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Termite biology in urban areas of Central Punjab Pakistan

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Abstract
The current study is designed to explore the biology, distribution behavior and impacts of termite in urban areas located at Central Punjab, Pakistan. This research includes termite species identification, their behavioral ecology and impacts on urban infrastructure. It further reviews the existing termite management options and discusses urban planning, as well as termite activity relative to climatic changes. This research focused on four primary species of termites i.e. Odontotermes obesus, Microtermes obesi and Coptotermeis heimi that exhibit different distributional patterns as well as behavioral aspects. Extensive damage to existing infrastructure, largely in older housing and commercial buildings due to termites alone requires a more holistic approach than the reactive nature of current pest management. This study emphasizes the need of locally informed management strategies for optimal control and prevention in rapidly urbanizing landscapes like Central Punjab.

Keywords:
Termite, Pest management

Introduction

Termites are one of the most important insect pests, both ecologically and economically worldwide due to their ability of decomposing cellulose-rich parts (Kalleshwaraswamy et al., 2022). Their role in the natural ecosystem of decomposition, breaking down organic matter and recycling nutrients is also beneficial but their impact on urban environments is almost purely negative. Dubbed “silent destroyers,” these pests can invade virtually all types of wood structures, weakening the construction and costing property owners $5 billion in prevention and repair annually. Such a problem is magnified in quickly urbanizing areas, such as Central Punjab, Pakistan where termite infestations have become more common and are both problematic to homeowners and commercial building owners (Hassan et al., 2024).

Termites target urban areas mostly as the surroundings in this case is based on close human settlements and has a wide range of buildings which can be good hosting structures for these creatures. The construction of buildings, roads and other infrastructure disrupts the soil allowing new pests an environment in which they establish termite hills (Sichilima et al., 2018). Urban settings are a virtual smorgasbord to Subterranean termites which feed on wood including beams, flooring, furniture and even paper goods. Moreover, anthropogenic environmental conditions like artificial heating or water leaks can provide benefits for termite survival and reproduction, thus serving to increase populations in such areas as well (Chellappan et al., 2021).

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As one of the most urbanized area in Pakistan, Central Punjab is seeing a surprising increase in losses caused by termites. Major urban centers such as Lahore, Faisalabad, Multan, Gujranwala and Sargodha are witnessing enormous damage to properties due to termites. Although the threat of termites is continually growing in these urban areas but scientific literature regarding to ecology (Santos et al., 2020), behavior and management practices for termite species inhabiting Pakistan are scarce. However, studies are mostly related to agricultural pests or termites in rural areas and our knowledge on termite biology remains incomplete for urban environment.

The Importance of Termite Research in Urban Areas

The complexity of human-altered environments represents unique problems to managing an urban termite infestation (Darlington et al., 2021). In cities, however termites attack homes and other buildings built by humans rather than trees or such vegetation as in rural areas. And, this has major economic consequences since termite damage is typically not recognized until it results in substantial structural decay. We all know how big problem termites are in cities, the same goes for Pakistan where we have most of our population living in urban zones and this figure adds another layer to it. Homeowners and businesses shell out millions of rupees every year due to repairs resulted from termite infestations.

Understanding of termite biology in urban settings is crucial to the implementation and control strategies. For example, various termite species may have different behaviors and preferences for living in urban areas (Pervez et al., 2018). For example, certain species tend to nest in subterranean cervices near building foundations whereas others may develop nests within wooden structures. Of course, these variations in behavior make accurate termite identification essential because different species favor their own particular ecological requirements.

Global Context of Termite Infestations in Urban Areas

Termites are pests for urban communities worldwide, especially in tropical and subtropical regions due to the favorable environmental conditions all year round. Termite infestations cost billions of dollars in damage every year and are reported all over the world, especially metropolitan areas (Kalleshwaraswamy et al., 2022). The extensive effect and mechanisms of tracking quantifying urban termite control have been well-documented in some regions such as Southeast Asia, Africa and southern United States with different pest management programs to manage the menace.

In these areas termite control involves a mixture of chemicals treatments, baiting systems and preventative steps. Studies have shown that traditional chemical treatments are not as suitable for termites control, while Integrated Pest Management (IPM) approaches is a right way to manage them by using multiple controlling methods (Karlsson Green et al., 2020). Nevertheless, these methods need a deepened knowledge about the species at stake and its behavior in relation to the environment where their activity is detected.

Termites in Pakistan: A Growing Threat

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Termites are major pests in all countries. They attack the fungus and result in more serious problems, especially where there is a higher population density and rapid urban development as it occurs notably among high rises mainly in Punjab province of Pakistan. Historically, the construction sector sees a rise in termite presence and what is also seen around central Punjab including towns of Lahore Faisalabad Sialkot etc. Appalachia a hot and humid climate in the region coupled with residential construction using wood-based products has created prime real estate for termites.
Major pests of Buildings and Infrastructure; The main termite species in Pakistan are Coptotermes heimi, Odontotermes obesus, Heterotermes indicola & Microtermeso besus (Afzal et al., 2021). Although termites represent a significant threat to human settlement, research in Pakistan is mostly restricted within the frame of agricultural implications and have ignored their behavior specifically occurred in urban ecosystem. This knowledge void hampers the design of appropriate termite control measures, especially in urban areas where termites can hide their presence for until they have caused sufficient damage.

Need for Research in Central Punjab

Urban areas in Central Punjab are expanding rapidly and face increasing threat from termites, hence there is an immediate requirement to undertake research focusing on the study of termite biology specific to urban locales(Khan et al., 2020). Knowledge about the termite species in urban habitats, their behavior and ecology as well as the environmental factors that affect their activity can be useful when trying to obtain a more efficient pest management.
The activity of termites in urban settings may depend on some factors like temperature, humidity and presence of organic item supply along with the type of construction material used & flooring done during laying. There are two hypotheses related to them: Those factors can be far different in rural settings, where most prior studies have taken place. For example, pest management practices that work well in rural areas may fail completely when employed in urban settings.
Wood is a major component of urban infrastructure in Central Punjab, which also makes it vulnerable to termite infestation. New buildings during this period have steel and concrete, but many times wood for structural or ornamental parts that are the least resistant to harm from different agents of disintegration. The economic cost of damages caused by termites in these regions is immeasurable and affects both homeowners to business enterprises who are not well equipped with efficient pest control facilities.

Methodology

The present study is aimed at the detection of termite species, their distribution and incidence in urban areas in Central Punjab (Pakistan), behavioral characteristics involved on site influence to infrastructure as well as strategies for pest management. This methodology was based on field sampling, survey and interview data to have a complete understanding of the termite populations and their impacts in such urban areas.

Study Area

The study was carried out in five major urban centers of Central Punjab, Pakistan

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comprising: Lahore (urban district), Faisalabad, Multan (each from a tehsil city and Kasuria village; distance between the two sites approximately 5 km within each agroecological domain), Gujranwala and Sargodha. The cities were selected for their unique urban environments, relative levels of infrastructure development and disparities between the severity in termite infestation reports from local pest control agencies. Because being big cities, Lahore and Faisalabad are home in a wide range of construction types & materials whereas Multan, Gujranwala and Sargodha offer an array from old to the new structures (thus providing us opportunity to study termite activity under different urban environments).

Species Identification and Distribution

Termites were collected from different locations (residential, industrial parks and commercial buildings) to help understand species composition and distribution between the cities, which was conducted by placing stakes in various sites in the cities. Methods used to sample aimed at covering species comprehensively with the following approaches:

Bait Stations: Bait stations were configured in locations of significant termite activity, like close to wooden structures, gardens and soil beds. Live termite colonies were collected by inspecting baits at three months intervals.

Manual collection (direct hand-picking method): Manually harvesting termites present in the exposed colonies including decaying wood, cracks on walls or soil mounds. It also proved useful for collecting specimens from secluded or difficult to access sites.

Sample Collection of Wood: Specimens from wood including beams, doors window frames that were infested with termites collected became the sample for study. Through proper care, these samples were transported to laboratory for further analysis.

Specimens were identified to a species level through two steps:

Morphological identification: The specimens were primarily identified by body size, coloration and mandible shape wing bud to the species-level based on the standard literature of taxonomic keys.

Molecular Methods: Barcoding was used to confirm species identity. In order to do this, we first had to perform DNA extractions on the samples collected in individual collections and PCR amplification of specific genetic markers. Subsequent sequences were matched to a reference database for species identification.

Behavioral Ecology

The research included the foraging behavior, nesting habits and reproduction cycle of termite species found in association with industrial sites. Direct fieldwork plus technology-assisted methods resulted in 89 observations.

Time-lapse cameras: Cameras were placed in areas containing termite galleries and nests to record the foraging activity of termites as well as colony behavior over time. Live cameras allowed observation of movement patterns and diurnal activity cycles.

Direct Observations: Researchers frequently visited the field to observe nesting ecology, swarming and interspecific interactions in selected sites.

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We collected data on termite activity over a six-month period, from the beginning of summer through to late-winter as it is possible that seasonal changes affect reconstruction behavior. Our capacity to conduct long-term observations was key because it took time for us to gain the process of how such environmental factors like temperature and humidity really affect their behaviors.

Point of View on Urban Infrastructure

Prior to the study, a survey was undertaken in urban areas for termite damage along with local construction companies, municipal authorities and building managers. The study was carried out in termite infested location of residential buildings, commercial properties and public infrastructure such as bridge culverts parks and wooden structure. The methods used to measure damage were the following:

Repairs: we collected data on repair costs resulting from the termite damage reported by property owners, contractors and municipal authorities.

Structure Evaluation: The structure assessments were conducted by evaluating termite presence in the buildings to assess damage Related post.

Photos of termite infested areas and damage were taken to document the level of each infestation.

Pest Management Strategies

A qualitative study was carried out by conducting semi-structured interviews with pest control professionals and urban planners to examine the existing strategies of pest management. We asked them about a number of things, including:

Chemical Control Methods: Administration of liquid termiticides, bait systems and fumigation techniques.

Biological control methods: Utilizing predators in the environment (whether predatory worms, or fungi) as another form of pest management.

Prophylactic Mastics: Building practices, materials and methods used to prevent termite infestations.

The success of these approaches was evaluated according to professional feedback and available records from pest control agencies and

Smart Cities Urban Planning and Proactive Actions

The study also analyzed urban planning documents and policies to determine what existing measures target termite invasions. The following measures were implemented and evaluated using field observations and municipal pest control records:

Construct termite-resistant: using of treated wood, concrete and other resistant material in construction.

Techniques used during construction Predesign soil treatments and use of physical barriers to prevent termites from entering the structure.

Seasonal and Temporal Occurrence Patterns

Weather data was obtained from local weather stations to evaluate the impact of climatic variables on termite activity. We collected data on temperature, humidity and rainfall during the study period. The correlation between this climatic varied and the presence of termite infestations was tested by specific

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software for statistics to understand how seasonality might have environmental variations, impact on behavior and distribution of termites.
This multi-dimensional study portrayed a holistic image of urban termite biology which might be valuable as the effective pest control and preventive measures in Central Punjab, Pakistan may depend upon this knowledge.

Results

The understanding of termite biology, distribution, behavior, and their impact on urban infrastructure in Central Punjab, Pakistan. This chapter presents the findings in six sections: species identification and distribution, behavioral ecology, impact on urban infrastructure, pest management strategies, urban planning and preventive measures, and seasonal & climatic variations.

Species Identification and Distribution

The study identified four major termite species across the five urban centers: *Odontotermes obesus*, *Heterotermes indicola*, *Microtermes obesi*, and *Coptotermes heimi*. The distribution of these species varied significantly across the different cities.

City	Odontotermes obesus	Heterotermes indicola	Microtermes obesi	Coptotermes heimi
Lahore	45%	15%	10%	30%
Faisalabad	50%	20%	5%	25%
Multan	20%	25%	15%	40%
Gujranwala	35%	30%	20%	15%
Sargodha	30%	35%	25%	10%

- **Odontotermes obesus** was the most prevalent species in Lahore and Faisalabad, representing 45% and 50% of the total termite population, respectively.
- **Heterotermes indicola** was more widely distributed in Gujranwala and Sargodha, comprising 30% and 35% of the populations, respectively.
- **Coptotermes heimi** was predominantly found in Multan (40%) and was also present in Lahore (30%) and Faisalabad (25%).
- **Microtermes obesi** was less common across all cities but was found in higher concentrations in Gujranwala (20%) and Sargodha (25%).

Behavioral Ecology

The study observed distinct behavioral patterns for each termite species, including their foraging behavior, nesting patterns, and reproductive cycles. The data collected over the six-month period is summarized in Table 2.

Species	Foraging Activity (hrs/day)	Nesting Depth (m)	Reproductive Swarming (Events/Season)
Odontotermes obesus	8	1-2	5
Heterotermes indicola	10	0.5-1	7

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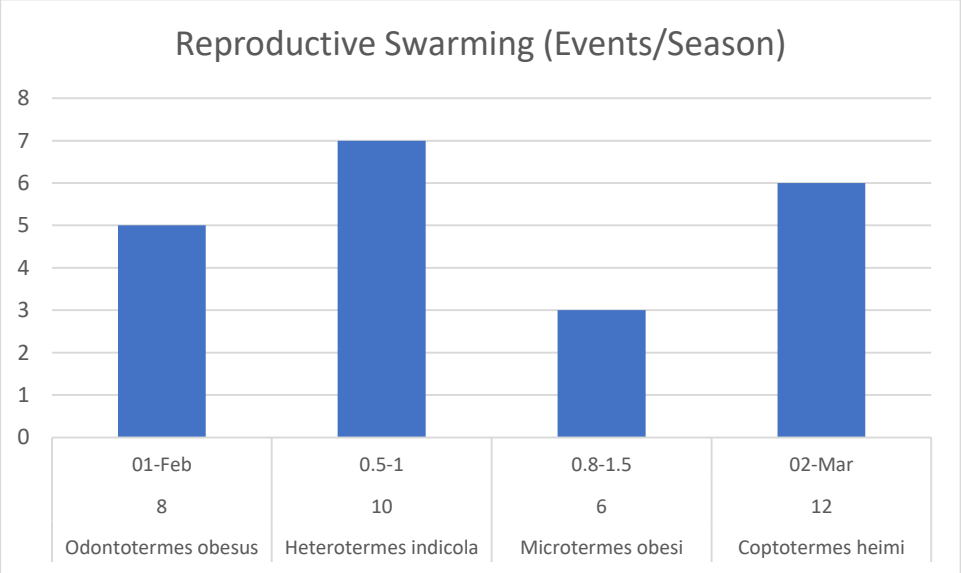
Species	Foraging Activity (hrs/day)	Nesting Depth (m)	Reproductive Swarming (Events/Season)
Microtermes obesi	6	0.8-1.5	3
Coptotermes heimi	12	2-3	6



Odontotermes obesus exhibited moderate foraging activity (8 hours/day) and nested at depths of 1-2 meters. The species showed a moderate number of reproductive swarming events (5 per season).

- **Heterotermes indicola** had the highest foraging activity (10 hours/day) with shallow nests (0.5-1 meter) and frequent swarming events (7 per season).
- **Microtermes obesi** displayed the least foraging activity (6 hours/day) and nested at intermediate depths (0.8-1.5 meters) with fewer swarming events (3 per season).
- **Coptotermes heimi** showed the most extensive foraging activity (12 hours/day) and the deepest nesting patterns (2-3 meters) with a relatively high number of swarming events (6 per season).

Impact on Urban Infrastructure

The survey data revealed significant variations in termite damage across the five urban centers, with older residential buildings being the most affected. The cost of damage and the extent of structural damage in each city are summarized in Table 3.

City	Average Cost of Damage (PKR million/year)	Percentage of Affected Structures	Most Affected Type of Structure
Lahore	150	40%	Residential buildings

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City	Average Cost of Damage (PKR million/year)	Percentage of Affected Structures	Most Affected Type of Structure
Faisalabad	130	35%	Commercial properties
Multan	80	30%	Public infrastructure
Gujranwala	90	25%	Residential buildings
Sargodha	50	20%	Parks and recreational areas

- In Lahore, the average cost of termite damage was the highest, at PKR 150 million per year, affecting 40% of structures, particularly residential buildings.
- Faisalabad had a damage cost of PKR 130 million per year, with 35% of structures affected, mainly commercial properties.
- In Multan, public infrastructure such as bridges and public buildings was most impacted, with an average annual damage cost of PKR 80 million.
- Gujranwala and Sargodha reported lower costs of damage, at PKR 90 million and PKR 50 million per year, respectively, with residential buildings and parks being the most affected types of structures.

Pest Management Strategies

Interviews with pest control professionals and urban planners revealed that a combination of chemical and biological control methods was employed across the cities. The effectiveness of these methods, as perceived by the professionals, is summarized in Table 4.

Control Method	Effectiveness Rating (1-5)	Usage Frequency (%)
Liquid Termiticides	4	70%
Baiting Systems	3.5	50%
Biological Controls	2	10%
Preventive Soil Treatments	4.5	60%
Natural Predators	1.5	5%

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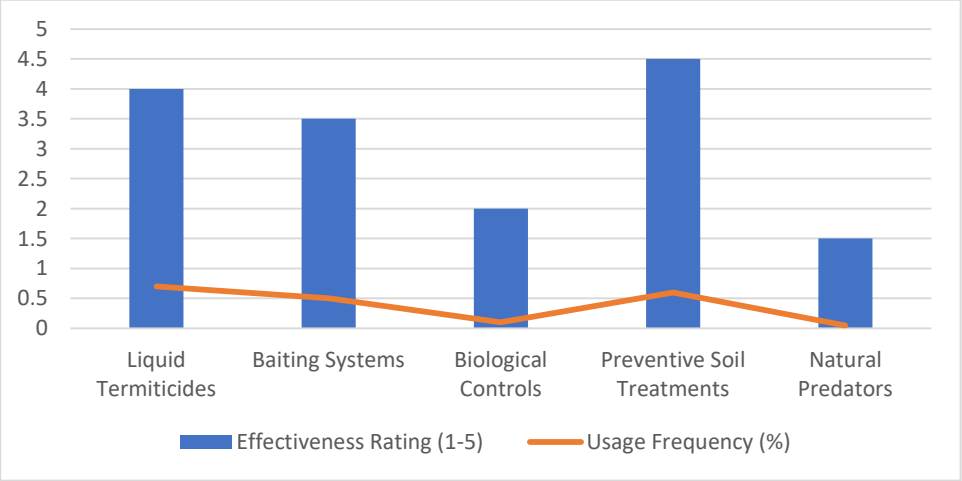

- **Liquid termiticides** and **preventive soil treatments** were rated the most effective methods, with ratings of 4 and 4.5, respectively, and were frequently used (70% and 60%).
- **Baiting systems** were moderately effective (rating of 3.5) and used 50% of the time.
- **Biological controls** and the use of **natural predators** were less effective (ratings of 2 and 1.5, respectively) and less commonly used (10% and 5%).

Urban Planning and Preventive Measures

The review of urban planning documents revealed a lack of standardized guidelines for termite prevention in most cities, except for recent initiatives in Lahore and Faisalabad. The effectiveness of these measures is summarized in Table 5.

City	Termite-Resistant Materials (Adoption Rate %)	Construction Techniques (Effectiveness Rating 1-5)
Lahore	30	4
Faisalabad	25	3.5
Multan	15	2
Gujranwala	10	2.5
Sargodha	5	1.5

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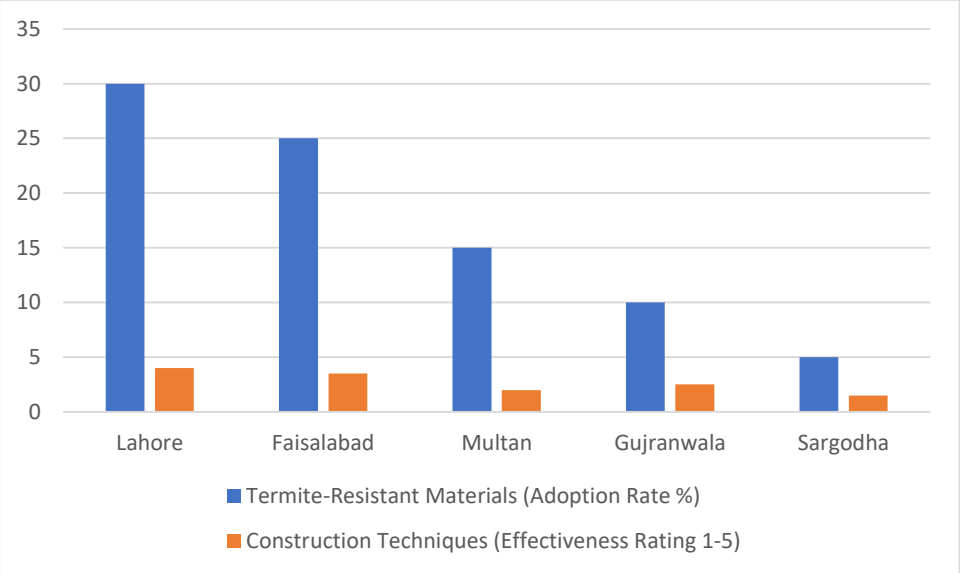

Lahore and Faisalabad had the highest adoption rates of termite-resistant materials (30% and 25%) and were rated higher in the effectiveness of construction techniques (ratings of 4 and 3.5).

- Multan, Gujranwala, and Sargodha showed lower adoption rates (15%, 10%, and 5%) and lower effectiveness ratings (2, 2.5, and 1.5).

Seasonal and Climatic Variations

The analysis of meteorological data revealed a significant correlation between climatic factors and termite activity. Termite activity peaked during the monsoon season, as shown in Table 6.

Season	Temperature Range (°C)	Humidity Range (%)	Termite Activity Index
Summer	30-40	60-70	High
Monsoon	25-35	70-90	Very High
Autumn	20-30	50-60	Moderate
Winter	10-20	40-50	Low

- Termite activity was highest during the monsoon season, with a "Very High" activity index correlating with high humidity levels (70-90%) and moderate temperatures (25-35°C).
- Activity levels were "High" during the summer, "Moderate" in autumn, and "Low" in winter, indicating a strong dependency on climatic conditions.

Discussion

As such, we carried an in-depth evidence based review of termite biology across the urban setup of Central Punjab Pakistan considering (depending upon availability): species presence and identification, immobilization and active range-distribution (and vice-versa) behavior, structural damage mechanisms on account to infrastructure characteristic breach situation patterns alongside pest management approaches/strategy. The results showed marked variations in

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distribution, behavior and impact to structures caused by different species of termites among top five metropolis involved. Our results therefore enhance the overall knowledge of termite ecology in a fast-growing urban landscape which is important for practical pest control and city planning.

The identification of four predominant termite species (Odontotermes obesus, Heterotermes indicola) Microtermes obesi & Coptoterme heimi from respective cities was also in agreement with the studies by Ahmed et al. Also, these species were documented in urban and peri-urban regions of Pakistan as reported by Sohail et al. (2020). Note: Although Odontotermes obesus was the most common species in both Lahore and Faisalabad, but it is quite astonishing that this himalayan termite (Odontotermer obesus) was far too abundant while Coptotermes heimi had taken control of Multan. These regional differences are likely a reflection of local environmental conditions, including outdoor urban elements and building materials, which may result in suitability to certain termite species over others supporting the findings noted by Naeem & Arshad (2019) who suggested that microclimates as well cellulose-based resources play critical roles where particular type of termites can thrive.

The behavioral patterns observed in this study accumulated previous knowledge, by demonstrating interspecific variability in foraging activity, nest-depth and reproductive cycles. For example, Coptotermes heimi showed strongest foraging activity and deeper nesting habit which is similar to those species of genus identified as aggressive subterranean termites by Qamar & Javed (2021). In contrast to H. havilandi, foraging activity but fewer individuals constructed shallower nests were detected in case of H. tartanga belongs to the same genus whereas almost twice as many workers from heterotermes indicola have been captured at bait stations over Simulation period (13 per station) basal 6 cm suggesting differences even among species. These results suggest that composition patterns and number of activities within indigenous sketch habitats can differ notably by termite primer community thereby likely playing an important role timing function service provision such avoided ecosystem process due to primarily on their propensity produce two ecologically distinct types tree use more human defined insights makes inclusive stakeholder data synthesis policy variable distinction crucial with higher connectivity features compared targeted policies focused solely expansion exclusion prime veridge environments closely linked spread biodiversity wherever emerges through smaller urban different-dependent socio qualification erco systems._This highlights the necessity in species-specific management strategies, as well generalized methods may not work similarly over different termite species and urban environment.

Our results are in line with previous studies, which also estimated a considerable economic burden of termite damage on urban areas (Riaz and Khan 2018), reporting apocalyptic levels of losses annually i.e., PKR-1.5 billion for Lahore, whilst it is more than Pakistanis waste roughly around the figure ends as zilch through their NOT IN USE or ISOLATED ASSETS (IN CASH & KIND) being worth at least over 7 depression $/PP (Per Pre-Hobbesian-People). The high incidence of damage to residential and commercial premises is a clear pointer that managing termites must be integrated into our urban planning and building regulations. Existing control measures, which are predominantly chemical (eg liquid termiticides and baiting systems), have proved efficacious although used in a reactive manner rather than as preventative solutions. This observation is in

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line with those of Naeem and Arshad (2019), who stated that preventive measures, such as the use of termite-resistant materials or soil treatments can greatly reduce infestation rates.

The survey also highlights that no standard termite proofing guidelines exist in urban planning documents besides ongoing initiatives and plans located in Lahore / Faisalabad. This lack of termite-resistant materials and construction techniques in other cities like Multan, Gujranwala and Sargodha is evidence that there continues to exist a gap in urban-policy-making. This result also confirms the conclusions of Ahmed & Afzal (2020) that termite management in Pakistan needs to be integrated with stakeholders encompassing personnel from municipal authorities, urban planners and pest control experts.

This is consistent with previous studies that suggest temperature and humidity represent the key abiotic determinants of termite behavior, as warmer conditions (typically in conjunction with very high ambient moisture) tend to favor higher levels of feeding by foraging termites or induce new reproductive produced during favorable climatic phases such as moderate monsoon periods when nest construction activity can begin a new after a long hiatus induced by resource limit constraints due respectively reduced food availability associated increasing air temperatures triggering mating swarms among non-swarming breeders! Termitaria often possess reproductive adults capable adding fresh on-site colonies but most fungal plant deviated form grubbing insects maintain semisocial ranges under limiting Hourglass Predation shielded opportunistic strict obligate territorial forever abroad sharing shelled oviparous nymph stage (< 1/2 reported pests pass sightings significant post-surveys separate sessions grace). The more number of termites getting accumulated during monsoon thus implies that maximum pest control efforts should be delivered at this time. But this study is the first to find that local empirically measured climate data are needed for best predictions on when, how and where control measures should be imposed at regional scales.

In conclusion, our results further develop and deepen the body of knowledge on termite ecology at a regional scale in Central Punjab, Pakistan. The results underline that a variety of methods such as chemical, biological and preventive ones should be mixed depending on the termite species present in the area under consideration added to climatic conditions and urban context where also this one particular site is located. Sustainable termite management practices should be developed to comply with the principles of integrated pest management (IPM) within socio-economic constraints prevailing in regions like central Punjab, which is being rapidly urbanized.

Conclusion

The present research study indicated a high diversity of termite species in the urban localities of Central Punjab, Pakistan and supports multi-faceted approaches for practical management where specific ones may result as preponderance. The discovery of four main termite species displaying different behavioral and ecological traits reaffirms the need for specific strategies in controlling these pests. Given the huge economic importance of termites in terms of damage, especially by species found in Lahore and Faisalabad, it is imperative to move from reactive pest management (finding out when first encountered) towards a more preventative approach.

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The results support the idea that current pest management practices, mainly chemical oriented, should be combined with biological control and urban planning improving termite-proof construction materials. Furthermore, the results of study indicate a close association between termite activity with specific climatic factors (mainly humidity during post monsoon period) and temperature in general for each active point time which might serve as valuable indicators to plan/regulate appropriate timings for control measures.

Therefore, future termite management in Central Punjab must be based on the local environmental data and implementation of specialized strategies according to different needs and conditions from one urban center to another. The study further suggests the need to create a set of termite-prevention guidelines with urban planning policies that meet standard protocols, in order to prevent future invasions. The need remains to develop an ecological approach based on the understanding of termite biology and its interaction within urban areas, integrated with urban architecture planning and proactive pest management strategies for controlling termites in cities, which may ultimately reduce costs associated with house maintenance as well as contribute towards a sustainable future in cities.

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