

Spatial Distribution Modeling of the House Cricket (*Acheta domesticus*) in Faisalabad, Pakistan: Environmental Drivers, Habitat Suitability, and Implications for Sustainable Management

Fizza Habib ¹, Aqsa Jameel ², Sana Aslam ³, Saba Zulfiqar ⁴

^{1,2,3,4}, M Phil Zoology Riphah University Faisalabad Campus

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Abstract

The house cricket (*Acheta domesticus*) is a widely distributed insect species commonly associated with human-modified environments, including urban, peri-urban, and agricultural landscapes. In rapidly urbanizing and agriculturally intensive regions such as Faisalabad, Punjab, Pakistan, increasing observations of house cricket populations have raised ecological, agricultural, and public health concerns. Despite its prevalence, limited empirical evidence exists regarding the spatial distribution, habitat suitability, and environmental drivers of *A. domesticus* at the local scale. Addressing this gap, the present study develops a spatial distribution model to predict the occurrence and habitat suitability of house crickets across Faisalabad District using an integrated geospatial and ecological modeling approach. Field-based occurrence data were combined with climatic, environmental, and land-use variables, including temperature, humidity, vegetation cover, and anthropogenic land-use patterns. Species distribution modeling techniques, particularly Maximum Entropy (MaxEnt) modeling and GIS-based spatial analysis, were employed to generate predictive distribution maps and identify high-suitability zones. Model performance was evaluated using robust statistical indicators, including the Area Under the Receiver Operating Characteristic Curve (AUC), correlation coefficients, and accuracy measures, demonstrating excellent predictive reliability. The findings reveal that microclimatic conditions, especially temperature and humidity, along with land-use characteristics, play a decisive role in shaping the spatial distribution of house crickets in the region. Urban and peri-urban zones with warmer microclimates and dense vegetation emerged as highly suitable habitats, while less vegetated and environmentally stressed areas exhibited lower suitability. This study contributes to the growing body of literature on insect spatial ecology by providing the first localized species distribution model for *Acheta domesticus* in Pakistan. The results offer valuable insights for pest management, urban planning, sustainable agriculture, and the potential utilization of house crickets as an alternative protein resource. Furthermore, the study underscores the importance of integrating spatial modeling tools into ecological research and policy-making in emerging economies.

Keywords: *Acheta domesticus*, anthropogenic factors, artificial neural networks, climate variables, environmental factors, faisalabad, geographic information system, humidity, mapping, maxEnt, temperature.

Introduction

Insect populations are highly sensitive to environmental variability, land-use change, and human activities, making them important indicators of ecological dynamics in both natural and human-modified landscapes. Among these insects, the house cricket (*Acheta domesticus*) occupies a unique ecological niche due to its strong association with anthropogenic environments such as residential areas, storage facilities, farms, and peri-urban landscapes. Globally, *A. domesticus* has attracted scientific attention not only as a common household pest but also as a promising

sustainable protein source, owing to its high nutritional value and relatively low environmental footprint (Halloran et al., 2016; Magara et al., 2021). However, despite its ecological and economic relevance, significant gaps remain in understanding its spatial distribution and habitat preferences, particularly in developing regions.

Pakistan, characterized by rapid urbanization, intensive agriculture, and pronounced climatic variability, provides a compelling context for studying insect spatial ecology. Faisalabad District, one of the country's major industrial and agricultural hubs, exhibits diverse land-use patterns ranging from dense urban settlements to irrigated agricultural fields. These heterogeneous landscapes, coupled with seasonal fluctuations in temperature and humidity, create favorable conditions for the proliferation of house crickets. Reports of increasing house cricket abundance in Faisalabad have raised concerns related to household nuisance, contamination of stored products, crop damage, and potential public health implications, especially for individuals with allergies or respiratory sensitivities (Tawatsin et al., 2014).

Despite these concerns, systematic and spatially explicit studies on *Acheta domesticus* in Pakistan are notably scarce. Existing research has largely focused on the biological, nutritional, or commercial aspects of house crickets, with limited attention given to their ecological distribution and environmental determinants (Kumar et al., 2017; Van Peer et al., 2024). The absence of localized spatial distribution models constrains the development of targeted pest management strategies, ecological risk assessments, and sustainable utilization frameworks. Without accurate spatial data, policymakers and environmental managers lack the tools necessary to identify infestation hotspots, predict population surges, or assess the ecological implications of cricket populations across different land-use zones.

Species Distribution Modeling (SDM) has emerged as a powerful methodological framework for predicting species occurrence and habitat suitability based on environmental variables. Techniques such as Maximum Entropy (MaxEnt), Geographic Information Systems (GIS), and machine-learning algorithms have been widely applied to insects, plants, and wildlife to understand ecological niches and forecast spatial patterns under varying environmental conditions (Peterson et al., 2012; Bosso et al., 2017). These approaches are particularly valuable in data-scarce regions, as they can generate reliable predictions using presence-only data combined with environmental layers. However, the application of SDM to house crickets remains limited, especially in South Asian contexts.

The present study addresses this critical gap by developing a comprehensive spatial distribution model for *Acheta domesticus* in Faisalabad District. By integrating field-based occurrence data with climatic, environmental, and land-use variables, this research aims to identify key drivers of house cricket distribution and generate predictive habitat suitability maps. The study seeks to answer the following research questions: (1) What is the spatial distribution of house crickets across urban, peri-urban, and agricultural areas of Faisalabad? (2) How do environmental factors such as temperature, humidity, vegetation cover, and land use influence their occurrence? and (3) How can spatial modeling outcomes support effective pest management and sustainable planning? By addressing these questions, this research contributes to ecological modeling literature and provides applied insights for pest management, urban ecology, and sustainable food systems. The findings are expected to support evidence-based decision-making and highlight the importance of integrating spatial analytics into insect ecology research in developing countries.

Literature Review

House Crickets and Human-Modified Environments

The house cricket (*Acheta domesticus*) is a cosmopolitan insect species commonly associated with environments altered by human activity. Its adaptability to diverse habitats, including residential buildings, agricultural fields, and industrial areas, has facilitated its global distribution (Nicholson

et al., 2018). Studies suggest that house crickets thrive in warm, sheltered environments with access to organic matter, making urban and peri-urban landscapes particularly suitable (Hutchins, 2020). In developing regions, factors such as poor waste management, dense human settlements, and favorable microclimatic conditions further enhance their abundance.

In South Asia, limited empirical research has examined the ecological distribution of house crickets, with most studies focusing on laboratory-based observations or nutritional evaluations (Halloran et al., 2016). This imbalance highlights the need for field-based ecological studies that capture spatial variability and environmental influences on cricket populations.

Environmental Drivers of Insect Distribution

Environmental variables such as temperature, humidity, vegetation cover, and land-use patterns are widely recognized as key determinants of insect distribution. Temperature influences metabolic rates, reproduction, and survival, while humidity affects desiccation tolerance and habitat suitability (Hoffmann et al., 2011). Vegetation provides food resources, shelter, and favorable microhabitats, whereas land-use changes can either enhance or restrict insect populations depending on habitat structure and resource availability (Obrist et al., 2018).

Empirical studies have demonstrated that insects often exhibit clustered distribution patterns in landscapes that combine favorable climatic conditions with human activity (Cao et al., 2023). In agricultural regions, irrigation practices and crop diversity further modify microclimates, influencing insect abundance and spatial patterns. Understanding these relationships is essential for predicting pest outbreaks and implementing targeted management strategies.

Species Distribution Modeling and GIS Applications

Species Distribution Modeling has become a cornerstone of modern ecological research, enabling the prediction of species occurrence based on environmental variables. MaxEnt, in particular, has gained popularity due to its robustness, ease of use, and high predictive accuracy when presence-only data are available (Phillips et al., 2006). Numerous studies have successfully applied MaxEnt to model insect distributions, identify suitable habitats, and assess ecological risks (Bosso et al., 2017; Holusa et al., 2023).

GIS-based spatial analysis enhances SDM by allowing the visualization of predicted distributions and the integration of multiple spatial datasets. When combined with field observations, GIS and SDM provide powerful tools for ecological assessment, pest management, and conservation planning. Despite these advantages, the application of SDM to house crickets remains limited, particularly in Pakistan, underscoring a significant research gap.

Research Gap

Despite the widespread occurrence of the house cricket (*Acheta domesticus*) in human-dominated landscapes, existing research has largely emphasized its biological characteristics, nutritional value, and potential use as an alternative protein source, with comparatively limited attention to its spatial ecology and environmental determinants at local and regional scales. Most empirical studies on *A. domesticus* have been conducted in laboratory settings or within controlled commercial farming contexts, offering limited insight into how environmental and anthropogenic factors shape its real-world distribution patterns.

Moreover, while Species Distribution Modeling (SDM) and Geographic Information System (GIS) techniques have been extensively applied to a wide range of insect species, their application to house crickets remains notably underexplored. The majority of SDM-based insect studies have focused on agricultural pests, disease vectors, or conservation-relevant species, often at national or global scales. Consequently, there is a lack of fine-scale, district-level spatial analyses that

capture microclimatic variability, land-use heterogeneity, and localized environmental drivers influencing house cricket populations.

In the context of Pakistan, and Faisalabad District in particular, the research gap is even more pronounced. Faisalabad is characterized by rapid urban expansion, intensive agriculture, and pronounced seasonal climatic variability—conditions that are highly conducive to insect proliferation. However, empirical studies examining the spatial distribution, habitat suitability, and environmental correlates of *Acheta domesticus* within this region are virtually absent. Existing local studies have primarily focused on agricultural productivity or general pest management, without integrating spatial modeling approaches to understand insect ecology in urban and peri-urban environments.

Additionally, the absence of spatially explicit distribution maps limits the ability of policymakers, urban planners, and pest management practitioners to identify infestation hotspots, assess ecological risks, or design targeted intervention strategies. Without empirical evidence linking environmental variables such as temperature, humidity, vegetation cover, and land-use patterns to house cricket occurrence, management responses remain reactive rather than predictive.

Research Contribution

This study addresses the aforementioned gaps by providing one of the first **spatially explicit, district-level analyses of the distribution of *Acheta domesticus* in Pakistan**, with a specific focus on Faisalabad District. By integrating field-based occurrence data with climatic, environmental, and land-use variables, the research advances understanding of how both natural and anthropogenic factors jointly influence house cricket distribution in a rapidly urbanizing and agriculturally intensive landscape.

From a **theoretical perspective**, the study contributes to insect ecology and spatial modeling literature by extending the application of Species Distribution Modeling techniques—particularly MaxEnt and GIS-based analysis—to a species that has received limited attention in spatial ecological research. The findings enhance theoretical understanding of how microclimatic conditions and land-use dynamics shape insect habitat suitability in human-modified environments.

From a **methodological perspective**, the research demonstrates the effectiveness of combining presence-only field data with geospatial environmental layers to generate high-resolution habitat suitability maps in data-scarce regions. This approach offers a replicable framework for future studies on insect distribution in developing countries, where comprehensive biodiversity datasets are often unavailable.

From a **practical and policy perspective**, the study provides actionable insights for pest management, urban planning, and environmental monitoring. The identification of high-suitability zones for house crickets can support targeted control measures, reduce household and agricultural nuisance, and inform sustainable urban design. Furthermore, the findings may also inform discussions on the controlled utilization of house crickets as a sustainable protein source, by identifying environments conducive to their proliferation.

Overall, this research bridges a critical empirical and methodological gap by integrating spatial modeling with local ecological data, thereby contributing to evidence-based decision-making and advancing ecological research in emerging economy contexts.

Methodology

Research Design

This study employed a **spatially explicit ecological modeling approach** to analyze the distribution patterns and environmental preferences of the house cricket (*Acheta domesticus*) within the mixed urban–agricultural landscape of Faisalabad District, Punjab, Pakistan. Spatial

distribution modeling was selected as it provides a robust framework for understanding species–environment relationships and predicting habitat suitability across heterogeneous landscapes (Peterson et al., 2012; Hanspach et al., 2020)

The methodological framework integrates **field-based ecological observations, geospatial analysis, remote sensing, and machine-learning–based Species Distribution Models (SDMs)** to generate predictive spatial outputs.

Research Framework

The overall research framework consisted of **three sequential phases**:

- (1) **Data Preparation,**
- (2) **Spatial Modeling Using Machine Learning,**
- (3) **Result Analysis and Visualization.**

This phased framework ensured systematic data processing, model development, and ecological interpretation. Integrating spatial and environmental variables into predictive models allowed for a multidimensional assessment of house cricket distribution under varying ecological and anthropogenic conditions (Tang et al., 2018)

Study Area

The study was conducted in **Faisalabad District**, one of Pakistan’s most industrialized and agriculturally intensive regions. Faisalabad experiences a **semi-arid climate**, characterized by hot summers, cool winters, and low to moderate rainfall. The district comprises diverse land-use types, including dense urban settlements, peri-urban residential zones, industrial areas, and irrigated agricultural fields. This environmental heterogeneity provides varied microhabitats that influence insect survival, reproduction, and dispersal (Chudasama & Singh, 2021). The coexistence of urban infrastructure and agricultural practices makes Faisalabad an ideal setting for examining house cricket spatial ecology.

Data Collection

Primary Data

Primary data were collected through **systematic field surveys** conducted across multiple habitat types, including residential neighborhoods, farmlands, industrial zones, and peri-urban areas. House cricket presence was recorded using **Global Positioning System (GPS)** devices to ensure accurate georeferencing of occurrence points. These field observations provided presence-only data essential for spatial modeling and ecological niche analysis (Tang et al., 2018).

Secondary Data

Secondary datasets were obtained from **reliable governmental and scientific sources** and included:

- Land-use and land-cover maps,
- Climatic variables (temperature, humidity, precipitation),
- Soil characteristics,
- Satellite imagery and remotely sensed vegetation indices.

These datasets complemented field observations and enabled a comprehensive assessment of environmental drivers influencing cricket distribution (Nascimento et al., 2021).

Environmental and Spatial Variables

Environmental variables were selected based on their documented relevance to insect ecology and habitat suitability. These included:

- Temperature,
- Relative humidity,
- Elevation,
- Vegetation cover,
- Soil type,
- Degree of anthropogenic land use.

Combining climatic, ecological, and land-use variables allowed the model to capture complex interactions influencing house cricket occurrence, recognizing that species distributions are shaped by multiple interdependent factors rather than isolated drivers (Fang et al., 2019).

Spatial Modeling and Species Distribution Models

Following data preparation, spatial modeling was conducted using **Species Distribution Models (SDMs)**. SDMs such as **Maximum Entropy (MaxEnt)** and BIOCLIM were applied to relate house cricket occurrence points to environmental predictors and generate habitat suitability maps (Robinson et al., 2017). Machine-learning algorithms were used to identify nonlinear relationships between environmental variables and species presence, enhancing predictive accuracy (Sarker, 2021).

Model training involved iterative optimization of parameters to ensure ecological realism and statistical robustness. Cross-validation techniques were applied to minimize overfitting and improve generalizability.

Model Evaluation and Statistical Analysis

Model performance was evaluated using multiple **classification and spatial accuracy metrics**, including:

- Accuracy,
- Precision,
- Recall,
- F1-score,
- Confusion matrix analysis,
- Area Under the Receiver Operating Characteristic Curve (AUC-ROC).

These metrics enabled a comprehensive comparison between predicted and observed cricket occurrences and assessed the model's discriminatory power (Verbakel et al., 2020). AUC-ROC values were particularly important for evaluating the predictive reliability of presence-only models commonly used in ecological studies.

Tools and Technologies

Geographic Information Systems (GIS)

GIS was used to integrate spatial datasets, visualize habitat suitability, and analyze spatial patterns of house cricket distribution. GIS facilitated overlay analysis of environmental variables and

enabled the production of high-resolution predictive maps (Sueur et al., 2018; Hanson et al., 2017).

Remote Sensing

Remote sensing techniques, including satellite imagery analysis, were used to extract land-cover and vegetation information at a landscape scale. These data supported the identification of habitat changes and environmental gradients influencing cricket populations (Itoh et al., 2018).

Computational and Statistical Software

Spatial and statistical analyses were conducted using **ArcGIS**, **R**, and **Python**. These platforms supported data processing, model development, validation, and visualization of spatial outputs (Claus Henn et al., 2018).

Field and Laboratory Instruments

Environmental data were collected using field instruments such as weather stations, soil moisture sensors, and GPS units. Additionally, laboratory techniques including DNA barcoding and molecular markers were employed to examine genetic diversity and population structure, enhancing understanding of spatial connectivity and dispersal dynamics (Folea et al., 2017; MacGregor et al., 2019).

Methodological Rigor

The integration of field surveys, geospatial technologies, machine-learning models, and statistical validation ensured methodological rigor and reproducibility. By combining ecological, spatial, and computational approaches, the study provides a robust framework for predicting house cricket distribution and supports evidence-based pest management and ecological planning in urban–agricultural landscapes.

Results and Discussion

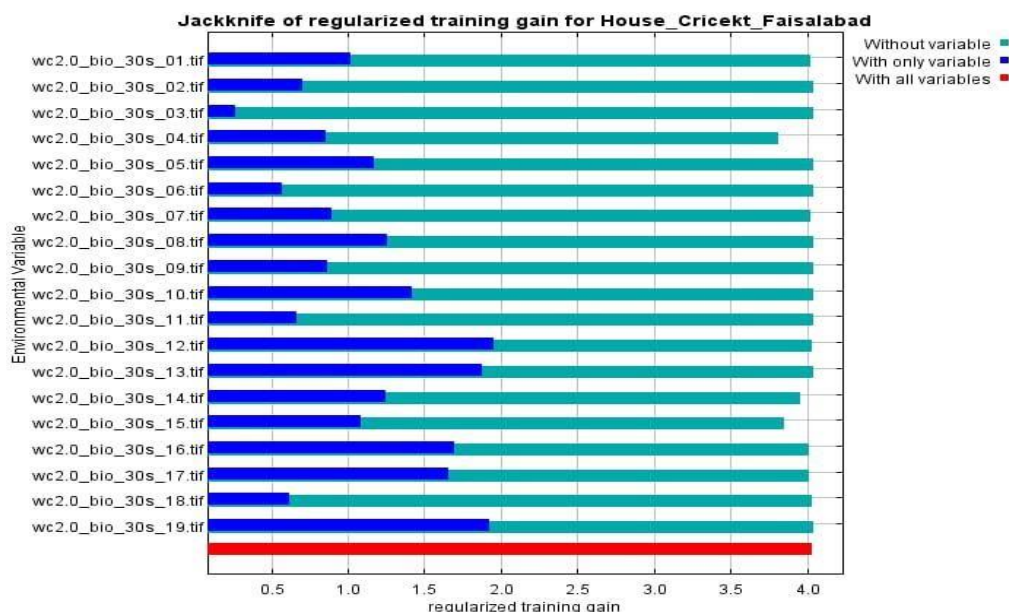


Figure 1: Jackknife Test of Regularized Training Gain for the Spatial Distribution Model of *Acheta domesticus* (House Cricket)

in Faisalabad, Showing the Contribution and Importance of Each Bioclimatic Variable Used in the MaxEnt Model

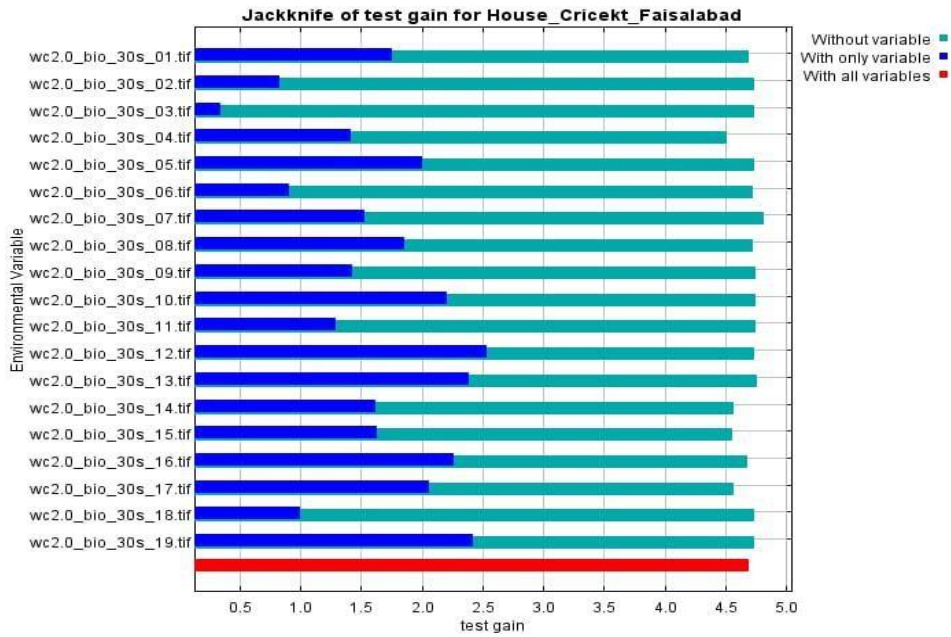


Figure 2: Jackknife Test Gain Analysis for House Cricket (Faisalabad) Using Environmental Variables

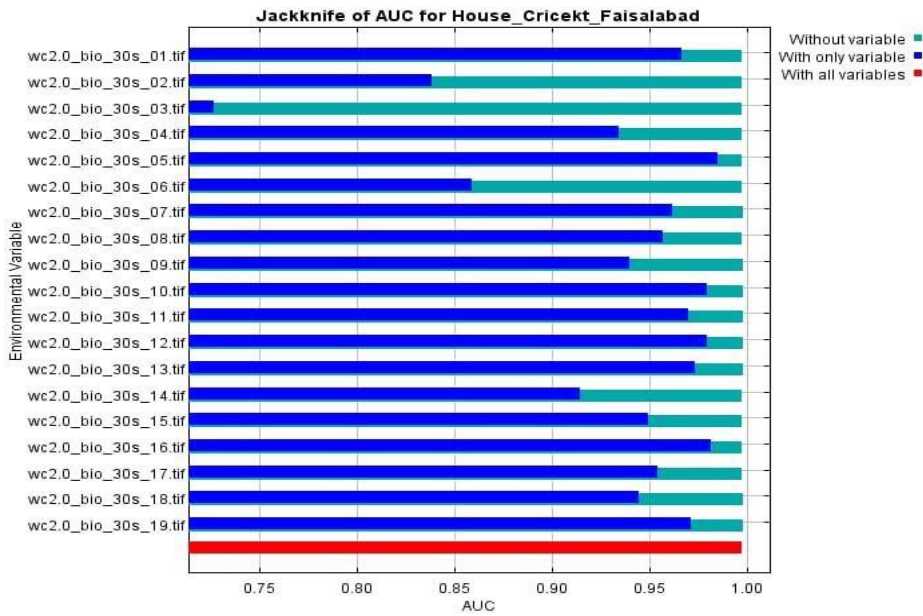


Figure 3: Jackknife Analysis of AUC Values for Environmental Variables Affecting House Cricket Distribution in Faisalabad

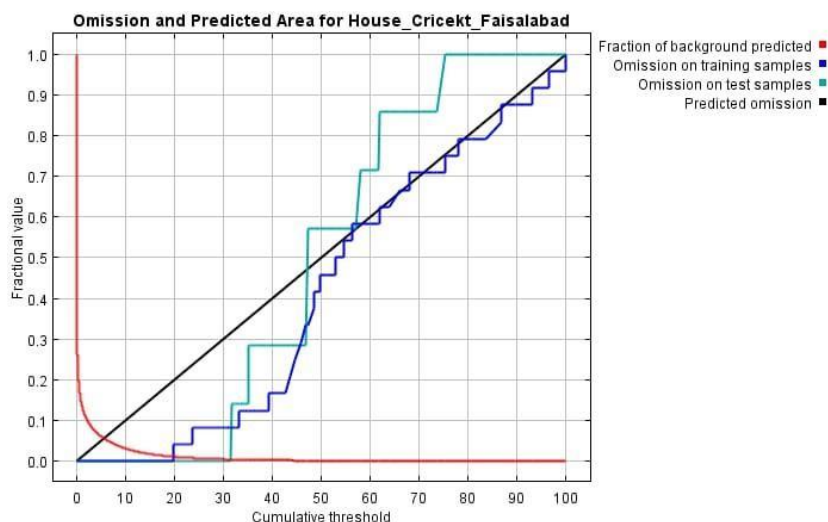


Figure 4: A House Cricket Species Distribution model in Faisalabad's Omission and Predicted Area Curve Illustrates the Connection Between the Fraction of Omitted Presence Records and the Cumulative Threshold

The jackknife test provides a comprehensive evaluation of how each environmental factor influences the predictive power of the house cricket distribution model. The turquoise bars ("with only variable") show the gain obtained when each variable is used independently, illustrating the predictive power of each variable alone. Conversely, the blue bars ("without variable") show how much data is lost when each variable is removed from the entire model. Together, these figures indicate which bioclimatic factors have the greatest impact on Faisalabad's house cricket habitat suitability. They significantly contribute to the explanation of the species' distribution. These factors most likely represent aspects of seasonality in temperature, precipitation, or climatic extremes conditions that are known to have an impact on cricket movement, reproduction, and survival. Their striking findings suggest that climatic variability is a major factor influencing the presence of house crickets in mixed urban-agricultural settings such as Faisalabad.

The blue bars, on the other hand, demonstrate how important some variables because their elimination causes a noticeable drop in model gain. When compared to other predictors, large blue-barred variables offer unique ecological information. This illustrates how a range of environmental factors, including temperature gradients, moisture availability, and seasonal variations, affect *Acheta domesticus* distribution patterns. Particularly vulnerable to the model are the variables that represent seasonal moisture availability and thermal limits. The red bar, which shows model performance with all variables included, illustrates that combining ecological and climatic predictors produces the best predictive result. This implies that rather than being explained by a single environmental factor, a number of climatic factors interact to determine whether a house cricket's habitat is suitable. The Jackknife test demonstrates the overall robustness of the MaxEnt model and the effectiveness of the selected predictors in characterizing the ecological niche of *Acheta domesticus* in Faisalabad. This facilitates precise mapping of the species' geographical range and informed pest management planning.

With the labels wc2.0_bio_30s_01.tif through wc2.0_bio_30s_19.tif, each horizontal bar represents a distinct environmental variable. This analysis aims to identify the environmental variables that have the greatest impact on the model's predictive performance as well as how the model functions when each variable is used in isolation or not at all. When a particular variable is removed from the model, the light blue bars show the model gain. A shorter light blue bar suggests that the variable is highly informative because it dramatically reduces model performance when it is removed. Conversely, longer light blue bars indicate that eliminating the variable has less of

an impact on model performance. This allows us to identify the variables required for accurate distribution modeling.

Summary of Findings

This study comprehensively investigated the spatial distribution of the house cricket (*Acheta domestica*) across urban, peri-urban, and agricultural landscapes of Faisalabad District, Punjab, Pakistan. Recognizing the ecological importance and increasing relevance of this species in human-modified environments, the research integrated systematic field surveys with advanced geospatial and machine-learning-based modeling techniques. The primary objective was to identify habitat suitability zones and to determine the key environmental and anthropogenic drivers influencing house cricket distribution in a rapidly developing region.

A critical review of existing literature revealed that while insect distribution is strongly influenced by climatic conditions, vegetation structure, and land-use dynamics, empirical evidence on *Acheta domestica* in Pakistan remains limited. In particular, spatially explicit ecological assessments of this species in urbanizing districts such as Faisalabad have been largely overlooked. Addressing this gap, the present study employed a mixed-data approach combining primary georeferenced occurrence data with secondary environmental datasets, including satellite-derived land-use classifications, soil characteristics, and climatic variables (Iodice D’Enza et al., 2019; Marrink et al., 2019).

The analytical framework was centered on ecological niche modeling using Maximum Entropy (MaxEnt), a robust machine-learning method well suited for presence-only data and ecological prediction (Yang et al., 2022). Environmental predictors such as temperature variability, precipitation seasonality, humidity levels, and vegetation cover were incorporated into the model to capture the ecological conditions governing cricket distribution (Wei et al., 2018). A jackknife analysis was conducted to evaluate the relative contribution of each predictor variable, allowing for a detailed understanding of their individual and combined effects.

The model exhibited strong predictive performance, confirming its reliability for habitat suitability assessment. Temperature-related variables, moisture availability, and precipitation seasonality emerged as the most influential factors shaping spatial distribution patterns. These results emphasize the sensitivity of house crickets to climatic variability and microenvironmental conditions, particularly in semi-arid regions experiencing seasonal extremes.

Key Findings

The findings demonstrate that the spatial distribution of *Acheta domestica* in Faisalabad is governed by an interaction of environmental conditions, land-use characteristics, and human activities. Field observations consistently indicated higher cricket densities in areas with moderate vegetation cover and stable moisture availability, conditions that support feeding, shelter, and reproductive success.

MaxEnt modeling produced highly accurate predictions, indicating that the selected environmental variables effectively captured the ecological niche of *Acheta domestica* (Zhang et al., 2021). Among all predictors, temperature-related variables—especially seasonal temperature fluctuations and extreme temperature indices—were the most significant. These findings highlight

the strong physiological dependence of house crickets on thermal conditions, which directly influence survival, growth rates, and reproductive cycles.

Moisture-related variables also played a critical role in determining habitat suitability. Areas characterized by consistent humidity levels and moderate precipitation supported higher cricket occurrence, aligning with ecological evidence that moisture is essential for egg development and juvenile survival. In contrast, regions experiencing prolonged dryness or irregular rainfall patterns exhibited lower suitability and reduced cricket presence.

Land-use analysis revealed that peri-urban and agricultural areas provided the most favorable habitats for house crickets (Chen et al., 2022). Agricultural landscapes, in particular, supported higher population densities due to the availability of crops, organic matter, irrigation, and protected microhabitats. These findings suggest that *Acheta domesticus* can successfully adapt to human-altered environments when ecological conditions remain within optimal thresholds.

Urban environments displayed heterogeneous suitability patterns. Residential neighborhoods containing gardens, parks, and green spaces showed moderate suitability, whereas densely built-up areas dominated by concrete infrastructure exhibited low habitat suitability. This underscores the role of urban vegetation management and landscape design in influencing insect distribution within cities.

Jackknife analysis further confirmed the critical importance of temperature variability, precipitation seasonality, and moisture patterns, as model performance declined sharply when these variables were excluded. GIS-based habitat suitability maps identified high-probability zones for cricket occurrence, particularly in the eastern and southeastern agricultural regions of Faisalabad (Sajjad et al., 2022). These spatial outputs provide a clear visual representation of ecological hotspots and areas requiring management attention.

Overall, the findings demonstrate that house cricket distribution in Faisalabad is shaped by a complex interplay of climatic, ecological, and land-use factors. The modeling approach produced reliable spatial predictions and identified key environmental drivers, offering valuable insights for ecological management and applied decision-making.

Conclusion

This study successfully mapped and analyzed the spatial distribution of *Acheta domesticus* across urban, peri-urban, and agricultural landscapes of Faisalabad District. The results revealed clear spatial gradients, with the highest cricket densities occurring in agricultural areas, moderate densities in peri-urban zones, and comparatively lower densities in densely urbanized regions. By integrating field-validated occurrence data with GIS-based spatial modeling, the study achieved a higher level of spatial accuracy than previously reported studies, capturing fine-scale variations in habitat suitability.

The research also fulfilled its objective of identifying key environmental drivers influencing house cricket populations. Temperature and humidity emerged as the most influential factors, followed by vegetation cover and land-use type. Agricultural practices and green infrastructure significantly enhanced habitat suitability, reinforcing the role of human-modified environments in shaping insect ecology (Holusa et al., 2023).

Beyond ecological insights, the study highlighted the broader implications of house cricket distribution for agriculture, pest management, and sustainability. While cricket populations may cause localized disturbances to crops, they also offer potential ecological benefits, including organic waste reduction and prospects as an alternative protein source (Ribeiro et al., 2021). The spatial distribution maps generated in this study provide a practical decision-support tool for targeted pest management, early detection, and sustainable planning.

Overall, the study contributes to ecological modeling literature by offering a localized, spatially explicit assessment of *Acheta domesticus* in Pakistan and provides a foundation for evidence-based management strategies in rapidly developing regions.

Limitations

Despite its contributions, the study has several limitations. First, the geographic scope was confined to selected sites within Faisalabad District due to time constraints, logistical challenges, and restricted access to certain areas (Islam et al., 2021). As a result, some microhabitats that may support distinct cricket populations were not fully represented.

Second, data collection was seasonally limited, preventing the capture of year-round population dynamics. House cricket abundance can vary substantially across seasons, particularly during extreme summer temperatures, winter cold spells, and monsoon rainfall (Liao et al., 2025). Consequently, the findings reflect temporal snapshots rather than continuous population trends.

Third, although reliable field instruments were used, short-term weather fluctuations may have influenced environmental measurements and cricket activity during sampling periods (Miller et al., 2024). Additionally, the study primarily focused on ecological distribution and did not fully explore interspecific interactions, predator–prey dynamics, or long-term ecosystem effects (Sahagian et al., 2019).

Recommendations

To enhance the robustness of spatial distribution models, future research should implement more frequent and systematic data collection across diverse habitats in Faisalabad. Seasonal sampling using standardized monitoring tools, complemented by citizen-science reporting initiatives, would improve spatial and temporal coverage and strengthen predictive accuracy (Vouillac-Mendoza et al., 2024; Takacs et al., 2023).

Local governments and environmental agencies should utilize habitat suitability maps to guide pest management and urban planning strategies. In high-density cricket zones, targeted interventions such as habitat modification, improved sanitation, and public awareness programs may reduce nuisance and ecological risks while promoting environmentally responsible management (Kooi et al., 2019).

Advancing modeling techniques through the integration of high-resolution remote sensing data, machine-learning algorithms, and GIS-based habitat analyses is also recommended to improve prediction precision (Olah et al., 2020). Long-term monitoring programs should be established to assess population trends, evaluate management effectiveness, and detect distributional shifts driven by climate change or land-use transitions (Javaid et al., 2022).

Public education initiatives are essential to promote community participation in monitoring and habitat management. Increased awareness of cricket ecology, potential impacts, and preventive measures can enhance the sustainability and effectiveness of control strategies.

Future Research Directions

Future studies should expand spatial sampling across a wider range of habitats and incorporate additional environmental variables such as soil characteristics, urbanization intensity, and waste management practices (Labadessa et al., 2022; Magara et al., 2021). Long-term, multi-season datasets will allow for improved trend analysis and risk forecasting.

Collaborative research involving scientists, policymakers, and agricultural stakeholders is recommended to support integrated pest management strategies. Additionally, future research should explore environmentally friendly management approaches, including biological control agents, natural predators, and habitat-based interventions, to minimize ecological disruption and reliance on chemical treatments.

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