

Ecological and Soil Quality Studies on Termite Fauna in and around Kalaburagi District, Karnataka, India

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Received November 14, 2022; Revised December 23, 2022; Accepted December 30, 2022

Abstract Termites are eusocial insects that live in colonies as workers, soldiers, and breeding castes that occur worldwide, mainly in the tropics, and act as decomposers of invertebrates, although they constitute a major only 3% of the species that live on it are pests that cause damage to agriculture, forestry, dwellings, and structures. In the present study we have recorded three species of termites in the study area; *Odontotermes obesus*, *Odontotermes longignathus* and *Odontotermes horni*. Out of the 3 species recorded the *Odontotermes obesus* and *Odontotermes longignathus* were both found in tree and mounds, except *Odontotermes horni* which was only found in mounds and was absent in the tree. The study was conducted in open areas of Gulbarga University, Kalaburagi and Swami Samarth math National Highway, Humnabad road. 4 sites were selected based on the diverse ecological conditions. The levels of pH, EC, Nitrogen, Phosphorous and Potassium in soil varied significantly in tree and mound habitats. Where the *O. longignathus* in tree had 6.43±0.14, 1.03±0.02, 249.9±1.85, 41.68±0.86, and 214.1±1.96 respectively. Whereas *O. longignathus* in mound had 6.22±0.17, 0.75±0.02, 287.1±3.21, 29.2±1.13 and 118.1±4.28 respectively. pH of all soil samples were towards neutral, EC also in normal range and In all the soil samples N is more followed by K and P (N>K>P). From the results it is clear that the soil sample of *O. Obesus* is more of fertile than that of other one species soil samples, *O. Longignathus*. These soil samples can be utilize to improve the fertility of agricultural land so as to increase the crop production and for sustainability of fertility for long time.

Keywords: termites, Kalaburagi, ecological studies, Gulbarga University

Cite This Article: Neelkanth Wali, D. Vishwajit, and V. Prashant, "Ecological and Soil Quality Studies on Termite Fauna in and around Kalaburagi District, Karnataka, India." *Applied Ecology and Environmental Sciences*, vol. 10, no. 12 (2022): 806-815. doi: 10.12691/aees-10-12-16.

1. Introduction

Termites are terrestrial social insects with highly organized polymorphic colonies. These colonies developed around a nest system with a division of labor between different castes. Nest systems range from a single nest on a single site to a distributed network of galleries and underground chambers [1]. Termites are widespread in tropical and subtropical regions near the equator, with some species in high latitudes. Some termite species have extended their range from temperate to cold regions [2,3,4,5]. Termites are important exterminators and help recycle trees and plants. Termites are one of the most prolific groups of insects, living in most places except Antarctica. Due to their unstable nature, colonies are hundreds of nests in size or dispersed by individual termites. The aim of the study is to investigate the ecological and soil quality aspects of termite fauna in and around the Kalaburagi district, Karnataka, India and objectives are to identify the termite species present in the

study area. To assess the distribution of termite species in tree and mound habitats. Evaluate the levels of pH, EC, nitrogen, phosphorous, and potassium in soil samples from tree and mound habitats. Compare the soil fertility status of different termite species. To suggest ways to utilize the soil samples to improve the fertility of agricultural land for sustainable crop production. The study aims to provide insights into the ecological and soil quality aspects of termite fauna in the study area, which can be used to develop strategies for sustainable land use and management.

1.1. Classification and Distribution

Termites have castes of sterile male and female "workers" and "soldiers," just like ants, some bees, and some wasps. There are one or more reproductive females called "queens" and at least one fertile male named "king" in every colony. Termites primarily consume cellulose and dead plant matter, which can be found in wood, leaf litter, soil, or animal faeces. Termites are eusocial insects that belong to the cockroach order Blattodea, epifamily

Termitoidea, or at the taxonomic rank of infraorder Isoptera. Termites and cockroaches were formerly placed in different orders, but current evolutionary analyses show that during the Jurassic or Triassic epoch, termites diverged from cockroaches to become their close ancestors. Nonetheless, it's possible that the earliest termites appeared in the Permian or even the Carboniferous. There are still a few hundred species to be described after the existing 3,106 species that have been described. Despite frequently being referred to as white ants, these insects are not actually ants.

The average termite queen lives up to 50 years, making them the insects with the longest life spans. Each individual termite goes through an imperfect metamorphosis that includes the egg, nymph, and adult stages, unlike ants, which go through a full metamorphosis. Because termites are a member of an organism that can regulate themselves, colonies are referred to as super organisms. Seven families of termites are recognized in the order Isoptera, according to [6,7], including the Termopsidae, Rhinotermitidae, Serritermitidae, Hodotermitidae, Mastotermitidae, Kalotermitidae, and Termitidae. Together, these seven families contain more than 2600 species of termites. Lower termites are the first six families combined. Higher termites are referred to as Termitidae members. The most diverse family is this one, representing a variety of social characteristics [2,8]. Termites highly developed social organization [9] is largely responsible for their ecological success and subsequent economic significance [11,12,13,14]. Termite colonies are made up of Castes, which are physically and functionally unique. There are three categories of people: soldiers, workers, and those who reproduce (males and queens). Other divisions of the reproductive include main reproductives, which are in charge of establishing new colonies, and secondary reproductives, which serve as replacement reproductives [15,16].

1.2. Diversity

Except for Antarctica, every continent has termites. Only 10 species and 50 species, respectively, of termite species are known from North America and Europe, whereas over 400 species are known from South America. Of the 3,000 termite species now recognized and categorized, 1,000 species are only found in Africa, where termite mounds are particularly prevalent in some areas. The Northern Kruger National Park alone is home to some 1.1 million active termite mounds. There are 435 different species of termites in Asia, the majority of which are found in China. Termite species in China are only found in mildly tropical and subtropical ecosystems, particularly those south of the Yangtze River. With approximately 360 species categorized, all ecological groupings of termites (damp wood, dry wood and subterranean) are native to Australia. Termites do not reside in cool or cold climates because of their delicate cuticles. Termites can be divided into three ecological groups: damp wood, dry wood, and underground. Dry wood termites are only found in hardwood forests, while damp wood termites only inhabit in coniferous forests. Subterranean termites inhabit a wide range of habitats.

1.3. Size

Termites are typically tiny, with lengths ranging from 4 to 15 millimeters (0.16 to 0.59 in). The queens of the species *Macrotermes bellicosus*, which may grow to a length of more than 10 cm (4 in), are the biggest termite species still in existence. *Gyatermes styriensis*, an extinct giant termite with a wingspan of 76 millimeters (3 in) and a body length of 25 millimeters, lived in Austria during the Miocene (0.98 in).

1.4. Termites Casting and Their Role

Castes of sterile, wingless laborers and soldiers (Wood and Lee, 1971). The workers are in charge of nest construction, foraging, caring for eggs, larvae, and royal pairings as well as maintaining the fungal garden. They are not sexually mature (in Macrotermitinae). Moreover, workers feed the reproductive pairs, soldiers, and larvae because they are unable to feed on them. [17]. Soldiers are in charge of colony defense and are distinguished by their distinctive head capsules. Although being unable to eat for themselves, their strong mandibles allow them to protect the colony from several predators. Many internal and external factors affect caste ratio. Soldiers are typically few in number, whereas workers make up the majority of castes. A few species of lower termites are the only actual workers. Although they are known as pseudogates, these people will be referred to as "workers" moving forward. Pseudogates are generally assumed to stay juvenile for their whole lifespan. When necessary, they can still differentiate by caste for troops or reproductives. Due to its volatile nature, the chemical message that causes those modifications is secreted by soldiers and/or reproductives and spreads throughout the nest, or it is dispersed by individual termite termites.

2. Materials and Methods

2.1. Study Area

Location: The Kalaburagi district is located between 170 12 and 170 46 North latitude and 760 40 and 770 42 East longitude in northern Karnataka. Geographically speaking, the district of Kalaburagi has an area of 10,951 sq. km. The typical height of Kalaburagi, which is located in the Deccan Plateau at 17.330 N and 76.830 E, is 450 meters above mean sea level. Climate: There are three distinct seasons in the Kalaburagi district. From late February to mid-June is considered summer. The southwest monsoon, which lasts from late June to late September, follows it. Dry winter weather lasts until mid-January after it. The following temperatures are typical for each season: summer (370-460°C), monsoon (250-370°C), and winter (120-320°C).

Site A: Gulbarga University Gate 1.

Site B: Gulbarga University main campus behind exam section.

Site C: Swami Samarth math National Highway 218, Humnabad Road.

Site D: Gulbarga University Back Gate kusnoor Road.

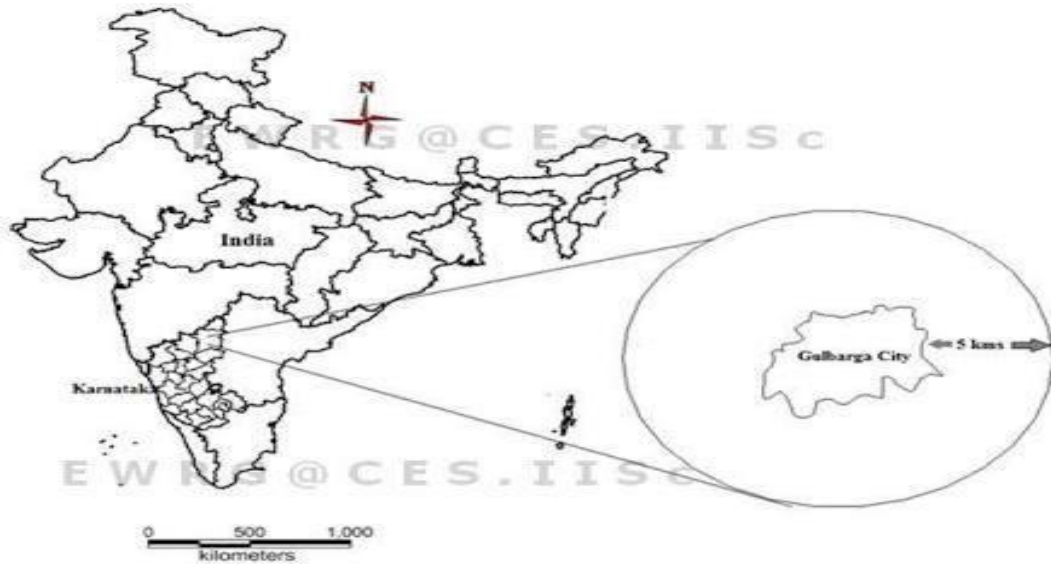


Figure 1. Study area

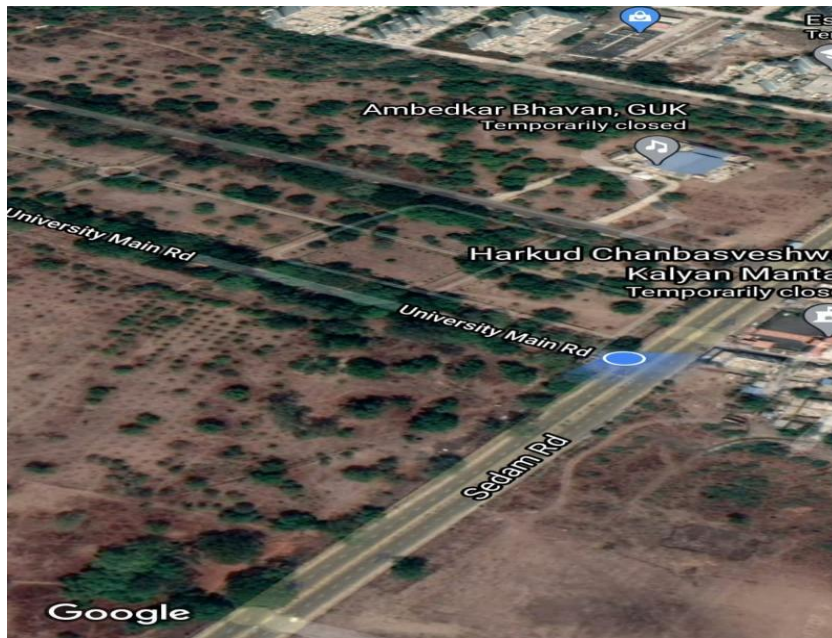


Figure 2. Gulbarga University Gate 1 (Site A)



Figure 3. Gulbarga University main campus behind exam section (Site B)



Figure 4. Swami Samarth math National Highway 218, Humnabad Rd. (SiteC)

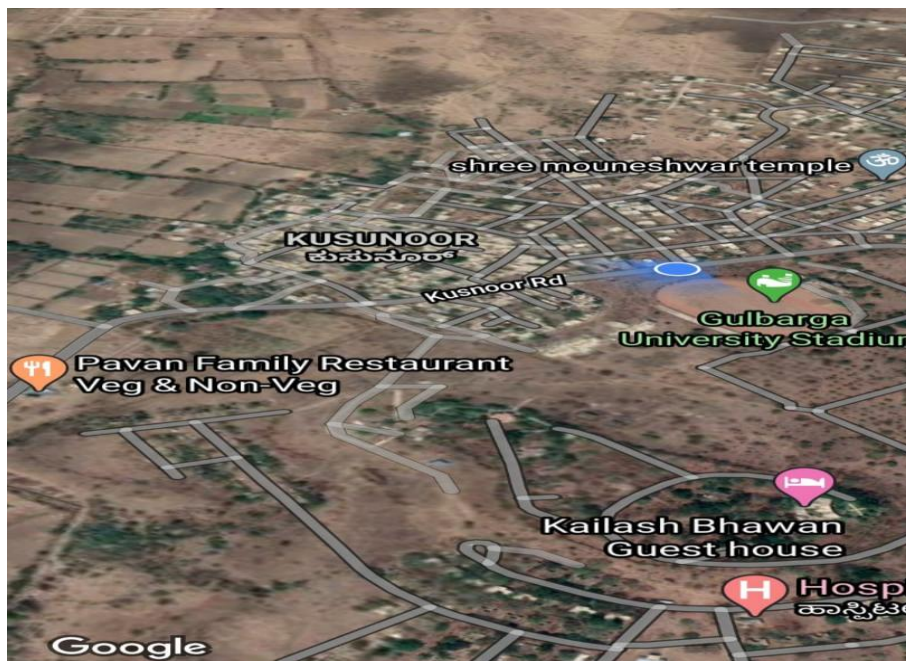


Figure 5. Gulbarga University Back Gate kusnoor Road (Site D)

2.2. Survey Work

The survey of termites was conducted in and around Kalaburagi.

The survey was carried out as per the standard insect collection method

- a) Transect method
- b) Quadrata method.

Three sites of Gulbarga University campus and few sites around Kalaburagi were marked and were surveyed from September/2019 to Feb/2020. Study areas were chosen keeping in mind, the variation in soil type. The termites were collected during morning and evening hours as they are active during this time. The termites were collected in the glass vials. Later preserved in the 80% alcohol and they photograph with the help of stereoscope microscope.

2.3. Quadrata Method

From a broad area with an insect population, a tiny area of quadrates will be randomly selected (Quadrata 5X5m). Estimates of the quadrata's extent in relation to the surrounding area are made, and the quadrata's precise insect population is also known. Insects can be readily counted or collected, and their numbers can be directly correlated with field populations. The accuracy of estimations derived from this method depends on how representative the quadrates or the entire population are, as well as how precisely the numbers are counted.

2.4. Line Transect Method

In order to count the number of individuals encountered, this method involves a person moving through a habitat in

a straight line at a constant speed. This encounter-based data can be used to estimate the absolute population. The pace of the person affects the amount of encounters, the population under study's density, the distance over which they can be seen in advance, and the population's speed.

2.5. Chemical Analysis of Termite Soil

Chemical analysis of termite soil sample was done in the Department of Soil Science and Agricultural Chemistry, Agriculture College, Raneppeer road near Aland check post Kalaburagi. The physico- chemical analysis was done with respect to pH, EC and NPK so as to correlate with of the soil fertility.

2.6. Identification

The termites were identified by examining their physical attributes, including the external shape of their mounds and the arrangement of their body parts, such as their head, eyes, antennae, thorax, abdomen, and wings. This identification method was qualitative, meaning that it relied on observations rather than precise measurements or numerical data. To verify the identification, experts consulted specialized books on termites, including titles such as "A Guide to Termites and Other Wood-destroying Pests" by Michael Rust, "Termite Biology and Control" by Paul Eggleton, and "The Termites of the United States: A Handbook" by Thomas Snyder and Richard Canello. These books contain detailed information about termite physical characteristics and behavior, which were useful in identifying the specimens.

3. Results

Total of 3 species were identified in the study area;

1. *Odontotermes obesus* (Rambur)

Classification:
Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Isoptera
Family: Termitidea
Genus: *Odontotermes*
Species: *O.obesus*



Figure 6. *O.obesus* (Soldier)



Figure 7. *O.obesus* (Worker)

2. *Odontotermes longignathus* (Holmgren)

Classification:
Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Isoptera
Family: Termitidea
Genus: *Odontotermes*
Species: *O longignathus*



Figure 8. *O.longignathus* (Soldier)



Figure 9. *O.longignathus* (Worker)

3. *Odontotermes horni* [Wasmann]

Classification:
 Kingdom: Animalia
 Phylum: Arthropoda
 Class: Insecta
 Order: Isoptera
 Family: Termitidae
 Genus: *Odontotermes*
 Species: *O.horni*



Figure 10. *O.horni* (Soldier)



Figure 11. *O.horni* (Worker)

Figure 12 provides a visual representation of the distribution of various species in the study area. It presents a clear picture of the abundance and diversity of species in the region. The graph also displays the values for three particular species: *Odontotermes obesus*, *Odontotermes longignathus*, and *Odontotermes horni*. This information is particularly useful for further research and conservationists who are interested in studying the ecology of the area and monitoring changes in the

populations of these species over time. By analyzing the data presented in this graph. We can better understand the dynamics of the ecosystem and make informed decisions about conservation efforts.

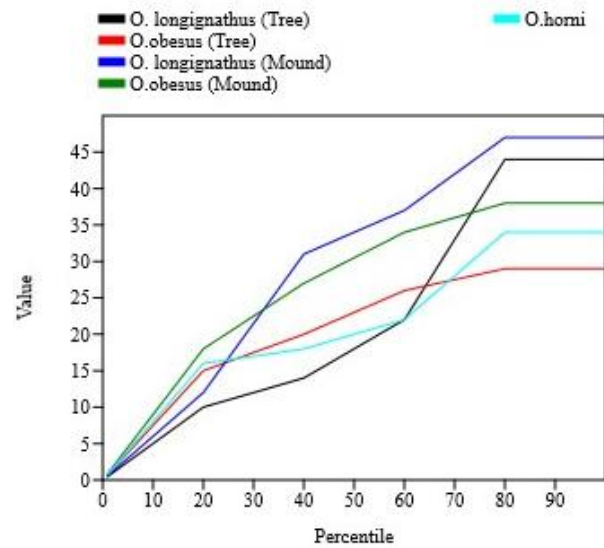


Figure 12. Percentage plot of the species

A total of 182 species of termites were discovered across four different sampling sites. Three of these species were identified as *Odontotermes obesus*, *Odontotermes longignathus*, and *Odontotermes horni*. *Odontotermes* was the most common species found in the sampled areas. All four of the sampling sites had three species present in high numbers. The most common termite families found in the Kalaburagi area were *O. longignathus* (Tree), which made up 32% of the population, *O. longignathus* (Mound), which only made up 9%, *O. obesus* (Tree) at 19%, *O. obesus* (Mound) at 24%, and *O. horni* at approximately 16%. The dominant species found was *O. longignathus*, which covered 32% of the area, while the least dominant species was *O. longignathus* (mound), which only covered 9%.

Assessment of Environmental Variables

Environmental variables such as forest type, soil texture, and drainage conditions were recorded at each of the sampling sites. Physico-chemical analysis of the soil samples collected from sites where different termite species were found was conducted. The soil samples were analyzed for pH, Electric conductivity (EC), Nitrogen (N), Phosphorus (P), and Potassium (K) [18]. Table 1, presents the results, which indicate a significant difference in soil characteristics among the different termite species. The pH of all the soil samples was found to be between 6.01-6.43, which is considered neutral. The highest pH value (6.43) was recorded in *O. obesus* (tree) soil samples, while the lowest (6.40) was found in *O. longignathus* (mound) samples. Electric conductivity ranged between 0.79-1.23 with respect to the availability of macroplant nutrients NPK/Kg/ha, with the highest value (1.23) recorded in *O. obesus* (mound) samples and the lowest (0.79) in *O. longignathus* (mound) samples. Overall, *O. obesus* had higher pH and electric conductivity values compared to *O. longignathus*. Nitrogen content was found to be highest (Kg/ha) in all the soil samples, followed by potassium, while phosphorus content was the least in all soil samples (N > P > K).

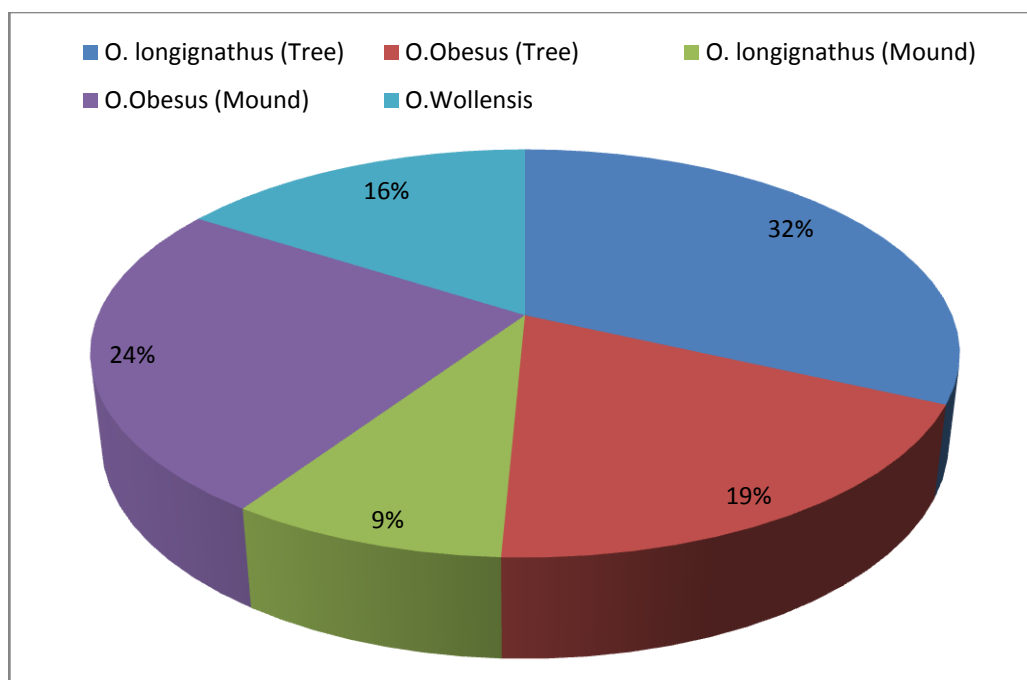


Figure 13. Percentage of species distribution

Table 1. Physico-chemical analysis of different soil samples collected from sites of different termite species

Soil Sample	pH	EC	N (Kg/ha)	P (Kg/ha)	K (Kg/ha)
<i>O.longignathus</i> [Tree]	6.43±0.14	1.03±0.02	249.9±1.852	41.68±0.86	214.1±1.96
<i>O.longignathus</i> [Mound]	6.22±0.17	0.75±0.02	287.1±3.212	29.2±1.13	118.1±4.28
<i>O.obesus</i> [Tree]	6.41±0.24	1.12±0.05	302.2±1.873	38.82±0.77	236±1.42
<i>O.obesus</i> [Mound]	6.2±0.15	1.21±0.13	253.3±6.32	44.42±1.53	142.4±1.42
<i>O.horni</i>	6.02±0.14	1.25±0.10	250±1.765	32.44±1.20	121±2.30

Table 2. Elemental analysis of the different soil sample

Soil sample	Magnesium Conc. mg/L	Potassium Conc. mg/L	Manganese Conc. mg/L
Red soil	4.134	8.772	23.939
Black soil	4.173	8.427	23.939
Grey soil	4.202	8.768	23.939

Different termite species exhibit preferences for certain types of soils. For example, some species may prefer sandy soils, while others may prefer clay soils. Soil texture can also affect soil moisture and nutrient availability, which can influence termite activity and mound construction [19]. Elemental analysis of different soil types can provide insights into the distribution and abundance of termite species in different habitats, as well as their potential impact on soil properties and nutrient cycling. This information can be useful for ecosystem management and understanding the role of termites in soil processes. Additionally, studying the relationship between termites and soil can help in identifying potential agricultural or environmental applications, such as using termites to improve soil fertility or managing termite damage in crops.

Studying the levels of magnesium in soil is significant when examining termite mounds as magnesium is an essential nutrient for termite survival and development. Magnesium is vital for termites as it is involved in several physiological processes including enzyme activation, energy metabolism, and neuromuscular function. Termites

obtain magnesium from the soil via feeding or tunneling activities, and they may also accumulate magnesium in their mounds. [20] Analyzing the magnesium levels in soil can, therefore, provide valuable information on the nutritional needs of termites and their impact on soil properties. It can also aid in understanding the distribution of termites in different environments and their interactions with other soil organisms. Furthermore, the presence or absence of magnesium in termite mounds can impact the physical and chemical characteristics of soil, influencing plant growth, and having implications for agricultural practices and ecosystem management. (Figure 14) showing the highest amount of manganese in grey soil in the study area.

Soil elemental analysis of potassium is an important aspect of studying termite mounds. This is because potassium plays a vital role in the physiological processes of termites, including enzyme activation, osmoregulation, and water balance. Termites obtain potassium from the soil through feeding or tunneling activities and can accumulate it in their mounds. [21]. Soil elemental analysis of potassium can provide insights into the

nutrient ecology of termites and their impact on soil properties. Furthermore, potassium is an essential nutrient for plant growth, and its availability in soil can affect agricultural productivity and ecosystem health. Hence,

studying the distribution of potassium in termite mounds can have implications for agriculture and ecosystem management. (Figure 15) Showing the Potassium levels are higher in grey and red soil in the study area.

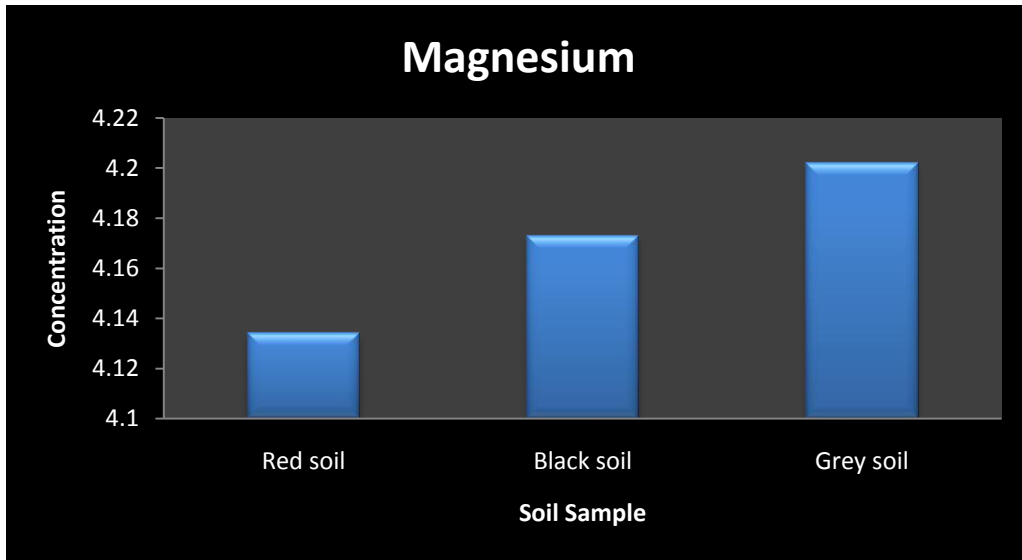


Figure 14. Graph showing elemental analysis of Magnesium

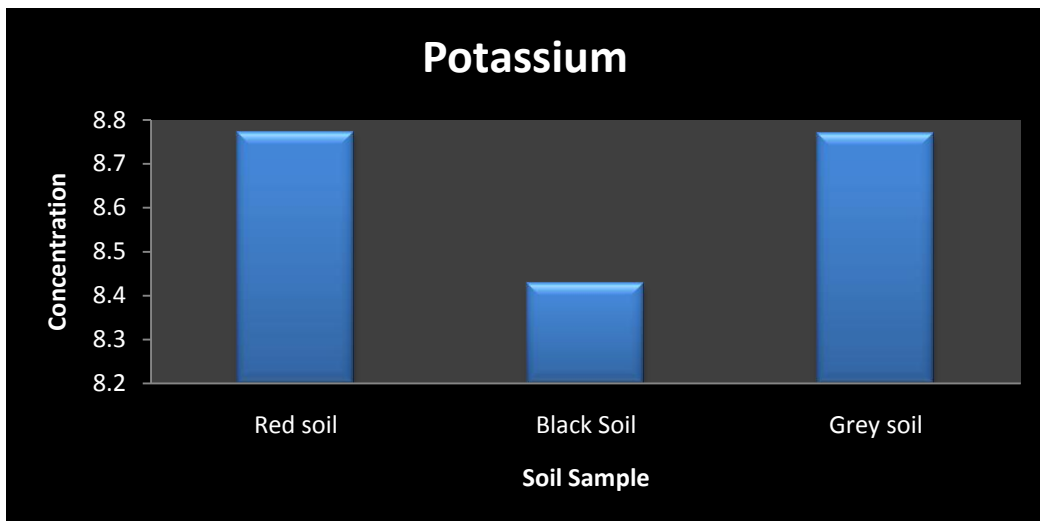


Figure 15. Graph showing elemental analysis of Potassium

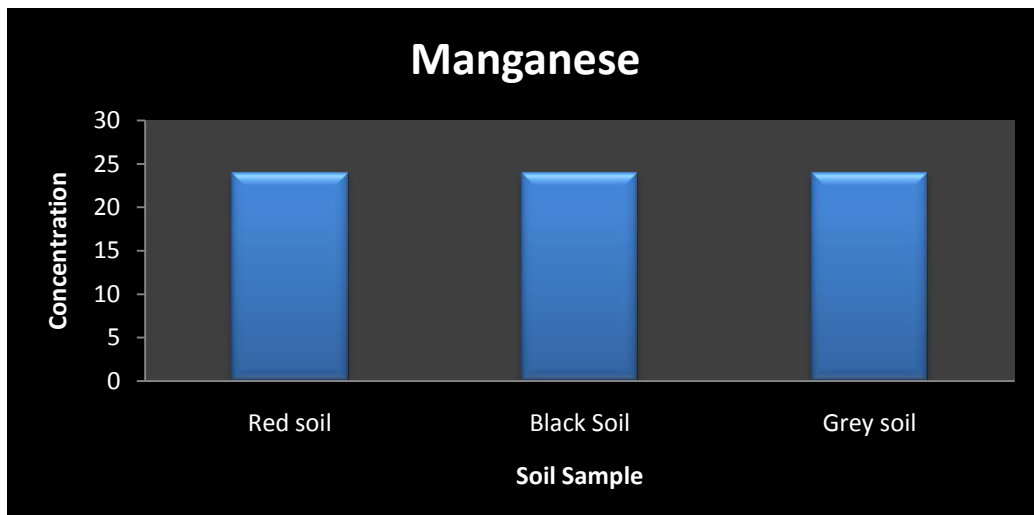


Figure 16. Graph showing elemental analysis of Manganese

Manganese is a vital micronutrient for termite growth and development. [22]. It plays a crucial role in various physiological processes, such as enzyme activation, photosynthesis, and antioxidant defense, among others. Termites obtain manganese from the soil, and they may accumulate it in their mounds, which can affect the soil's nutrient cycling and availability. By analyzing the manganese content in termite mounds and surrounding soil, researchers can gain insights into the nutritional ecology of termites and their interactions with soil microorganisms. Moreover, manganese deficiency or toxicity in the soil can impact plant growth and ecosystem functioning, making the study of this micronutrient crucial for agricultural and environmental management. (Figure 16) Showing the manganese levels in grey, red and black soil are almost same in the study area.

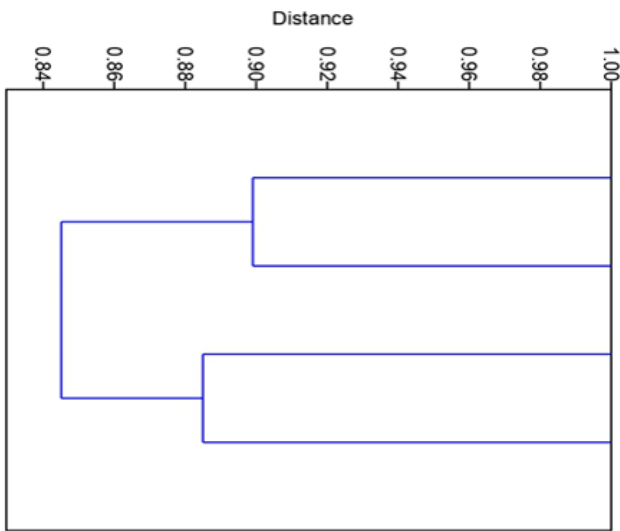


Figure 17. Dendrogram showing similarities and differences of termite fauna

The research conducted by [23] employed cluster analysis to evaluate the relative similarity between termite species at each site. The outcome identified two groups of species, as illustrated in Figure 17. The first group comprised species located at site A, while the second group encompassed species from site C, along with two species (*Odontotermes Obesus* and *Odontotermes Longignathus*) found in both areas. Site A had two species in common with each of the other reserves (Figure 17). The dendrogram, utilizing the average linkage method and Euclidean distance, depicted the similarities and

differences of the termite fauna across the study area. These findings provide valuable insights into the distribution and diversity of termites in the region.

During the sampling process, only two species of termites that feed on wood were found. *O. Longignathus* (tree) and *O. Obesus* (tree) were discovered at Site A. The nests of *O. Obesus* were located on the roots and leaves of decomposing and woody matter in the middle of an open area at Site D. *O. Longignathus* (mound) was found on decaying wood and dry dung close to an old enclosure at Site C. At the center of the decomposing wood in Site D, *O. Obesus* (mound) was discovered in epigeal nests, with feeding habits that included litter, roots, and woods of germinous. *O. Wollensis* was observed mainly feeding on litter and was located around the hypogeal sector of mounds at Site B. *O. Obesus* (tree) was found to feed on decomposed woody material and was collected from the wood at Site D. *O. Longignathus* (mound) was collected near the roots of a fallen tree, feeding on dry dung and decaying wood at Site C. *O. Longignathus* (mound) was discovered under dead branches, with feeding habits that included litter, roots, and leaves of germinous and wood at Site D. The proportions of different feeding groups were recorded in the termite fauna of Site A, B, C, and D.

4. Discussion

The apparent disagreement across the research is likely brought about by variations in sampling techniques and locales. Yet, the findings of this study highlight the significance of ecological research in the Kalaburagi region. The study provides significant insights into the diversity and distribution of termite fauna in Kalaburagi, India. The finding that *Odontotermes* is the most common family is consistent with previous studies. However, the dominance of *O. longignathus* is a new observation that requires further investigation. The differences in soil characteristics among the different termite species highlight the ecological importance of termites in maintaining soil quality. The findings of the study may also be useful in identifying potential biomarkers for soil quality in Kalaburagi, India. The identification of feeding habits and nesting preferences of different termite species provides a deeper understanding of their ecological roles in the study area. Overall, the study highlights the importance of understanding the diversity and ecological roles of termites in maintaining ecosystem services.

Table 3. Termite species inhabiting Sampling sites (A) (B) (C) and (D), with data about collection sites and feeding habits

Family-Termitidae	Collection sites	Feeding habits	Location
Subfamily-Odontotermes			
<i>O. Longignathus</i> (Tree)	Dead branches	Wood	Site A
<i>O. Obesus</i> (Tree)	Galleries on dead trees	Decomposed woody material	Site B
<i>O. Longignathus</i> (Mound)	Mound	Dry dung, decaying wood	Site C
<i>O. Obesus</i> (Mound)	Epigeal nests	Litter, roots and leaves of germinous, wood	Site D
<i>O. Wollensis</i>	hypogeal sector of mounds	Litter	Site B
<i>O. Obesus</i> (Tree)	Decomposed woody material	wood	Site A
<i>O. Obesus</i> (Tree)	wood	Decomposed woody material	Site D
<i>O. Longignathus</i> (Mound)	Roots of fallen tree	Dry dung, decaying wood	Site C
<i>O. Longignathus</i> (Mound)	Under Dead branches	Litter, roots and leaves of germinous, wood	Site A
<i>O. Obesus</i> (Mound)	Epigeal nests	Litter, roots and leaves of germinous, wood	Site D

5. Conclusion

The present study recorded 182 species of termites across four different sampling sites, with *Odontotermes* being the most common species found. The dominant termite families found in the Kalaburagi area were *O.longignathus* (Tree) and *O.obesus* (Mound), with *O.longignathus* covering 32% of the area. Soil analysis revealed a significant difference in soil characteristics among the different termite species, with *O.obesus* having higher pH and electric conductivity values compared to *O.longignathus*. Two groups of species were identified through cluster analysis of the relative similarity between termite species at each site. Only two species of termites that feed on wood were found during the sampling process. Overall, this study provides valuable insights into the termite fauna of the Kalaburagi area and their ecological roles.

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