Monitoring Termite's Activities In Built-Up Environment Using Geographic Information System (GIS) Based Approach. (A Review)

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Abstract
Termites' attacks to building has been a major concern to builders, home owners and Government Agencies desiring solution due to cost of constant replacement of affected wooden parts. Termites control can be more efficient when information on the current status of its prevalence and severity in a given area is available. This review paper focused on monitoring termite's activities in built-up environment using GIS based information. Available literature revealed that there are little information available on the destructive termites' attacks to build-up environment in Nigeria. This review was therefore carried out with a view to providing baseline information on prevalence of activities of termites and the use of GIS in the survey of termites severity in guiding builders, home owners and Government agencies in taking informed decision before, during and after construction also ensuring building safety.

Keywords: Termites, Geographic Information System (GIS), Termite Probability Map, Built-environment

Introduction.

Termites are social ecosystem engineers which play a major role in the ecosystem across the world especially in the tropics (Jouquet *et al*., 2006 and Rahman *et al.,* 2013). They help in the recycling of cellulosic material and aeration of the soil. However, when it comes to building and other wooden structure they are enormous menace. They destroy wooden materials and a lot of money is been spent annually by home owners for repair and replacement of damage parts (Owoyemi *et al*, 2017). The annual estimated cost of global damage by termites are in billions of dollar (Su, 2002; Rust and Su, 2012). In the recent times, there is the need for builders to take adequate precautionary measure before construction. This is done by ensuring that building are sited in a safe environment, which is free from termites or any other biodeteriorating agent. One way of doing this, is by carrying out preconstruction investigation to ascertain termites prevalence and severity level in order to adopt appropriate construction technology which will guarantee the safety of the building to prevent loss as most of the buildings are constructed on mortgage. In the United States of America, Florida for example, the building code contain regulation on termites control for pest control company and building owners on the need for continued protection of building from termite unlike country like Nigeria (Florida building code, 2010). The Certificate of Protective Treatment for Prevention of Termites must be provided prior to the issuance of the Certificate of Occupancy as per Section 104.2.6 of the code of Florida. This certificate is needed when home owners want to sell their properties or accessing loan facility from bank as the buyer and bank will want to be sure that the building is safe from termite infestation (Florida building code, 2010; Anonymous 2022 and Freedom mortgage 2019). This review is therefore aimed at providing information on monitoring termite's activities in built environment using Geographic Information System which will serve as a guide to homeowners, developers and pest control companies in taking informed decision during planning and execution of projects.

Termite activities.

Termites are social insect living in colonies. They live in self-constructed mounds called termitaria. A termite colony is very organized and has castes that are morphologically and functionally distinct. (Lee and Wood, 1971; Richards and Davies, 1977). Termite belongs to the Order Isoptera (Grimaldi and Engel, 2005). Termites have different group comprising of over 2600 species in 280 genera worldwide, 80 termite species were considered serious pests and subterranean termites accounted for 38 species (Lee and Chung, 2003; Ahmed *et al*. 2011; Rust and Su, 2012). Subterranean termites, especially those from the subfamily Macrotermitinae (Odontotermes spp. and Macrotermes spp.) and Rhinotermitinae (Coptotermes spp.) are seriously attacking building and *Coptotermes* spp genus has the largest number of species (Sornnuwat *et al*., 1996; Kirton and Azmi, 2005; Rust and Su, 2012). Termites occur in most tropical countries and are also found to a limited extent in some semi-temperate climate including North America and several European countries (Fig. 1) (Berry, 1994; Owoyemi, 2008). The estimated number of termite species distribution worldwide for Africa, North America, South America, Europe, Australia are 435, 1000, 50, 400, 10 and 360 respectively (Meyer *et al.,* 1999 and UNEP 2015). Also the rate of its destructive activities is a function of the species of termites, soil properties and climatic condition of the area (Owoyemi *et al*, 2017). The attack of termite to building mostly originated from their nest on the ground to the building (Fig. 2). The galleries are usually constructed in the top 300mm of soil but may be deeper (Owoyemi *et al*, 2008). It access the building through galleries built on any material (Ghaly and Edwards, 2011). Owoyemi *et al*, (2013) reported that termites have become very prominent and of great economic importance among other wood destroying agents as a result of its destructive nature. Worldwide estimate of losses incur due to termite attack are in billions of US dollars annually (Eko *et al.,* 2015) However, in some Africa countries like Nigeria, are unable to give the right account of losses incurred due to termite attack to building (Ye, Jones, & Ammar, 2004), this could be the difficulty in collecting such kind of data. There is little information on the cost of termite control to building in Nigeria annually unlike records found (Table 1) for countries like USA, Indonesia, Malaysia, Japan, China, Hong Kong, Taiwan and Philippines (Eko *et al.,* 2015). Despite the allocation of thirty million naira for termite control in a school in Ekiti state by the state government, there was no indication that anything was done to eradicate the destructive activities of termites which threaten to ruin the school after four year intervention (Iretomiwa, 2021).

Table 1 Country estimated economic losses due to termites attack to building annually

SN	Country	Economic losses due termite attacks per year
1	Indonesia	IDR 90 billion
2	Malaysia	USD 10-12 million.
3	*Japan*	US $ 1 billion
4	China	RMB 1700-2000 million
5	*India*	280 millions rupee
6	Taiwan	4 million US dollars
7	*USA*	$1.5 billion

Source. (Eko *et al*. 2015) and Su Nan-yao and Rudolfh. Scheffrahn. (2000)

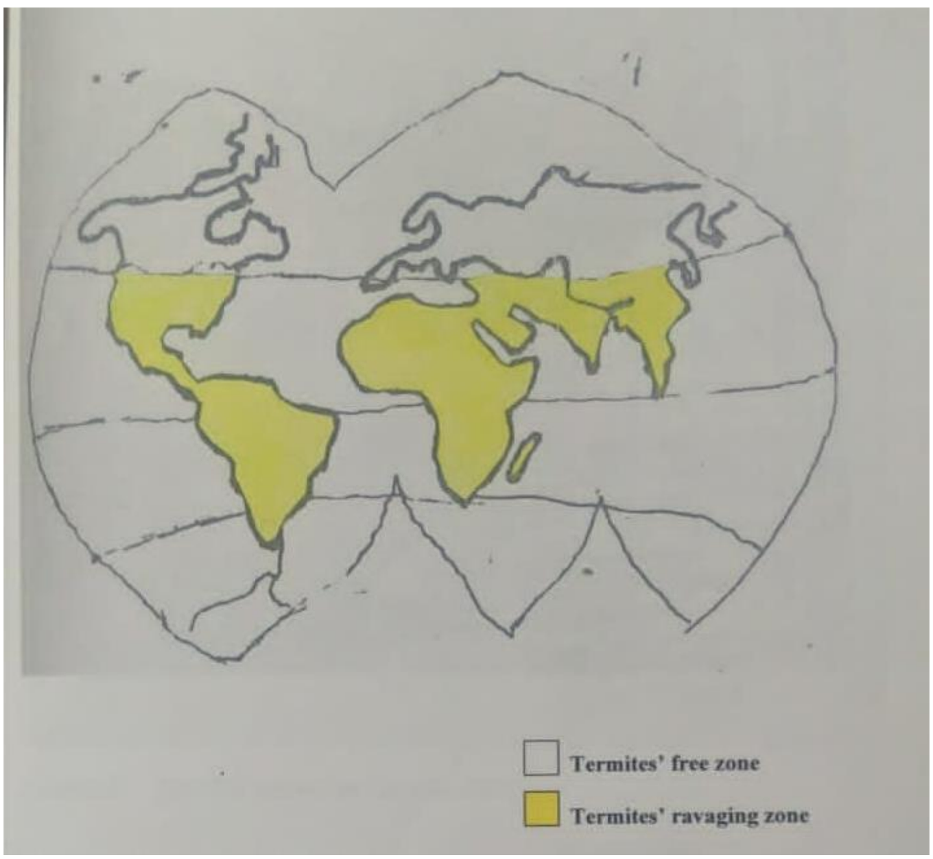

Figure 3: World Distribution of Termites. Source: Berry (1994)

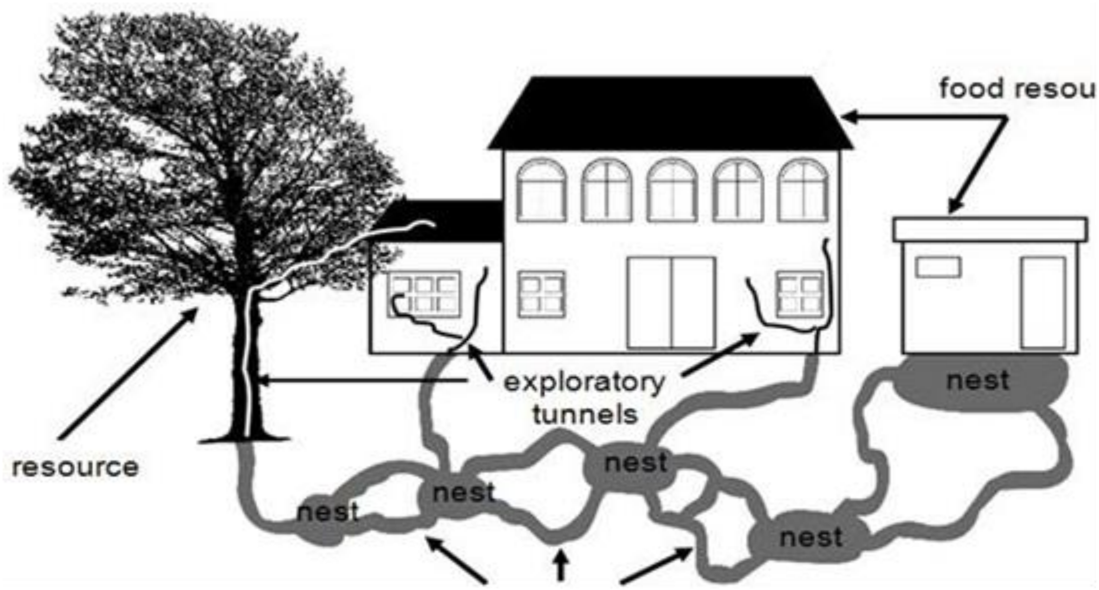

Figure 2: Typical Termites activities in building. (Eko *et al*. 2015).

Monitoring termite's activities

Monitoring of termites activities is important in managing its destructive activities to structures. This could be expensive and time-consuming; it involves establishment of termite monitoring station around the outside perimeter of the building's foundation at about 3 to 6 meters intervals. The monitoring station composed of plastic holder and a cellulosic materials. The station housing is a hollow green plastic cylinder, about 225 mm long by 50 mm wide, with slits along the sides for termites to enter. Initially, each station contains two untreated pieces of wood, intended as monitoring devices for the presence of termites in the area. (http://www2.ca.uky.edu/agcomm/pubs/ent/ent65/ent65.pdf). Also developing termite's probability map for documenting activities of termite for an area is important reference tools for planning and siting structures. It is a rigorous activities, well plan, time consuming and costly (Sónia *et al,* 2016, Su and Scheffrahn 2000). According to Owoyemi *et al*, (2021), the process of developing termites probability map for an area include digitizing the study area and then converted from the ArcGIS shape file format (.shp) to Google earth-compatible format (.kml). The digitized boundary of the shaped file will then be opened on the Google earth interface to extract the Google earth images that fall within the study area boundary. Other known features, such as the roads, river, and buildings, from the acquired images will be obtained without further need for georeferencing. The data will then be loaded on QGIS software where the plot sampling followed a systematic sampling technique using the "Research tools" on QGIS by dividing the georeferenced study area map into rectangular grids populated with serially regular numbered points. Sampling locations will be randomly selected among the regular points spread across the gridded area with the help of a randomization device.

The coordinates of the selected points will be exported to Google earth to ascertain their exact locations on the study area location, where a selected location falls on a structure or other facilities, the nearest suitable location besides it will be selected. Finally, a reconnaissance survey (ground truthing) will be carried out to assess the ground locations of the selected points and subsequently establish the timber graveyard at these selected locations.

Defect free less durable wood will then be used as termite's bait at the timber graveyard in the selected locations processed into standard sample sizes of 35 × 35 × 450 mm according to ASTM D3345-17 (2017). All the samples will be labeled for easy identification and their initial wet weight obtained using a weighing balance, after which they will be oven-dried weight at a constant temperature of 103 ± 2 °C for twenty-four (24) hours until a constant weight is obtained. The oven-dried weights of each sample will also be noted, and this will served as the starting (i.e., initial) weight of each of the samples with respect to weight loss assessment. Wood samples will be buried to a depth of 225 mm below the ground surface and at the spacing of 1000 × 1000 mm from each other in each of the selected locations. The samples will be subsequently inspected weekly for between twelve weeks to one year which will be revalidated every five years since termites migrate from one place to another due to noise and anthropogenic activities of man and climate change (Owoyemi, 2008; Grzegorz and Cloe, 2017) .Termites species will also be collected in each of the area of study for proper identification because of the numerous species of termite known worldwide over 2600 species as the rate of attack differ from each other.

Furthermore, soil sample from each of the location will also will be taken to determine some physical properties like bulk density, particle size and percentage moisture content. At the end of the assessment period, data obtained from the weight loss assessment and soil properties tests will be used to prepare a termite probability map using QGIS print composer.
The map will be colour coded following United States Forest Service codes for subterranean termite's probability map (Table 2) according to ASTM D3345-17 (Peterson *et al,* 2006):

Table 2: United States Forest Service codes for subterranean termite's probability map

ASTM Rating	Description	Colour
10	None to slight attack	White
9	Slight attack	Green
7	Moderate attack	Yellow
4 and 0	Heavy attack	Red

A depiction of the steps taken from the acquisition of the location boundary map to the preparation of the termite severity probability map is shown in Fig 3

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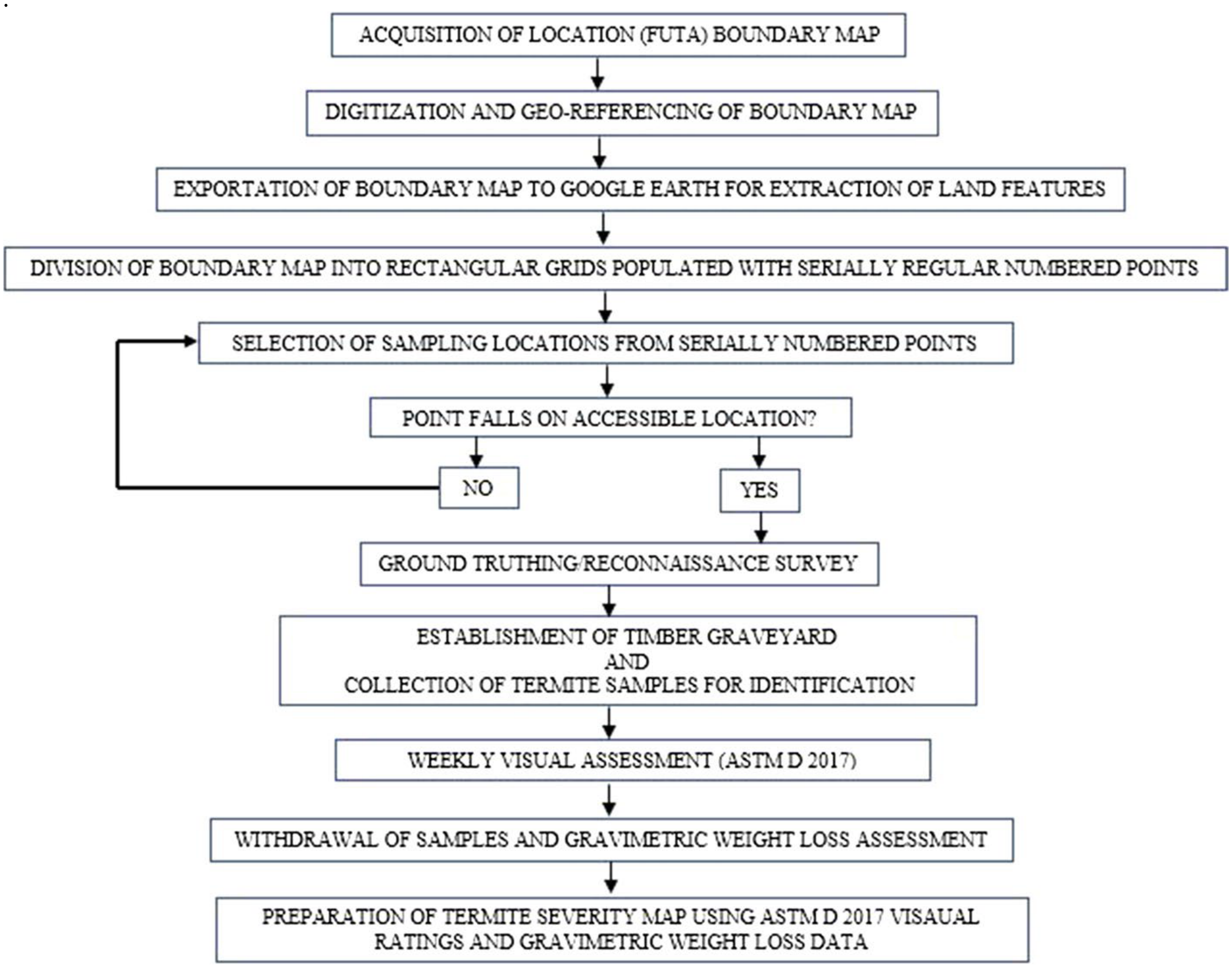

Figure 3: Flowchart depicting the steps followed in the preparation of the termite severity probability map. Source (Owoyemi et al, 2021)

Application of Geographical Information System (GIS) in monitoring termite's activities

A Geographical Information System (GIS) is a set of hardware, software, and methods for managing, manipulating, analyzing, modeling, representing, and displaying geo-referenced data in order to solve complex problems in resource planning and management (Ranjan and Vinayak, 2020). Its data are flexible, precise, and accessible for meeting operational and other software requirements (Acharya *et al.,* 2018). It uses georeferenced data, that is, having unique location information, such as postal addresses, or point coordinates. Geovisualization is used to explore, analyze, and present spatial data, however, a GIS mapping system also supports on-screen digitizing of spatial features on top of background maps. Point, line, and polygon object features are often displayed over a base map, e.g. a satellite image, which can be provided through a Web mapping service within the GIS (fig. 4) (Hochmair *et al*, 2013).

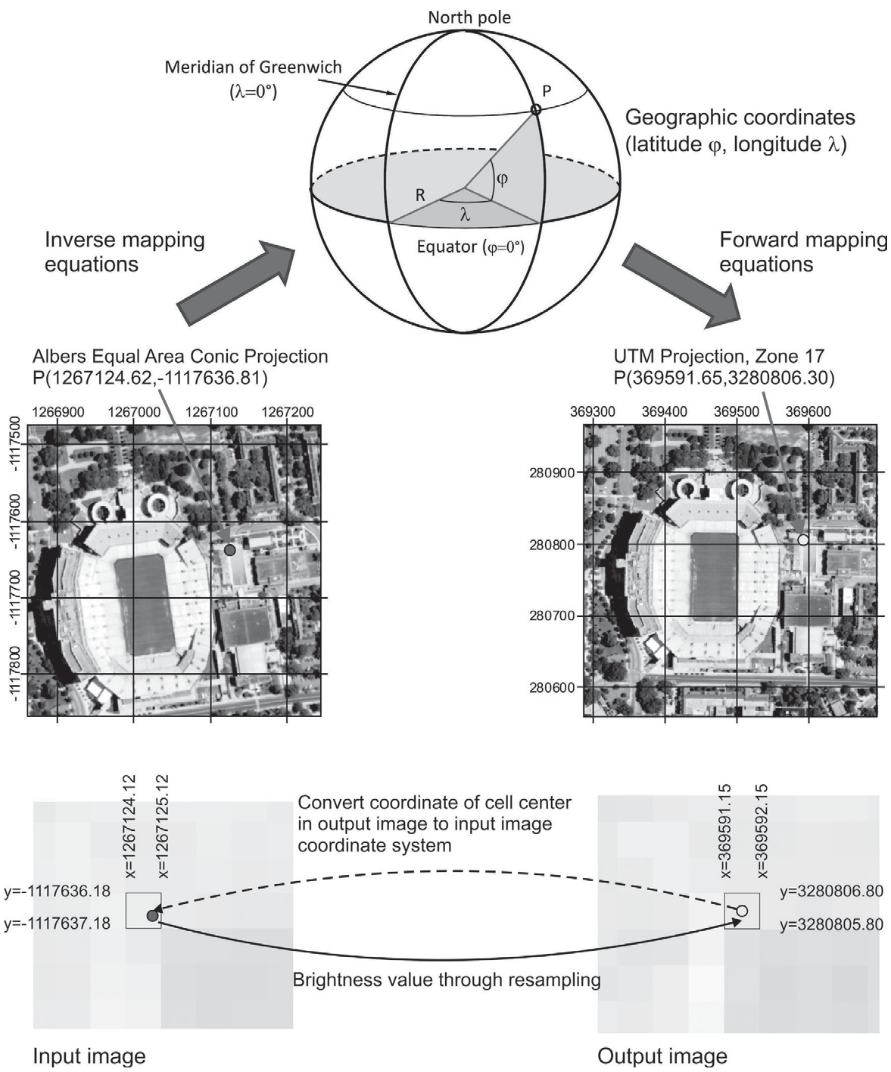

Figure 4: Re-projection of a 1-m resolution aerial image between Albers Equal Area Conic projection and UTM Projection (Zone 17) using geographic coordinates as an intermediate step. Resampling is used to fill pixel values in the output image through pixel values derived from the input image. Sources: (Hochmair *et al*, 2013).

GIS output maps with clear captions and varied groupings of colouring and patterns make it simple to visualize even with inexperienced GIS users to feel at ease (Paramasivam, 2019). With GIS we can produce maps to monitor termites hazard (Fig 5, 6 and 7) and tell where and why the populations are higher and lower in any through relating, comparing, analyzing the information more precisely via graphical representation in a map for better decision making approaches. The knowledge of GIS can also be applied in precision building technology construction together with remote sensing. GIS system helps in analyzing past records or databases with reference to the geographical maps by producing various models for building technology construction, and in entomology these technologies have great potential and offer many new opportunities and methods for studying and managing insect pests (Dminić *et al*., 2010).

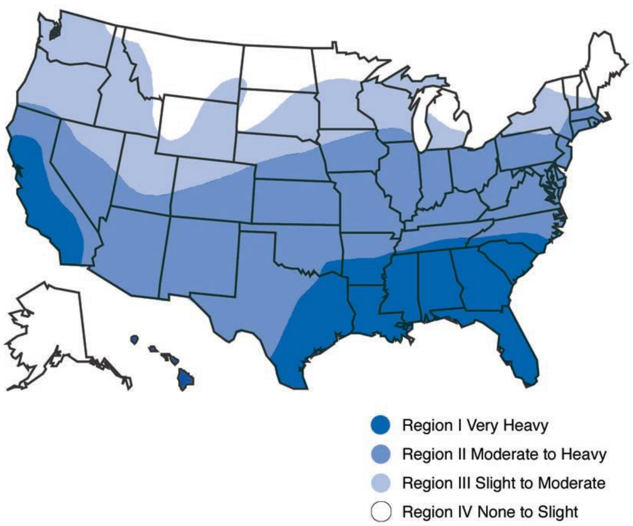

Figure 5 Relative hazard of subterranean termite infestations in the United States. *(*Source. Peterson *et al*., 2006*)*

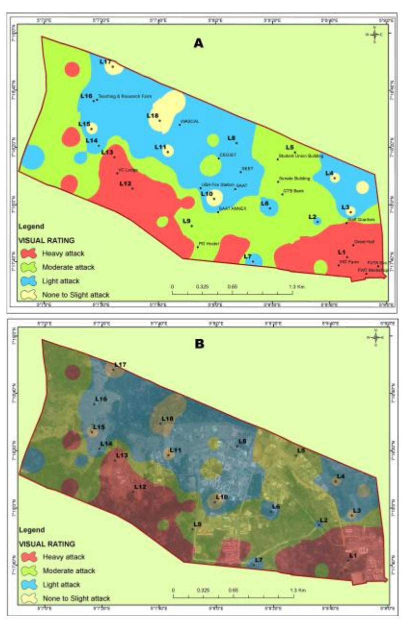

Figure 6**:** Termite severity probability map of FUTA campus area showing the severity of termite attack as determined by the averaged ASTM D3345-17 visual ratings of the 18 locations across the campus with key academic and administrative buildings that fall within the study area boundary. **B** Map showing extracted
Google earth images of the campus that fall within each severity class. Source *(*Owoyemi *et al,* 2021*)*

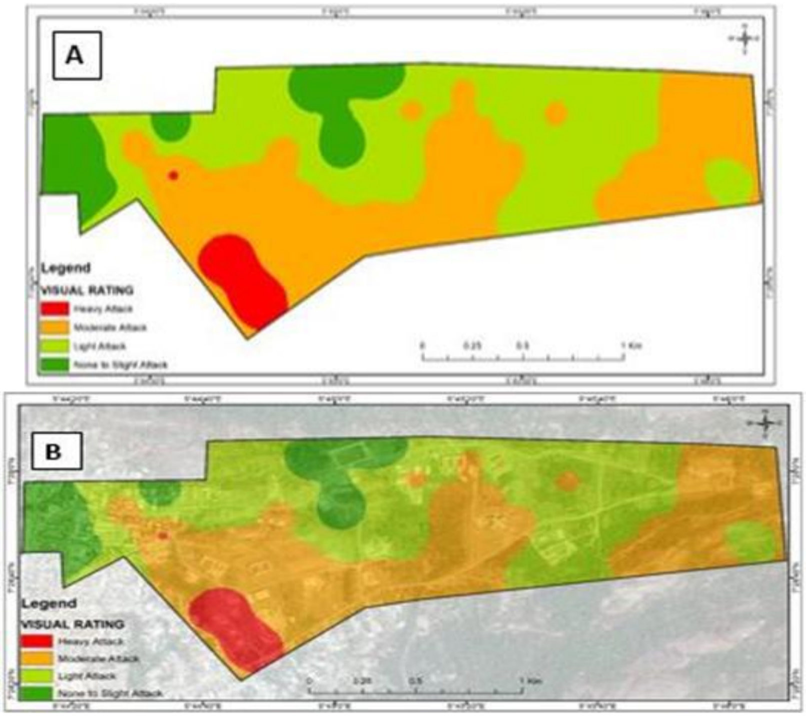

Figure 7: Termite Infestation Probability Map of AAUA campus; A: Map showing the termite severity on the campus-based on the visual ratings of the selected locations, B: Termite severity of the AAUA campus superimposed on the extracted Google earth imagery showing other known features that fall within the campus boundary.(Owoyemi *et al*, 2022)

Benefit of GIS in termites monitoring

GIS as a tools can create a data concepts to describe the real-world life systematically classifying features into a series of thematic layers. To produce layers, GIS can incorporate geo referenced data like termite's species and abundant, severity of it attack, soil type and climatic condition. Each layer can be evaluated independently or features between two or more layers can be analyzed together. Single kind of theme or data can compose a map layer and a complete database can combine themes representing similar areas. For the analysis of interaction between and within different themes GIS works as a tool. And without GIS, it would be impossible to manage and analyze these vast databases (Duarte et al., 2015, Saifatul et al, 2022). Also, GIS can be used to create and visualize dynamic simulation models. The simulation shows the evolution of the phenomenon of interest through time and may involve multiple sub processes. Dynamic modeling allows scientists to experiment with policy options and what-if scenarios. It also allows them to implement ideas about the behavior to the world (Longley et al. 2011, Hochmair *et al*, 2013).The ability to manage geospatial data has made GIS an important tool for a wide range of applications over the past decades, including management of natural resources, analysis of wildlife movement, ecological niche modeling, or land records management **(**Hochmair *et al*, 2013). Termite's probability maps produced with the aid of GIS serve as baseline data for builders, home owners and government on the destructive activities of termites. It serves as easy reference tool in guiding builders on the right constructional technology to employ during construction. Cost effectiveness is ensured as frequent replacement of wood in service is avoided and also contribute to the sustainable forest management.

Conclusion

The aggressive and destructive activities of termites to structures in recent time call for concerted effort in managing the activities of termites. Baseline information on the activities of termites in an area where a structure is to be constructed is required in planning before construction. Regular termites mapping of environment using GIS has therefore become a potent tool in planning and erecting building structures in built-environment.

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