounds or few meters below the mound, the nests of subterranean termites can occur anywhere below the tree or where the stump of the tree is located [15] or below any flat surface area of land. Nests of these termites might also be located somewhere below the concretes of some houses.

For the effective termite prevention from the house being constructed, pretreatment is vital in following four areas: (i) Treatment of the entire soil


Fig 9. Termite nests & tunnels from where volumes were calculated for each mound

Fig. 10. Colony size assessment & collecting termite samples from the site for storage

surface to be covered with concrete including: garage floors, entrance platforms and filled porches, (ii) Additional chemical to the soil beneath those areas lying adjacent the foundation walls, beneath interior walls, around sewer and utility openings and all other possible points of termite entry, (iii) Treatment of footings and backfill **outside** foundation walls and **inside** walled areas, where there is a crawl space. Accessible areas like these could be treated later, but nevertheless, treatment at construction time is the best time. (iv) Treatment of hollow areas or voids inside foundation walls. If the slab concrete is poorly done and develops cracks, termites do take advantage of that and subsequently tunnel through the cracks and up to the wall until they reach the ceiling or roof where they start destroying planks [36].

While treating areas in this manner, use the following four approved methods in preventing termite entry as follows: a) use of construction methods which make entry of termites impossible, b) use of physical barriers such as stainless steel mesh or crushed granite, c) application of chemical barriers, either hand-sprayed on the sand pad or distributed through a series of pipes laid under the concrete slab and d) use of termite resistant materials [14,35]. Dampness prevention mechanisms is performed simultaneously, to enable the building to sit on a well-protected slab concrete. [14,37]. In a case of the runways at airport or indeed the road construction, the engineering component involving several stages of chemical mixtures and heavily compacting of soils, up to bitumen level is itself equated to constructing a termite proof structure.

Termites are extremely persistent in finding their way from the nest up into the building and finally into the ceiling and roof where plenty of cellulose can be found. They would take advantage of a very small crack into the slab concrete or at any joining sections of the slab [14].

*Categorizing Variables and Statistical Analysis*

The size of mounds and obtaining nests were expressed in their respective volumes. Two sets of 300 smaller mounds (as 150 mounds per set), with associated volumes and colony sizes were categorized and assessed as **smaller (a)** and **smaller (b)**. Similarly, two sets of 1,400 mounds (as 700 mounds per set) with associated volumes and colony sizes were categorized as **larger (a)** and **larger (b**). Set (a) for smaller mounds comprised a category of smallest mounds while set (b) of the smaller mounds had relatively bigger mounds. Mounds were equally ranked and assessed for large (a) and large (b). Ultimately, these categories enabled the justification for the progression of volume and colony sizes in small and larger mounds. Separate univariate statistical analyses for small and large mounds were performed using SPSS, to compute a two way ANOVA table for comparison of *p*-values, involving the mean colony sizes and the mean volume of nests for small and bigger mounds. The ratios affecting the larger range in volume of nests for small, medium and larger mounds were divided into the cumulative volumes of mounds, to assess whether the ratio size of mound can affected the volume of nest (Table 1).

### Results

Aerial surveys revealed a variety of 1,880 termite mounds, spreading over the landscape of 137.4km$^2$ at the site, with an average estimation of 14 mounds per 1km$^2$ (Figs. 2 and 3). Results further showed that out of 1,880 mounds captured on site, only 65% of them were occupied by termites while 32% and 3% were deserted and occupied by other creatures, respectively (Figs. 11 and 12). Out of the 1,222 mounds that were occupied by termites, 798 were larger mounds while 300 and 124 were small and medium, respectively. Similarly, the 602 deserted mounds comprised 546 larger mounds, in comparison to only 56 mounds which were medium sized (Table 1).

Progression on the volume of nests in bigger and smaller mounds, significantly tallied with the size of mound at $p < 0.0121$ and $p < 0.0346$, respectively (Figs. 13). Similarly, the colony size of termites in small and larger mounds was significant at $p < 0.002$ and $p < 0.001$, respectively (Fig. 14). The nest volume ratios of small, medium and large mounds were also markedly increasing with the size of mound at 1:8.7-small, 1:32.8 medium and 1:1,098.6-large, respectively (Fig. 15). On the other hand, results on the trials conducted on the efficacy of fipronil (5% SC) showed that the chemical was 100% efficient in killing termites, within 10-15 days from the first treatment date (Table 2).

### Discussion

It was evident from this study that only 65% of 1,889 mounds were actively housing termites while 32% of these mounds were seemingly deserted. Furthermore, out of 56 mounds that contained various occupants other than termites, 29 mounds contained ants while 21 mounds were occupied by rodents while 6 mounds housed snakes which were either in singles or several of them, suggesting that snakes and rodents can live and reproduce in termite mounds (Fig. 12). It was unclear however, whether these intruders that were found in termite mounds, occupied them when termites had already deserted them or they entered mounds on a hunting mission, to capture termites for food and after they overpowered the occupants, they fed on them to the extinction of the entire colony and eventually decided to take over their habitat nest and tunnels after a fierce conquest battle.

It was unclear however, whether the 32% of mounds that were detected without termites had been indeed deserted or rather some of them had nests deeply located beyond the detection capability of the instrument we used. According to Lee et al., [37], and

Table 1. Showing termite colony size, number of mounds and different geometrics of mounds at site.

| Size of mound | Height (m) | Width (m) | Quantity (n) | Volume of mound ($m^3$) | Volume of nest ($cm^3$) | Colony size (n) | Mounds with termites | Deserted mounds (n) | Cumulative Volume of mounds ($cm^3$) |
|---|---|---|---|---|---|---|---|---|---|
| Small | 0.2-0.5 | 0.2-0.6 | 300 | 0-1 | 5-15 | 7,850 | 300 | 0 | 130 |
| Medium | 0.5-1.5 | 0.5-1.8 | 180 | 1-20 | 15-25 | 18,520 | 124 | 56 | 820 |
| Large | 3-6 | 5-25 | 1400 | 20-981 | 25-45 | 38,750 | 798 | 546 | 49,436 |
| **Total** | | | **1,880** | | | | **1222** | **602** | |

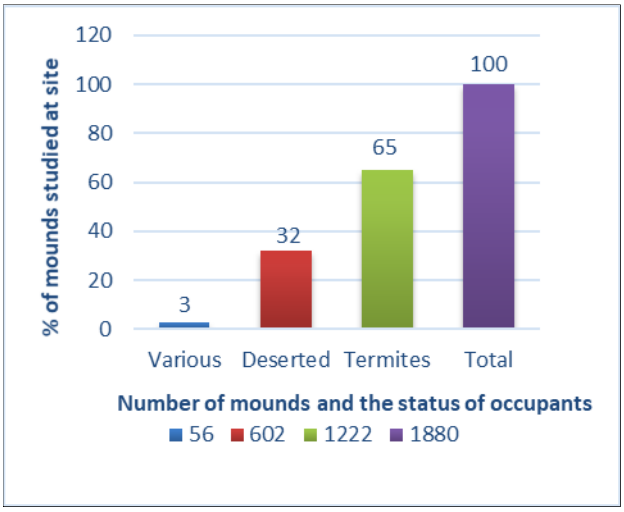



Fig. 11. Number of mounds at site and their contents

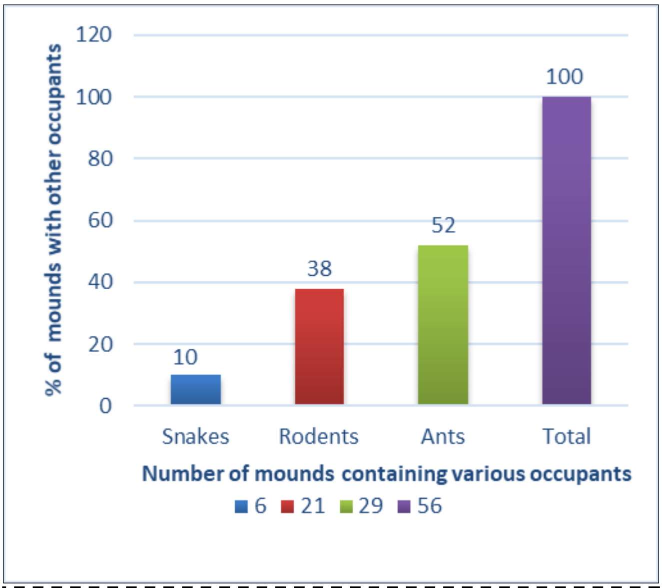
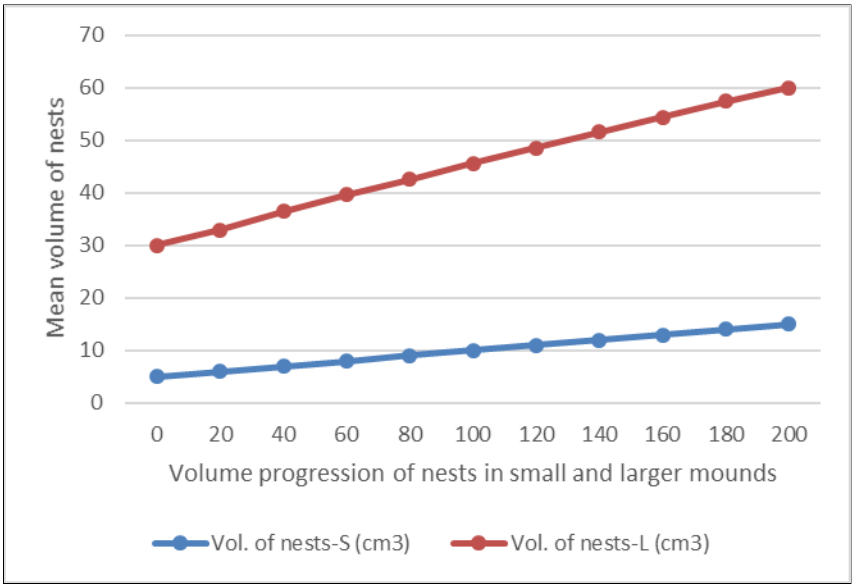



Fig. 12. Number of mounds with various occupants

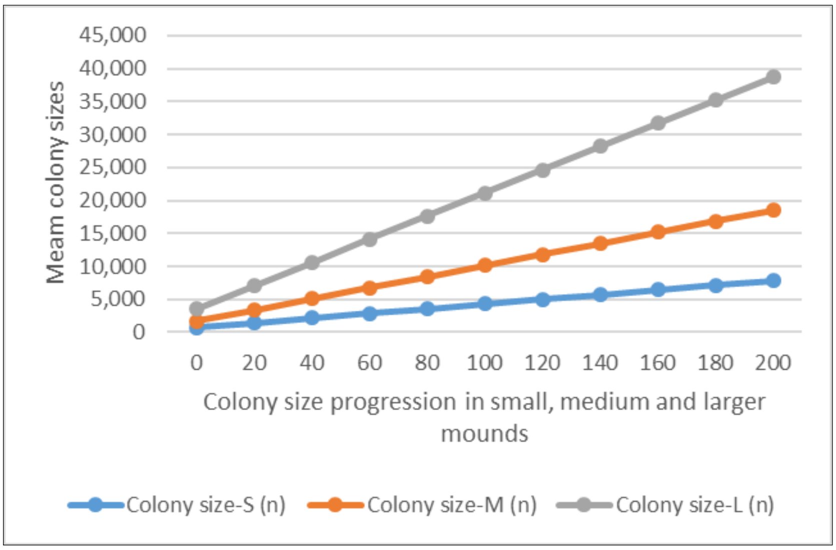



Key: S=small mounds, and L=Larger mounds

Fig. 13. Progression of volume for nests in $cm^3$ in small and larger mounds


Key: S=small mounds and L=Larger mounds

Fig. 14. Progression in number of colony size in small and larger mounds




Key: S=small mounds, M=Medium mounds, L=Larger mounds

Fig. 15. Progression in numbers of colony sizes in mound categories as generated from ratios

Table 2. Showing the efficacy of fipronil on termite control in mounds at the site.

| Size of mound | Height (m) | Width (m) | Quantity (*n*) | Experimental period on mounds | Colony size (*n*) | Termites still alive in the first 5 days | Termites alive after 10 days | Termites alive after 15 days of application |
|---|---|---|---|---|---|---|---|---|
| Small | 0.2-0.5 | 0.2-0.6 | 300 | 01-30/07/17 | 7,850 | 0 | 0 | 0 |
| Medium | 0.5-1.5 | 0.5-1.8 | 180 | 01-30/08/17 | 18,520 | 750 | 0 | 0 |
| Large | 3-6 | 5-25 | 1400 | 01-30/09/17 | 38,750 | 2,320 | 0 | 0 |
| **Total** | | | **1,880** | | | **3,070** | **0** | **0** |

van Huis [38], some termites can establish their nests 10 -70m deep underground, in their quest to avoid intruders and also to enable them maintain the suitable moisture for tunneling. It is for this reason why we also felt that termite mounds could be used by mining prospectors in exploring for minerals like: gold, zinc, uranium and other important metals [39]. To this effect therefore, termites can also make mineral prospecting easier because companies in this business, can save a lot of money from drilling deeper.

A number of anecdotal reports in the ecology of termites have exhibited conflicted results on whether the colony size would have an effect on the size of nest and size of mound. This study has confirmed results that smaller colony sizes are always associated with smaller nests and mounds, and vice versa with the larger colony sizes (Figs. 13, 14 & 15). It was also interesting to observe that there were 546 of larger mounds deserted while only 56 of the medium sized were deserted and none of the smaller ones was deserted, suggesting that in smaller mounds, termites rarely desert for the reason that they were still establishing themselves (Table 1.).

A spontaneous check at the Copperbelt University (CBU) buildings, revealed that some old office door-frames and boards were severely damaged (Fig. 16). We assumed that there could be a widespread of unreported termite attack on important buildings in Zambia. To this effect, the home owners often get a rude shock at selling their property when evaluators tremendously undervalued them. Worse still, such buildings are death traps in that they are the ones that fall first in an event of a tremor or earthquake.

Our study concurs with that of van Huis [38] where it was reported that some termite mounds were found occupied by ants, rodents and snakes.

## Limitation of Study

Although we finally used the general preventive measures of termites at the site, including both the mound building and the subterranean termites, we felt that our instrument used in the survey, might have not successfully captured some termite nests which were located 10-70m below the mounds [38]. On this fact therefore, some of the 32% of deserted mounds could still house termites but which were not detected. In addition, our study mostly concentrated on mound building termites with less focus on subterranean termites [40], whose nests can be found below any surface soil.

## Conclusion

(i) Not every existing termite mound is occupied by termites.

(ii) The size of nest proportionately increased with the size of mound.

(iii) The size of colony concurrently increased with that of the volume of nest.

(iv) This study unravels some intriguing and conflicting suggestions that smaller mounds can still have larger colonies underground and vice versa.

Fig. 16. Termite damage spotted on door frames and boards at CBU offices in Kitwe, Zambia

(v) These ecological studies on termite mounds, involving geometrics of nest habitats, coupled with the control measures in the infrastructural engineering are the first to be conducted in Zambia.

### Recommendations

(i) There is need to carry out more research surveys on the termite prevalence and extent of attack on buildings and other plantations located in the two Cities of Ndola and Kitwe, together with their outskirts.

(ii) Follow up studies on the cause of termite desertion from mounds and hence with the occupation of other creatures can be studied further.

(iii) The termite identification of the species located at the new International Airport and the surrounding Cities will be carried out and reported in the subsequent paper.

(iv) Further studies involving soils as associated with termites in mounds might be beneficial to both the farming community, the mining companies and indeed to the general members of communities in Zambia, especially those that have the appetite of eating the mound clay soils.

### Acknowledgement

This research work was funded by a Chinese engineering company "Zhejiang provincial transportation and engineering group of companies" which is currently on termite consultancy with Copperbelt University (CBU). Authors deeply appreciate the CBU management for enabling a joint scientific collaboration in both infrastructure engineering and the entomological sciences on termites without which this study would not be realized. We only expect that this joint benefit and cooperation between our two organizations can go a long way.

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