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POPULATION ASSEMBLAGES OF A TERMITE SPECIES, *Macrotermes gilvus* HAGEN (BLATTODEA: TERMITIDAE) AT DIFFERENT LAND USES

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ABSTRACT

Several studies were conducted on the distribution of *Macrotermes gilvus* Hagen (Blattodea: Termitidae) especially in northern part of Peninsular Malaysia. However, information on distribution of this termite species in different type of landscapes was scarcely reported. Therefore, a study was conducted to investigate the *M. gilvus* population and distribution in different land uses as well as the variation of mound size based on different areas. Four areas of different land use in Universiti Putra Malaysia, Selangor, Malaysia; oil palm plantation, landscaped garden, farmland, and urban area were selected to survey the quantity and size of their mounds as well as the population of *M. gilvus*. For each area, three *M. gilvus* mounds from three size categories: small (height of 1 to 20 cm; diameter of 1 to 50 cm), medium (height of 21 to 40 cm; diameter of 51 to 80 cm), and large (height of 41 to 60 cm; diameter of 81 to 120 cm) were randomly selected. The result of this study shows that oil palm plantation has the highest number of mounds and population density of *M. gilvus* (51.4% and 845882.35 individual per ha), followed by landscaped area (35.5% and 401940.00 individual per ha). The farmland recorded the lowest number of mound and population density (13.1% and 164385.59 individual per ha), meanwhile the species was absent in urban area. All areas except the urban setup were significantly dominated with large size of mounds, followed by medium size mounds and the least was small size of mounds. This study concluded that the species preferred to inhabit the shaded area, dense-canopy cover with less human activities and buildings, which provided the species a good area to build mound and foraging for food.

Keywords: Human disturbance, land uses area, *Macrotermes gilvus*, termites, termite habitat

ABSTRAK

Beberapa kajian telah dijalankan ke atas taburan *Macrotermes gilvus* Hagen (Blattodea: Termitidae) terutamanya di kawasan utara Semenanjung Malaysia. Walaubagaimanapun, maklumat tentang taburan anai-anai daripada spesies ini di kawasan guna tanah yang berbeza adalah kurang dilaporkan. Oleh itu, satu kajian telah dijalankan untuk mengkaji populasi dan taburan *M. gilvus* di kawasan guna tanah yang berbeza termasuk variasi saiz busut di kawasan yang berbeza. Empat kawasan guna tanah yang berbeza di Universiti Putra Malaysia, Selangor, Malaysia; ladang kelapa sawit, taman berlandskap, kawasan kebun dan kawasan perbandaran telah dipilih untuk ditinjau kuantiti dan saiz busut anai-anai termasuk populasi *M. gilvus*. Untuk setiap kawasan, busut *M. gilvus* daripada tiga kategori: kecil (tinggi dari 1 ke 20 cm; diameter dari 1 ke 50 cm), sederhana (tinggi dari 21 ke 40 cm; diameter dari 51 ke 80 cm) dan besar (tinggi dari 41 ke 60 cm; diameter dari 81 ke 120 cm) dipilih secara rawak. Keputusan kajian menunjukkan bahawa ladang kelapa sawit mempunyai busut dan kepadatan populasi tertinggi *M. gilvus* (51.4% dan 845882.35 individu per ha), diikuti dengan kawasan berlandskap (35.5% dan 401940.00 individu per ha). Kawasan kebun mencatatkan jumlah busut dan kepadatan populasi yang terendah (13.1% dan 164385.59 individual per ha), manakala spesies ini tidak didapati di kawasan perbandaran. Semua kawasan kecuali kawasan perbandaran didominasi oleh busut bersaiz besar, diikuti dengan busut bersaiz sederhana dan paling kurang adalah busut yang bersaiz kecil. Kajian ini menyimpulkan bahawa spesies ini cenderung untuk mendiami kawasan yang teduh, berkanopi tebal yang kurang aktiviti manusia dan bangunan, yang menyediakan spesies itu kawasan yang sesuai untuk membina busut dan mendapatkan makanan.

Kata kunci: Gangguan manusia, kawasan guna tanah, *Macrotermes gilvus*, anai-anai, habitat anai-anai

INTRODUCTION

Genus *Macrotermes* Hagen (Blattodea: Termitidae) are fungus growing termites that can be found in Africa and Southeast Asia (Abe et al. 2000; Roonwal 1970). They cultivate fungus with plant materials on fungus comb, a unique structure that can be found in the mound of *Macrotermes*. Besides, this genus has the ability to alter the chemical and physical distribution of soil makes them important in soil conditioning and maintaining soil moisture (Jones et al. 2005). Nevertheless, they also build subterranean tunnels to assist their foraging activity further from the mound (Helmiyetti et al. 2021). In ecosystem, this genus was very important as primary decomposer and nutrient recycler in the soil (Subekti & Mar'ah 2019). Meanwhile, in some continents such as Africa, they were an important nutrient supply for human (Egan et al. 2021). However, the genus also a potential pest in agriculture and building by weakening the soil structure (Alia Diyana et al. 2020; Neoh & Lee 2009). According to Tho (1992), the common species in Peninsular Malaysia from the genus were *Macrotermes gilvus*, *Macrotermes carbonarius* and *Macrotermes malaccensis*.

Research on *Macrotermes gilvus* abundance and phylogeography was well established previously. For example, a study on caste composition and mound size of *M. gilvus* was conducted by Lee et al. (2012) in Penang, Malaysia. Similar study was conducted by Subekti and Mar'ah (2019) which estimated the population size of *M. gilvus* in Indonesia. In an advance study, Veera et al. (2017) documented the phylogeography of this species and their dispersal in Southeast Asia, using microsatellites and mtDNA markers. In addition, there were several investigations were carried out to observe *M. gilvus* as a pest in agricultural areas (Odeyakun et al. 2011; Rouland-Lefevre 2010; Zadji et al. 2014). For example, Lee et al. (2012) has reported the correlation between the *M. gilvus* colony size with a termiticide. A preliminary study on elimination of *M. gilvus* colonies using a chemical termiticide was conducted by Dhang (2011).

Besides their roles as an important pest especially in agriculture, but their major contribution towards the environment as decomposer is also imperative (Vesala et al. 2017). Across the regions, humans pose a major threat to this species through their activity and lands used which altered the species habitat (Davies et al. 2021). However, there was no reports on the effect of the anthropogenic activities toward the population of *M. gilvus*. Although the species of termites received well attention from the scientists, but the effect of human activities towards the termite species was scarcely reported. It is important to understand the activities that promote the major threat to *M. gilvus*, therefore control and management of the species is carried out properly. This study was conducted to fill the void and further our understanding about the population and distribution of *M. gilvus* in different type of land uses that content exposure from various types of human activities.

MATERIALS AND METHODS

Study Site

The study was conducted in Universiti Putra Malaysia (UPM), Serdang, Selangor, Malaysia as depicted in Figure 1. The image was retrieved from Google Earth Pro software (Version 7.3.6.9345). Four sites were selected based on different land uses *Macrotermes gilvus* population observation: 1) oil palm plantation 2) landscaped garden 3) farmland and 4) urban area.

Figure 1. The four sites selected in Google Earth Pro

The oil palm plantation was located at 2°59'17.91"N, 101°43'35.91"E (Figure 2a). From the record, the oil palms were planted at the area of 3.74 ha back in 2011. The land has a gentle slope with elevation around 68 m a.s.l. In general, condition inside the plantation is shady and weedy. The *M. gilvus* mounds were easily spotted in the area.

For the landscaped environment, a park known as Expo Hill inside UPM was selected (2°59'17.60"N, 101°42'41.89"E) (Figure 2b). The average elevation is 46 m a.s.l with the size of 5 ha. The park was surrounded with ornamental trees such as rain tree, shrubs and the ground is cover with turf grass. In ordinary days, the park was visited and hosted many events. In this study, a farmland which surrounded with many spots for agriculture research was included as one of the land uses with different type of agricultural activities (Figure 2c). It was located at 2°59'27.11"N, 101°42'56.18"E, which covered 4.72 ha of land and situated at 41 m a.s.l. In the area, tilling was carried out once every few months to prepare the land for new planting season of short-term crops such as corn and most of the crops were irrigated with sprinkler system. Trees were minimal and a few ponds were scattered around at the area.

To represent the urban set up inside the campus, the area which comprised of administration buildings, lecture hall, main hall, cultural hall and library was selected (Figure 2d). As other urban area, it consisted concrete and steel buildings, roads, car parks and ornamental trees and shrubs. As an important location in the campus, it was frequently visited by people especially during working hours of weekdays. The area 6.8 ha and located at 3° 0'10.69"N, 101°42'20.64"E, 46 m a.s.l.

Figure 2. Study sites in UPM. a) oil palm plantation, b) landscaped garden, c) farmland and d) urban setup area

***Macrotermes gilvus* Mounds Survey and Observation**
In every location, the site was divided into several zone to ease the survey and observation activities. During the survey, the number of *M. gilvus* mounds in every area were recorded. Besides that, the physical parameters of the mounds such as height and diameter were measured using measuring tape. The height is measured vertically from the tip of the mound to the lowest part of the visible mound. Meanwhile, the diameter of the mound was the measurement of the widest part of the mound's base. From the mound physical parameters data, they were categorised into three sizes based on the classification according to Lee et al. (2012) (Table 1).

Table 1. *Macrotermes. gilvus* mound size classification by height and diameter (Lee et al. 2012)

Mound Parameter	Size Category		
	Small	Medium	Large
Height (cm)	1 - 20	21 - 40	41 - 60
Diameter (cm)	1 - 50	51 - 80	81 – 120

The quantity of mound for each size category were recorded. The GPS coordinates of the mounds were recorded with smartphone's GPS functionality (with accuracy of ±4m radius) and the coordinates were labelled with location and mound size. This data was later plotted in Google Earth Pro software to visualise the distribution of mounds by size.

Sampling of *M. gilvus* and Species Identification
The sampling of the soldier termite samples was conducted alongside with the mounds survey and observation, to confirm the termite species that build the mound. The sampling activities was carried in morning because the termites inactively foraging (Andi Saputra et al. 2017; Lee et al. 2012). In every site, termite sample was collected from three mounds of different size. The termite mounds were excavated with a geologist's hammer. Three major soldiers' termites were collected using a tweezers and preserved in universal bottles containing 70% ethyl alcohol. The bottles were labelled with location and mound size. The identification of termite species was conducted in laboratory using dissecting microscope (Leica ZOOM 2000). The termites were identified using Tho (1992).

Data Analysis
The population of *M. gilvus* in a mound was estimated by the mound size since the population was proportional to the size of the mound (Jones et al. 2005). Based on study by Lee et al. (2012), the population of *M. gilvus* in a mound was estimated as shown in Table 2.

Table 2. Estimated population of *Macrotermes gilvus* based on size category (Lee et al. 2012)

Mound size	Estimated populations (individuals)
Small	15400
Medium	33500
Large	61400

Therefore, the estimated population density of the species per hectare in each of the areas was calculated by multiply the quantity of mound of each size with their respective estimated population, then divide the sum by the area surveyed. The calculation was simplified as follows,

$$Estimated\ population\ density = \frac{(\text{Quantity of small mound} \times 15400) + (\text{Quantity of medium mound} \times 33500) + (\text{Quantity of large mound} \times 61400)}{\text{Surveyed areas (hectare)}}$$

The number of mounds and population density of *M. gilvus* between the different areas were statistically compared using Analysis of Variance (one- way ANOVA) which was performed by Statistical Package for the Social Sciences (IBM® SPSS Statistics).

RESULTS

Based on the identification of the termite species collected in this study, the species was confirmed as *Macrotermes gilvus* morphologically (Figure 3). According to Tho (1992), *M. gilvus* was distinguished from other *Macrotermes* by its small size and having the anterior region of the hyaline tip of the labrum broadly conical. All other species have a trilobed hyaline tip. Generally, all *Macrotermes* including *M. gilvus* was the largest termite in Peninsular Malaysia, with a subrectangular head, a dome-shape labrum with a small but prominent hyaline tip. The soldier also has large sabre-shaped mandible that lack marginal teeth.

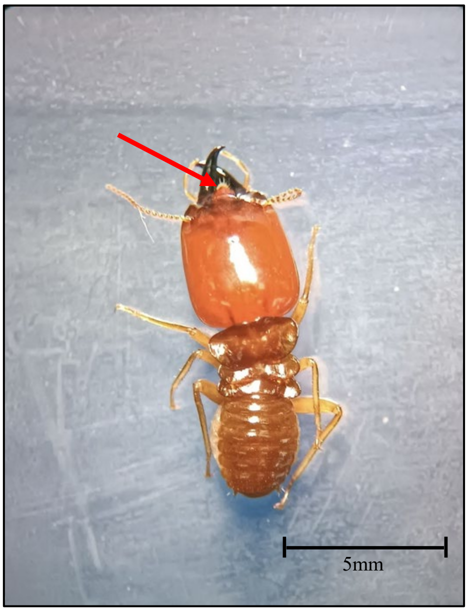

Figure 3. A soldier of *M. gilvus* collected in this study. The conical shape of the anterior region of the hyaline tip of the labrum was clearly seen (pointed with red arrow)

Based on the survey that were conducted, the number of *M. gilvus* mounds in all four sites was shown in Table 3. In general, the number of mounds were the highest in oil palm plantation. Based on localities, all areas were dominated with large size of mounds, except for urban area. The percentage of the large mound was recorded in oil palm plantation (54.5%), followed by landscaped garden (33.0%) and farmland (12.5%). This pattern was similar for medium mounds. For medium size mound, 42.9% was recorded in oil palm plantation, followed by 35.7% and 21.4%, each in landscaped garden and farmland, respectively. However, small mound was recorded only in oil palm plantation (20.0%) and landscaped garden (80.0%). This size of mounds was absence in farmland and urban areas.

Table 3. Mound quantity and percentage (%) categorised by the mound size in four different land uses

Land Uses	**Number of Mound (Percentage %)**			
	Small	**Medium**	**Large**	**Total**
Oil Palm Plantation	1(20.0)	6 (42.9)	48 (54.5)	55 (51.4%)
Landscaped Garden	4 (80.0)	5 (35.7)	29 (33.0)	38 (35.5%)
Farmland	0	3 (21.4)	11(12.5)	14(13.1%)
Urban Area	0	0	0	0
Total	5	14	88	

Macrotermes gilvus Etimated Population Density

Table 4 showed the population density of *M. gilvus* per hectare based on the number of mounds and number of mounds per hectare. The highest population of *M. gilvus* was recorded at the mounds in oil palm plantation, estimatedly 845882.35 individual per hectare. At the landscaped area, the population of *M. gilvus* was half from the population in oil palm plantation (401940.00 individual/hectare). Based on the presence of the mounds, the population of *M. gilvus* in farmland was 2.4 times lower than the population in landscaped area. In this area, estimated population density of the termite species was 164385.59 individual per hectare and was significantly difference between between the number of surveyed mound mound sizes and the areas (one way ANOVA; $F_{3,11} = 1.5026$, $p<0.05$).

Table 4. Estimated population density of *M. gilvus* per hectare in each of the land uses

Site	**Estimated Population Density (Individuals/ha)**	**Mound Per Hectare**
Oil palm plantation	845882.35	14.71
Landscaped garden	401940.00	7.60
Farmland	164385.59	2.97
Urban area	0	0

Mound Distribution Plots

The GPS coordinates of all termite mounds surveyed were recorded with accuracy of ± 4m radius and visualised in Google Earth Pro software to show their distribution. Each dot on the maps corresponds to a mound. The colour of the dot represents the size of the mound. Green dot is a small mound, yellow dot is a medium mound and red dot is a large mound. Figure 4 shows the distribution of termite mounds in different sites. As displayed, the mounds at the oil palm plantation (Figure 4a) were more centred and adjacent to each other. This pattern was different compared to the location of mound in landscaped area (Figure 4b) and farmland (Figure 4c).

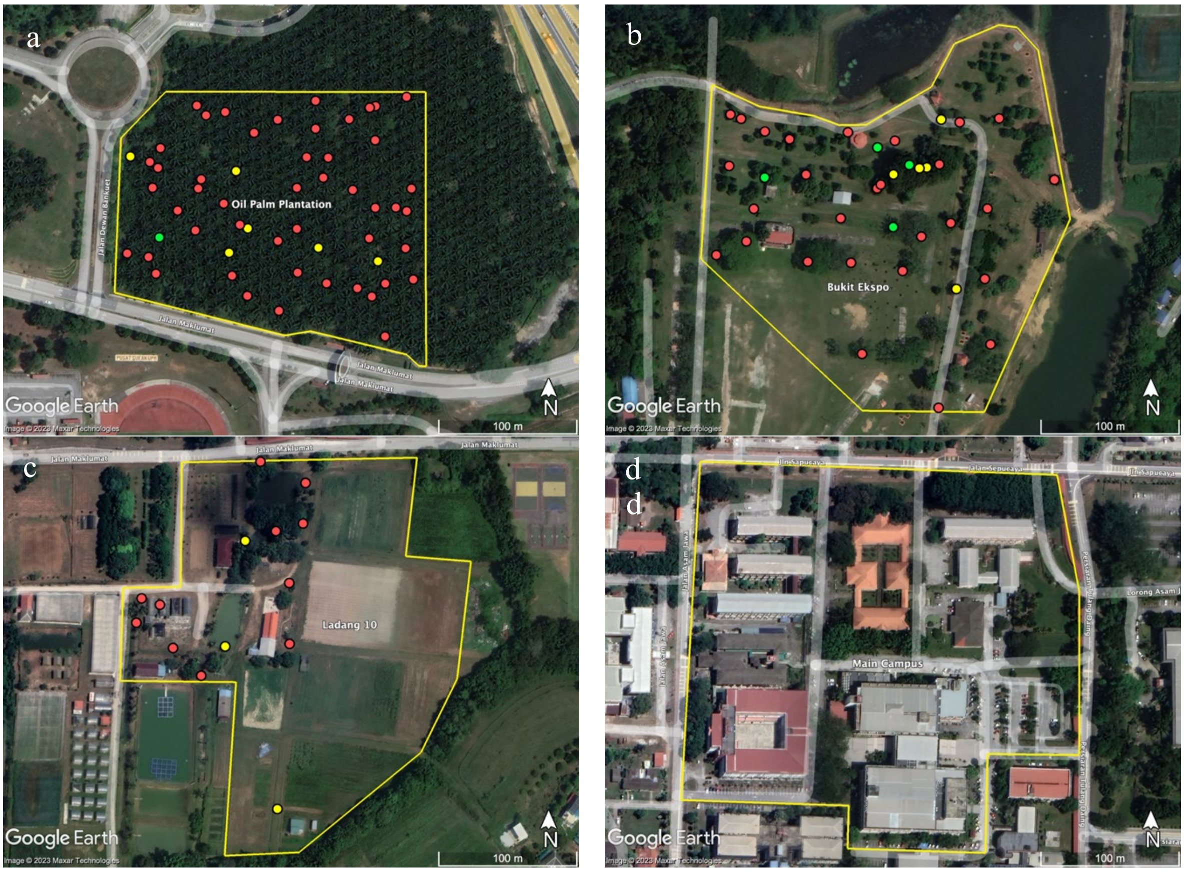

Figure 4. Distribution of different sizes of *M. gilvus* in different land uses in UPM campus, Serdang, Selangor. a) oil palm plantation, b) landscaped garden, c) farmland, and d) urban area. (Red = large mound, green = medium mound, yellow = small mound)

DISCUSSION

Population of the *Macrotermes gilvus* in Different Land Uses

Based on the physical appearance of the mounds and geographical images of the sampling areas, it was presumed that most of mounds was habitat for termites from species *Macrotermes gilvus*. According to Tho (1992), the habitat of *M. gilvus* were lowlands especially around rural habitation and in urban areas especially in large parklands. In this study, all excavated mounds were belonged to *M. gilvus.* The discovery of other species such as *Macrotermes carbonarius* was anticipated but the species was absence in the sampling areas, which in contrast with previous findings. Neoh and Lee (2009) reported that 32.4% of total *Macrotermes* in a study at northern part of Penisular Malaysia was *M. carbonarius*. According to Naeem et al. (2017), the habitat for both species was very similar. However, Tho (1992) reported that habitat of *M. carbonarius* was more common in low lying flat land especially in coastal forest. Based on the habitat characteristics, the absence of *M. carbonarius* from the study areas was justified since this site was roughly 39 km away from the coast. The difference in geography explained the absence of *M. carbonarius* in the survey sites.

Macrotermes gilvus Mound Distribution Between Different Land Uses

As expected, large mound recorded the highest population, followed by medium mounds while small mounds recorded the least population. The oil palm plantation has the highest amount of termite mounds despite having the smallest area surveyed among the four sites. Meanwhile, the termite species was absence in urban setup despite of its large area. According to Aiman Hanis et al. (2014), *M. gilvus* preferred habitat with low disturbance. In comparison between the oil palm plantation and other areas especially the urban area, it was obvious that oil palm plantation provided more ample conditions for the species habituation. However, this was in contrast with other findings which the *M. gilvus* preferred the area with low canopy cover (Arinana et al. 2016). Although the landscaped area comprised of trees and shrubs which provided similar condition as found in oil palm plantation, but it was regularly cleaned and maintained to provide conducive environment for human activities.

In the study, we observed that the number of mounds in a particular area contributed to the highest population of *M. gilvus*. According to Jones et al. (2005), *Macrotermes* mound size and the population within the mound have a proportional relationship. Therefore, collecting data on mound dimension and it's density allow us to derive an estimation of quantity of termite individuals per unit area. Lee et al. (2012) also emphasize that there was a significant and positive correlation in between population of *M. gilvus* and mound size. Therefore, the area with the highest number of mounds such as oil palm plantations, showed the highest number of the species.

Besides the conditions the areas that favoured the colonization of the *M. gilvus*, other factors also contributed to the number of mounds in the areas. Silva et al. (2021) highlighted that the termite colony needed to be a certain size and sufficient nutrient before the alates were produced and dispersed to start a new colony. This explained the high number of mounds in oil palm plantation. The highest number of large mounds which indicated the sufficiency of nutrient played an important role to produces other colonies of *M. gilvus* (Tasaki et al. 2023). This factor also explained high population of *M. gilvus* at the area (Abe et al. 2011). Besides nutrients sufficiency, other factors also affected construction of new *Macrotermes* mounds. According to Neoh and Lee (2009), *M. gilvus* preferred the windless condition. Among all four areas, it was presumed that the oil palm plantation provided less windy condition for the alate termite to disperse, compared to other areas due to more obstruction from the dense-canopy of palm trees (Stiegler et al. 2023).

At landscaped garden area, distribution of mounds was mainly at the area adjacent to the trees. As mentioned by Roonwal (1970), as *M. gilvus* required grass, leaves and stalk to be store in the nest, they will easily obtain all these materials enormously at the area close to trees. Meanwhile, in farmland area, distribution of the mounds was mostly at the area that was no planted with any crop, such as area with shelters, greenhouse and trees. As one of the agriculture practices of clearing the farmland, usually the mound was removed during the preparation of the land. Termite mounds decrease the land surface available for farmer to cultivate cash crops by interfere with plowing activities (Jouquet et al. 2017) and *M. gilvus* usually damages agricultural crops (Neoh & Lee 2009). Therefore, the mounds were removed by till aging. This practice destroys underground young *Macrotermes* nests before it could develop into mound (Roonwal 1970). In different occasion, Miyagawa et al. (2011) reported that farmers in Laos complained about termite mounds causing difficulty in maneuvering the tillage machines in paddy field, thus they tend to destroy the mounds. This situation was also observed in oil palm plantations. Most of the mounds were built right beside the trunk base of oil palm and few mounds constructed in between rows of oil palm. The mounds in between rows could obstruct plantation machines and making it difficult to harvest oil palm fruit and when weeding the plantation. There could be a possibility that the plantation workers intentionally destroyed the mounds that blocked their way (Nyagumbo et al. 2015).

In urban area, low number of mounds was due to light pollution that attracted the alates and exposing them to predators (Pearce 1997). Beside the light attractive behavior that increase their risk to start new colony (mound), the unfavourable surroundings such as concrete and asphalt unallowed the mound to be built, as they need to burrow into soil after pairing with opposite sex (Pearce 1997). It this study, there were assumed colonies of *M. gilvus* at the urban setup, but they were young nests. According to Roonwal (1970), most of *Macrotermes* young nests were subterranean. Since this study focused on the observation on termite mount, the underground colonies were left unobserved.

CONCLUSION

The land uses of the surveyed areas were dominated with *Macrotermes gilvus*. Based on the observation from this study, that the species of termite preferred to inhabit the agricultural areas with less human activities, large soil area and dense with canopy cover concluded. This type of area harboured this species and provided conducive environments which promoted the increasing of many colonies of the termite species. It was proven with the high number of mounds, size of the mounds and population density of the species in this type of land use. Except the urban setup, most of the areas was dominated with large size of mounds, indicated that the *M. gilvus* colonies were well established in the area especially at the oil palm plantation. In the urban setup which surrounded with buildings and concretes, the species was absence as no mound was found. Since the species required soil to build their nest, therefore they were not preferred to inhabit urban area which surrounded with concrete and asphalts road. As the study provide information about the species abundance and phylogeography, the management of the species can be carried out suitably in the future. Although many considered the species as pest, but their presence in a particular area indicated that the environment is healthy with less human activities and disturbance.

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AUTHORS DECLARATION

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Conflict of Interest
The authors declare that they have no conflict of interest.

Ethics Declarations
No ethical issue is required for this research.

Data Availability Statement
This is a Final Year Project (FYP) and the data are currently in FYP thesis of Chai Wen Lin (2023).

Authors' Contributions
Chai Wen Lin (CWL) and Wan Mohd Hafezul Wan Abdul Ghani (WMHWAG) conceptualized this research and designed experiments; CWL, Anis Syahirah Mokhtar (ASM)

and WMHWAG participated in interpretation of the data; CWL wrote the paper and WMHWAG and ASM participated in the revisions of it. All authors read and approved the manuscript.

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