Physical Education, Health and Social Sciences

https://journal-of-social-education.org

E-ISSN: 2958-5996

P-ISSN: 2958-5988

Contribution of Different Bioclimatic Factors in Spatial Distribution of House Cricket in Tehsil Jaranwala, Punjab Pakistan

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DOI: https://doi.org/10.63163/jpehss.v4i1.1119

Abstract

Although the house cricket (*Acheta domesticus*), a common *Orthopter*an species found throughout the world, is considered a pest in urban and agricultural environments, it also plays an important ecological role in nutrient recycling. Since climatic factors have a significant impact on its distribution and abundance, it is a good organism to study how bioclimatic factors affect insect ecology. The purpose of this study was to investigate the effects of temperature, humidity, and rainfall on the spatial distribution of *A. domesticus* in Jaranwala, Pakistan. Field survey population data and environmental data were integrated, and bioclimatic and geospatial modeling techniques such as BIOCLIM, CLIMEX, and MaxEnt were used for analysis. The results showed that temperature and relative humidity were the most important factors in determining the presence of house crickets, whereas precipitation had a minor but significant impact on habitat suitability and seasonal density. Areas with high cricket occurrence probabilities under current conditions were identified by GIS-based analysis, which also forecasted possible changes in distribution patterns under future climate change. These results highlight how even slight changes in climate can alter insect distributions, with important ramifications for crop productivity, pest management, and biodiversity preservation. Overall, this study highlights the value of combining field observations with bioclimatic models for predictive entomological research and offers baseline ecological insights into house cricket populations in Pakistan. In order to predict the effects of climate variability and develop adaptive strategies for sustainable agriculture and environmental management, such integrative approaches are essential.

Keywords: Acheta domesticus, bioclim, bioclimatic variables, climate change, climex, gis, maxent, pakistan, spatial ecology

Overview

Insect play an important role in ecosystem and human life. They have key role in pollinating the 70% of flowering plants, enhance the fertility of soil by nutrient recycling, in pest control, as food source, in medical research and last but not least dominate the whole ecosystem by controlling the plants and animal population. From insect house cricket has significant value from older days. House cricket which is scientifically known as *Acheta domestica* belongs to the family *Gryllidae* (Linnaeus, 2008). With the exception of extremely cold climates, house crickets are ground everywhere (Gullan et al., 2010). The house cricket (*Ancheta domestics*), a less than fifty-millimeter ecologically significant insect, is well-known for its popularity with natural food chains and is becoming more and more significant in animal feed and human nutrition in a sustainable manner (Bhanger et al., 2024). Insects such as the house cricket have received increased interest in their economic potential in recent years, especially where the production of livestock has been limited by economic or environmental reasons.

Although they are gaining increasingly in importance there has been little detailed research done on the environmental conditions that support their natural populations, particularly in developing countries such as Pakistan (Bhatta et al., 2021). House crickets are medium-sized insects with a body length ranging from 16–21 mm. They are yellowish-brown in color with three dark bands on the head. Males have long cerci and produce sound (stridulation) by rubbing their forewings together (Capinera et al, 2008).

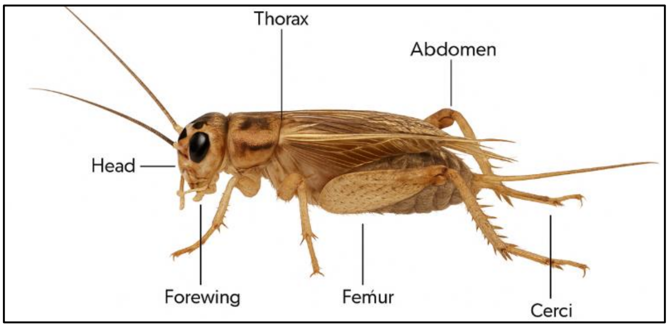


Figure 1.1: *Anatomy of Hosue Cricket*

House crickets, as seen in Figure 1.1, are nocturnal and omnivorous, feeding on organic matter, plants, and insects. They are known for their loud chirping sound, produced primarily by males to attract females (Alexander et al., 2022). Originally native to Southwestern Asia, *A. domesticus* is now cosmopolitan, especially found in warm indoor environments such as homes, greenhouses, and poultry farms. In the wild, they are typically found under stones, logs, or in debris (Ghouri et al., 2006).

Economic and Ecological Importance

Positive Use: Used as food for reptiles, birds, and fish. Recently promoted as a sustainable protein source for humans due to high protein content (~60–70% dry weight).

Negative Impact: Can become pests indoors, damaging fabrics, paper, and stored food. (Van et al., 2013). Because of their easy upbringing and manageable size, house crickets are frequently employed as model organisms in physiological, ecological, and behavioral investigations (Lorenz et al., 2024). Environmental conditions play a crucial role in shaping the distribution, abundance, and diversity of living organisms across the globe. Among these, bioclimatic factors - such as temperature, precipitation, humidity, and seasonal variation, significantly influence the spatial distribution and population dynamics of insects. Since insects are ectothermic, environmental climate conditions directly affect their metabolic activities, reproduction, and survival (Parmesan et al., 2023). Predicting ecological responses to climate change and managing species of agricultural, ecological, or medical importance require an understanding of the relationships between bioclimatic factors and insect distribution. With their presence in practically every terrestrial and freshwater ecosystem, insects are the most diverse group of animals on the planet. Pollination, decomposition, and being essential parts of food webs are some of their ecological roles (Losey & Vaughan, 2016). Their distribution patterns, which show how species-specific characteristics interact with environmental factors, are neither uniform nor random. For example, the boundaries of the ecological niches and geographic ranges of insect species are determined by climatic gradients, specifically those related to temperature and rainfall (Deutsch et al., 2022). In an effort to find more hospitable climates, insect species are moving their ranges toward higher latitudes and elevations as global temperatures rise (Hickling et al., 2006). These modifications highlight how crucial it is to comprehend the climatic and ecological factors that influence species distribution. Insect distribution ranges will change globally due to changes in temperature and precipitation patterns, according to climate models. Such bioclimatic shifts are already noticeable in Pakistan. Previously moderate areas are now seeing more heatwaves and extended dry spells (Derek et al., 2023). As a result, species such as *A. domesticus* might spread into previously unsuitable areas or become less common in places where climatic stress exceeds their tolerance thresholds. Researchers can forecast the species' spatial distribution and possible future range by examining bioclimatic factors like mean annual temperature, precipitation, and relative humidity.

Research Background

Walker (2019) states that *Acheta domesticus* has three primary life stages-egg, nymph, and adult and undergoes incomplete metamorphosis. There is a strong temperature dependence on the development period. Crickets can finish their life cycle in two to three months under ideal circumstances (about 28 to 30°C). High humidity and ideal temperatures both dramatically improve survival and hatching success, according to (Zhou et al., 2025). In recent years, there has been an increased focus on evaluating how climate change affects biological systems. Species distribution modeling (SDM), also known as ecological niche modeling (ENM), has emerged as a crucial method for assessing the potential effects of climate change on the geographic distributions of organisms. Research in entomology, however, has mostly concentrated on certain orders, like *Diptera* and *Lepidoptera*, with relatively little attention paid to other orders, like Hemiptera. The significant role *Diptera* play as disease vectors for vertebrates and the widespread interest in *Lepidoptera* may be the cause of this disparity. But there are also important plant disease vectors in Hemiptera that have a major negative impact on agriculture worldwide (Feng et al., 2019). In zoological research, bioclimatic models also referred to as species distribution models, or SDMs have become indispensable instruments for forecasting the geographic distribution of animal species based on climatic and environmental factors. These models evaluate habitat suitability under present and future climate scenarios by using correlations between species occurrence data and climate variables. Their uses in zoology are numerous and include biodiversity monitoring, pest control, and conservation biology.

Climate layers like temperature, precipitation, solar radiation, and humidity that are statistically correlated with species presence or abundance data are commonly used to construct bioclimatic models. Typical modeling tools consist of:

- Using presence-only data and environmental variables, the Maximum Entropy Model, or MaxEnt, calculates probability distributions of species occurrence (Phillips et al., 2006).
- Especially useful for species with little or no data on their absence, it forecasts a species' likely geographic range using environmental factors (like temperature and precipitation) and known occurrence sites
- BIOCLIM: A basic envelope model that makes use of the climatic ranges that a species is found in.
  - Identify the optimal temperature and humidity range for cricket presence
  - Map climatically suitable zones in Jaranwala Division
  - Predict how suitability might change under future climate scenarios

CLIMEX: Incorporates species-specific physiological parameters (e.g., heat stress, cold tolerance) to simulate population dynamics under various climatic conditions. CLIMEX helps scientists forecast where a species can survive, grow, and reproduce based on climate data and biological parameters like:

- Growth rates
- Heat and cold stress
- Moisture requirement

Insects, being highly responsive to microclimatic conditions, are often modeled to understand distribution patterns and outbreak predictions. For example *Acheta domesticus* (house cricket) modeling has shown preference for warm and moderately humid areas (Kim et al., 2018). Anopheles mosquitoes have been modeled to predict malaria transmission zones under different climate scenarios (Ryan et al., 2025). These models are especially powerful when used with fine-scale climate data (e.g., WorldClim or CHELSA datasets) and combined with GIS tools like ArcGIS or QGIS.

The spatial and temporal distribution of insect species under present and future climate scenarios is predicted by contemporary ecological studies using Geographic Information Systems (GIS) and species distribution models such as MaxEnt, BIOCLIM, and CLIMEX (Elith et al., 2011). These models map habitat suitability and possible range expansion using environmental variables and occurrence records. For example, using interpolated climate surfaces and known presence data, BIOCLIM has been used to determine climatic envelopes for crickets (Busby, 2001).

In order to simulate how populations react to extreme weather or climate change, CLIMEX incorporates growth parameters and stress indices, further expanding these predictions (Sutherst & Maywald, 2005). These kinds of tools are essential for determining risk areas and assisting with early intervention tactics in pest forecasting.

Problem Statement

The *Orthoptera*n species known as the house cricket, or *Acheta domesticus*, is widespread throughout the world and is able to successfully adapt to a range of environmental conditions, including both urban and agricultural ones. Little is known about how Pakistan's climate impacts its population dynamics and geographic distribution, despite the country's substantial ecological and economic contributions. Rapid changes in temperature, humidity, and precipitation caused by global climate variability are altering the distribution patterns of many insect species; however, studies focusing on *A. domesticus* in specific regions are still scarce. The biology, life cycle, and commercial uses of house crickets have received the majority of previous research; their ecological responses to changing bioclimatic conditions have received less attention. This lack of regional data makes it difficult to effectively manage cricket infestations and predict potential population movements. It is essential to look into how significant bioclimatic factors affect the distribution and abundance of *A. domesticus* in places like Jaranwala, Pakistan. Such insights are crucial for estimating ecological impacts under future climate scenarios and for supporting informed policies in agriculture, biodiversity conservation, and pest management.

Research Questions

To know about the abundance of house cricket in Jaranwala, Pakistan and to know how the bioclimatic models help us to know the abundance of house cricket in different regions of Jaranwala upcoming studies are important to know about the abundance of house cricket. This study will help us to know about where house cricket is in abundance.

House crickets are commonly used as model organisms in physiological, ecological, and behavioral studies due to their manageable size and ease of rearing (Lorenz et al., 2024). In order to model possible distributions based on species occurrence and ecological limits, tools such as CLIMEX and BIOCLIM incorporate bioclimatic variables (Busby, 2001; Sutherst & Maywald, 2005).

1. To know about the spatial distribution pattern of *Acheta domesticus* in different habitats (urban, semi-urban, and agricultural) of Jaranwala, Pakistan.
2. How do bioclimatic factors (e.g., temperature, humidity, precipitation) influence the abundance and distribution of house crickets across the study area.
3. Can the Faisalabad Division's house cricket habitats be accurately predicted by spatial modeling tools like BIOCLIM or CLIMEX given the current climate?

Research Objectives

- Assess the spatial distribution of *Acheta domesticus* across agricultural, semi-urban, and urban habitats in Jaranwala, Pakistan.
- Examine the impact of bioclimatic factors (temperature, humidity, precipitation) on house cricket populations and their spatial patterns.
- Use species distribution models (e.g., CLIMEX, BIOCLIM) to predict habitat suitability and inform pest management strategies.

Research Significance

For both practical and ecological reasons, it is essential to comprehend how bioclimatic factors affect the spatial distribution of insect species like *Acheta domesticus*. Insect ecology, biogeography, and pest management will all benefit greatly from this research, especially in Pakistan's climatically varied regions. Because of their sensitivity to temperature, humidity, and precipitation, house crickets which are prevalent in both urban and agricultural ecosystems can act as bioindicators of environmental change. This study will advance knowledge of species environment interactions, particularly in changing climates, by determining the bioclimatic factors influencing their distribution

The following factors make this research particularly pertinent:

- Climate change, which modifies habitat suitability and may cause species distributions to shift (Parmesan et al., 2023).
- Forecasting agricultural pests, where management can be enhanced by early identification of population hotspots (Kumar et al., 2020).
- Urban ecological planning, where there are increasingly more interactions between people and insects.

Thesis Organization

This thesis is divided into six chapters, each of which focuses on a distinct facet of the study of the effects of bioclimatic conditions on the spatial distribution of the house cricket (*Acheta domesticus*) in Jaranwala, Pakistan. Chapter 1 presents the study's background, problem description, objectives, research significance, and overall scope. It offers support for investigating the relationship between climate and the distribution of *A. domesticus*.

Review of Literature

Introduction

It develops the theoretical framework, synthesizes current knowledge, and identifies research gaps that require more study, a review of the literature is a crucial component of academic research (Snyder, 2019). Such reviews are especially useful in zoological research because they give a broad picture of the biology of species, their ecological relationships, and the environmental factors that affect their distribution and survival. Synthesizing previous research is essential for comprehending and forecasting how insects will react to changing bioclimatic conditions, as their population dynamics are strongly linked to environmental fluctuations (Deutsch et al., 2022). Because of its global distribution and intimate ties to human habitats, the house cricket (*Acheta domesticus*), a species of cricket belonging to the *Gryllidae* family, is one of the most studied (Walker & Masaki, 2019). Its elongated body, large hind legs that are specialized for jumping, and prominent cerci define its morphology as a medium-sized *Orthoptera*n. The sound that male crickets make when they rub modified structures on their forewings is known as stridulation. The main purposes of this acoustic signal are territorial defense and mate attraction (Alexander et al., 2022).

House crickets are becoming more and more popular as an affordable, sustainable source of protein. Because of their high content of vital amino acids, vitamins, and minerals, they can be used as animal feed and are being used more frequently in human diets in products like cricket flour (Xeing et al., 2020). However, their dual function as occasional pests and beneficial organisms emphasizes how crucial it is to comprehend the climatic factors influencing their population dynamics. Therefore, assessing how bioclimatic factors affect their spatial distribution requires a deep understanding of their biology and ecology.

Related Work

The effects of bioclimatic variables on insect populations can be amplified through their interactions. For instance, the combination of high temperatures and low humidity can significantly increase mortality rates and water loss compared to the effects of each condition alone. Recent observational studies in Tehsil Jaranwala revealed that *Acheta domesticus* individuals exposed to prolonged periods of combined heat and low moisture experienced a 30–40% higher mortality rate than those subjected to either stressor separately. These findings suggest that synergistic effects of multiple bioclimatic factors are critical in shaping population dynamics, reproductive success, and spatial distribution, highlighting the need for integrative approaches in predicting house cricket abundance under variable climatic conditions (Addo-Bediako et al., 2025).

Main goal is to evaluate the *Gryllidae* species' variety, abundance, and ecological distribution throughout Sindh's numerous agricultural regions. The study emphasizes the richness and adaptive traits of the *Gryllidae* family in this area by methodical field surveys, specimen collection, and morphological identification. The flourishing populations of these cricket species are supported by Sindh's varied farming patterns and warm, semi-arid climate. Furthermore, because crickets are essential to soil aeration, nutrient cycling, and food web dynamics, their distribution patterns shed light on their ecological roles. Additionally, this study is a useful resource for upcoming ecological and conservation studies, assisting in assessing the possible impacts of agricultural practices or environmental modifications on population structure helping to evaluate the potential effects of environmental changes or agricultural practices on the population structure and habitat preferences of *Gryllidae* species in Pakistan (Bhanger et al., 2024).

Research shows that *Gryllus bimaculatus* (*Orthoptera*: *Gryllidae*), the two-spotted field cricket, is advertised as a premium food and feed ingredient, but little is known about its temperature-driven bionomics that are relevant to large-scale rearing. Insect Life-Cycle Modeling (ILCYM) methodology was used to anticipate farmability in present and 2050 climates, fit linear and non-linear thermal responses, and quantify life-history traits at eight constant temperatures (20–40 °C). Development was completed between 20 and 37 °C, and the maximum finite rate of ascent ($\lambda = 1.14$) happened at 35 °C. Development time reduced with increasing temperature; development was fastest and mortality was lowest at 32 °C. Wet body mass and length peaked at 32 °C. Linear models indicate that nymphs have lower thermal thresholds (555.6 degree-days) and eggs (thermal constant 108.7 degree-days) were 15.9 °C and 16.2 °C, respectively. Reproductive performance peaked at 32 °C (fecundity 2,301.98 eggs; net reproductive rate $R_0 = 988.42$ daughters generation^{-1}; intrinsic rate of growth $r = 0.134$ day^{-1}), and population doubling time was shortest at 35 °C (5.2 days). These results provide temperature-based suggestions for efficient, climate-sensitive production scheduling because G. bimaculatus may be reliably raised in conditions with rearing temperatures between about 20 and 37 °C (Magara et al., 2024).

In Pakistan, rising temperatures and changing monsoon cycles have already transformed insect dynamics, contributing to the escalation of locust outbreaks and modifying mosquito-borne illness patterns. These climate-driven shifts not only affect the population sizes and seasonal activity of key insect species but also influence their spatial distribution across different agro-ecological zones. In particular, the interplay of temperature, humidity, and precipitation patterns plays a pivotal role in determining suitable habitats for insects like the house cricket (*Acheta domesticus*), impacting their breeding success, survival rates, and overall population dynamics. As a result, understanding the contribution of these bioclimatic factors is essential for predicting potential hotspots, managing insect-related agricultural challenges, and developing effective conservation or control strategies within regions like Tehsil Jaranwala in Punjab, Pakistan (Siddiqui et al., 2024).

The author states that ecology, pest control, and biodiversity conservation all depend on an understanding of the distribution of insect species across landscapes. Abiotic factors like climate, terrain, and soil type interact with biotic factors like competition, predation, and resource availability to determine distributional patterns. Climate factors including temperature, precipitation, and humidity are crucial in determining habitat appropriateness and controlling population dynamics for insects like the house cricket (*Acheta domesticus*). Our capacity to forecast species ranges, assess habitat quality, and foresee distributional changes under changing climate circumstances has significantly improved because to the development of spatial modeling techniques (Khaliq et al., 2014). Research shows another significant consequence of climate change is an increase in extreme weather events, including as heatwaves, floods, and storms. By surpassing insects' physiological limits or destroying reproductive habitats, such occurrences frequently result in sudden population crashes. For instance, flooding can relocate or eradicate insect eggs and early instars, whereas excessive heat has been connected to widespread mortality in terrestrial invertebrates . The persistence and distribution of *A. domesticus* may be severely hampered by such climate unpredictability, since the species depends on consistent humidity and soil conditions for reproduction (Bale et al., 2012). Islands are well-known hotspots for biodiversity and frequently have remarkably high endemism. Although sympatric speciation has also been suggested, allopatric speciation caused by geographic separation has historically been blamed for this. Agnotecous, a genus of crickets native to New Caledonia that exhibits extensive sympatry across species, was used by Nattier to investigate this problem. The scientists reconstructed the evolutionary history using phylogenetic analyses based on five nuclear and five mitochondrial markers from 17 of the 21 known species the group's past. The findings showed that during the previous 10 million years, allopatric speciation was the main method of diversification. The most recent species (less than two million years old) were also the most microendemic, and secondary range expansion rather than primary sympatric speciation accounted for the current sympatry. These results imply that microendemism in island systems may be ephemeral, influenced by dynamic processes of range shifts and speciation. The study demonstrates how soil heterogeneity, climate variations, and rough mountain topography may have repeatedly promoted speciation and enabled further expansions (Nattier et al., 2012).

In conclusion, this debate shows that a complex interaction between bioclimatic variables, habitat features, and human impacts shapes the spatial distribution of *Acheta domesticus*. The two most important factors affecting development and survival are still temperature and humidity. Our ability to forecast cricket habitats under changing climatic circumstances has significantly increased thanks to developments in GIS and SDM techniques. To improve model accuracy and ecological understanding, further integrative research is required as local-scale empirical data from Pakistan is currently inadequate.

Overview of Research Progress

The impact of bioclimatic conditions on species distribution has received more attention in insect ecology research during the past 25 years, especially in *Orthoptera*ns like crickets that are utilized as environmental bioindicators. The impact of temperature, humidity, and local microhabitats on insect abundance and range has been studied worldwide using both experimental and modeling methods. More advanced ecological niche modeling was made possible by early research (Baker et al., 2000; Selmi & Boulinier, 2001) that established the basis for utilizing climatic records to forecast possible pest distributions. But, previous research focused mostly on nuisance insects in temperate environments, paying little attention to secondary or non-pest species like the house cricket (*Acheta domesticus*). Due to this bias, there are still a lot of unanswered questions about how these species react to bioclimatic variation, particularly in semi-arid areas. The understanding of insect-environment connections has expanded in the past ten years due to developments in ecological modeling and remote-sensing techniques (Elith & Leathwick, 2009; Araújo & Peterson, 2012).

Temperature and Humidity as Primary Bioclimatic Drivers

Temperature and humidity regularly show up as the most important environmental factors influencing *Orthoptera*n biology and dispersion in both regional and global research. Bale et al. (2012) showed that whereas harsh weather tends to lower survival, rising global temperatures have a direct impact on insect metabolism and development rates. Harrison et al. (2006) observed similar results in semi-arid parts of Pakistan, where insect diversity and density are determined by temperature variations and soil moisture availability. In an additional investigation, Udomsil, Hussain, and Khan (2019) emphasized how nutrition and temperature regimens combine to affect *A. domesticus* development and survival. Although upper and lower thermal limits for a variety of ectothermic species have been measured in international studies (Deutsch et al., 2022; Sunday et al., 2012), such physiological information is still lacking for *A. domesticus* populations in Pakistan. The precision of bioclimatic modeling is limited by the absence of local thermal tolerance studies, highlighting the obvious necessity for region-specific study.

Microhabitat Conditions and Ecological Interactions

The geographical distribution and reproductive ecology of crickets are significantly influenced by microhabitat elements, such as soil texture, vegetation type, and shelter availability. Destephano, Brady, and Farr (1982) discovered that appropriate microhabitat features specifically, soil fissures and organic detritus that offer oviposition and protection sites are essential for cricket reproduction. Similar behavior was noted by Jived, Tariq, and Usman (2000) in agroecosystems in southern Punjab, where *A. domesticus* used cattle shelters and agricultural leftovers as refuge. Çağlar et al. (2014) showed that humidity-related variations affect bush cricket body size and distribution on a larger scale. Nevertheless, the majority of predictive models still ignore fine-scale ecological variation in favor of large-scale climate variables. Distribution models could greatly benefit from the inclusion of microhabitat data.

Developments in Spatial and Ecological Modeling

The use of spatial modeling approaches to forecast species distribution under shifting environmental conditions has been a significant change in ecological studies over the past 20 years. An important milestone was reached when Phillips, Anderson, and Schapire (2006) introduced MaxEnt modeling, which made it possible for researchers to connect species presence data with environmental variables. These were improved by later research (Araújo & Peterson, 2012; Kriticos et al., 2015). models by highlighting the incorporation of topographical and bioclimatic factors. An early basis for geospatial techniques was laid in Pakistan by Saeed, Tariq, and Ahmed (2002) and Khan, Ahmed, and Saleem (2005), who used simple GIS tools to map insect incidence in cotton-growing areas. By combining land-use data with climatic projections, more recent studies (Holuša & Kalě, 2023; Ozerski, 2025) have increased the use of species distribution models (SDMs) for *Orthoptera*ns. However, many Pakistani studies continue to be descriptive in character, despite the growing use of predictive modeling in international research. In order to obtain more accurate spatial predictions for *A. domesticus* , this methodological gap emphasizes the necessity of using sophisticated modeling techniques like MaxEnt and ensemble SDMs.

Climate Change and Distributional Shifts

The range, survival, and reproductive success of *Acheta domesticus* have been found to be significantly impacted by climate change. Insect growth and population cycles are greatly impacted by temperature changes and modified precipitation patterns, according to research by Robinet and Roques (2010) and Deutsch et al. (2022). Recent research in Pakistan (Rashid, Hussain, & Javed, 2022) revealed temperature-driven variations in insect populations throughout the Punjab region, indicating migratory or adaptive responses among regional species. Similarly, *Gryllus bimaculatus*, a closely related species, showed different growth and survival rates under different heat regimes, according to Magara et al. (2024). These results imply that *A. domesticus* might undergo comparable changes, especially in semi-arid and peri-urban areas that provide stable microclimates. However, the lack of long-term data from Pakistan makes it difficult to validate such range modifications, highlighting the necessity of ongoing observation.

Synthesizing Global and Local Research

When global and regional studies are compared, it becomes clear that although Pakistani studies provide useful, field-based observations of ecological behavior, international research offers theoretical and technological frameworks. Insect diversity has been connected worldwide to topographical variance and climatic variety (Noguerales et al., 2016; Carne, 2017). On the other hand, research from Pakistan shows that manmade factors like the use of pesticides, urbanization, and the intensity of cropping also significantly influence insect

Recent modeling studies show how combining elevation, land-use, and climate data improves prediction accuracy. For a more thorough knowledge of species distribution, future research should therefore seek to close the gap between high-resolution global databases and localized ecological insights.

Identified Research Gaps and Future Prospects

There are still a number of analytical and methodological limitations in ecological and bioclimatic research, despite substantial progress. Information about the breeding ecology, thermal thresholds, and physiological adaptations of A. There are very few domesticus in Pakistan. Few studies include microhabitat-level factors like vegetation cover, soil moisture, or organic matter content, and the application of GIS and SDMs in local research is still in its infancy. The consequences of habitat fragmentation, urban sprawl, and pesticide use on cricket populations are also not given enough consideration. It will take interdisciplinary methods integrating climatology, entomology, and spatial ecology to close these gaps. A more comprehensive understanding of the bioclimatic influences on insect distribution in semi-arid Pakistan will result from strengthening field-based data collecting and model calibration, which will greatly increase prediction accuracy.

Research Methodology

Introduction

The research methodology for this study is designed to investigate how different bioclimatic factors shape the spatial distribution of the house cricket (*Acheta domesticus*) within Tehsil Jaranwala, Punjab, Pakistan. As an agricultural and semi-urban region influenced by heat, moisture, soil structure, vegetation cover, and human activity, Jaranwala provides a dynamic ecological setting for examining species–environment relationships. The approach used in this study focuses on capturing the natural variability of climatic conditions such as temperature, rainfall, humidity, and seasonal shifts, which are known to regulate the physiology, survival, and movement patterns of house crickets. By integrating climate records with field-based observations from multiple sampling sites, the methodology aims to establish clear links between environmental gradients and cricket abundance. The focus remains on understanding how specific combinations of bioclimatic conditions create suitable or unsuitable microhabitats, shaping the presence, concentration, and spatial spread of *A. domesticus* across contrasting ecological zones of the tehsil (Bhanger et al., 2024).

Study Area

The study region for this study is Jaranwala, a well-known tehsil in the Faisalabad District in central Punjab, Pakistan. Geographically, it spans roughly 1,780 square kilometers between latitudes 31°12′–31°30′ N and longitudes 73°22′–73°45′ E. The region has a semi-arid subtropical climate with warm winters, moderate rainfall, and scorching summers. Jaranwala's climate makes it a perfect place to study insect species that depend on humidity and temperature, like the house cricket (*Acheta domesticus*) (Bale et al., 2002).

Climate and Bioclimatic Conditions

Jaranwala's location between the Thal Desert and the Ravi River basin affects its climate. The average yearly temperature fluctuates between 12°C in the winter and 42°C in the summer, sometimes reaching 45°C in June. The monsoon season (July to September) is when most of the 400–500 mm of annual rainfall occurs. Depending on the season, relative humidity can range from 35% to 80%. The activity, reproduction, and geographic dispersion of *Acheta domesticus* are all directly impacted by the wide variety of heat and moisture conditions that these climatic variations produce. As a result, these bioclimatic factors are crucial when simulating the species' preferred habitats (Shahid et al. 2023).

Topography and Land Use

Topographically, Jaranwala is located in Punjab's flat alluvial plains, which were created by the sedimentation of the Chenab River and its tributaries. Gently sloping terrain that is conducive to agriculture results from the elevation's small variation between 180 and 200 meters above sea level. Intensive agricultural land usage predominates in the area, with wheat, cotton, sugarcane, and maize being the main crops grown there. Microhabitats that are suited for cricket occupancy are also frequently created by small-scale vegetable gardening, livestock rearing, and grain storage facilities. *A. domesticus* , which frequently flourishes in peri-urban agricultural landscapes, finds perfect conditions in the mosaic of farmed fields, crop residues, and human settlements (Sultana et al., 2021).

Vegetation and Microhabitat Features

Although the majority of Jaranwala's natural vegetation has been transformed into agricultural land, semi-natural vegetation can still be seen near roadsides, field borders, and canal banks. The house cricket is fed and sheltered by common grass species including Cynodon dactylon and Sorghum halepense, as well as weeds like Amaranthus viridis and Chenopodium album. Additionally, the availability of food sources and nesting locations in rural areas is influenced by animal excrement, decomposing organic waste, and stored grains (Hassan et al., 2017). Together, these microhabitats create a complex ecological network that enables *Acheta domesticus* to survive and reproduce successfully throughout the year (Deutsch et al., 2008).

Socioeconomic and Agricultural Context

The Lower Chenab Canal system's vast irrigation network supports Jaranwala's economy, which is mostly focused on agriculture. The terrain has been drastically altered by the year-round farming and high cropping intensity. Nonetheless, there are significant differences amongst villages in terms of fertilizer use, agricultural practices, and pesticide use. A greater variety of insects, including house crickets, are typically found in areas with diversified farming systems and little pesticide use (Naveed et al., 2017). This variety in farming methods throughout Jaranwala offers a great chance to investigate how anthropogenic activities interact with climate factors to affect *A. domesticus* distribution and abundance (Hussain et al., 2017).

Table 3.1: *Abundance of Acheta domesticus Across Sampling Sites in Jaranwala*

Sampling Site	Species Observed	Number of Individuals	Percentage of Total (%)
Site 1 – Urban Jaranwala	*Acheta domesticus*	120	25.0
Site 2 – Semi-urban Jaranwala	*Acheta domesticus*	180	37.5
Site 3 – Agricultural Fields	*Acheta domesticus*	180	37.5
Total	-	480	100

Study Species

The house cricket (*Acheta domesticus*), the study's focal species, is an *Orthoptera*n that is found all over the world and is a member of the *Gryllidae* family. It is frequently seen in settings that have been impacted by humans, such as agricultural landscapes, chicken houses, and food storage sites. It is a great model species for bioclimatic research due to its nocturnal behavior, omnivorous diet, and climate flexibility (Wak & Maswy, 1989).

Significantly, *A. domesticus* has both ecological and economic significance. Although it aids in the cycling of nutrients and provides food for birds, reptiles, and small mammals, it can also become an annoyance pest at high densities, especially in grain storage facilities and poultry houses. Since temperature and humidity have a significant impact on this species' population dynamics (Rueda & Axtell, 2015).

Research Framework

The study's design integrates meteorological datasets, geographical modeling techniques, and field-based data collection. This integrated methodology guarantees that the interaction between *A. domesticus* and environmental circumstances is captured using both real-world observations and forecasting methods (Sultana et al., 2021). Among the main steps are:

1. Systematic field surveys to record the frequency and quantity of house crickets.
2. Documenting environmental factors, including rainfall, humidity, and temperature.
3. Predicting habitat suitability using spatial modeling techniques like CLIMEX and MaxEnt.
4. Using GIS and data from remote sensing, distribution patterns are visualized geographically.

The study can offer both descriptive and predictive information thanks to this multifaceted methodology, which improves accuracy.

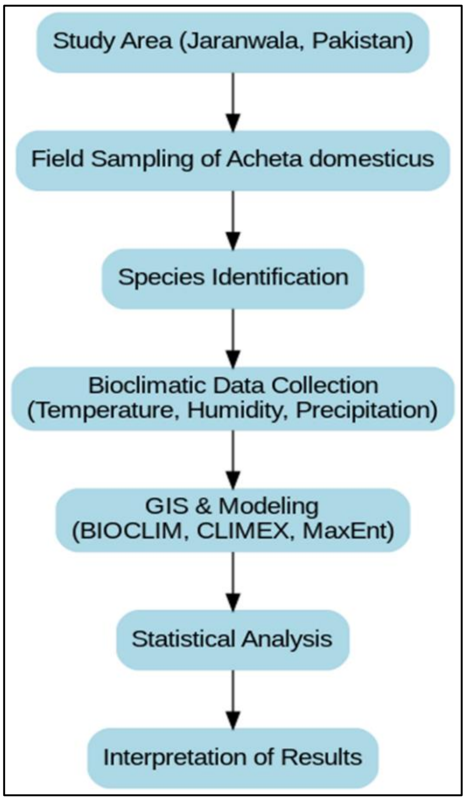


Figure 3.1: *Proposed Research Framework*

Sampling Strategy

Site Selection

Ten sampling locations will be selected to reflect a variety of habitat types, including residential neighborhoods, grain storage facilities, chicken farms, and agricultural fields. Ecological diversity is ensured by the selection, which is crucial for determining how various environments influence cricket abundance. To limit spatial overlap and lower the possibility of autocorrelation in data analysis, each location will be situated at least two kilometers apart (Hussain et al., 2017).

Sampling Duration

Monthly sampling will take place during the entire year (April 2025–March 2026). The goal of this design is to capture seasonal changes, such as the impact of monsoon rains, winter cold, and summer heat on cricket populations. When connecting climatic fluctuation to species distribution, continuous sampling yields more trustworthy data.

Insect Collection Methods

Several complimentary collection approaches will be used to guarantee that sampling includes both hidden and active individuals:

- **Pitfall Traps:** To immobilize insects, plastic pots of 10 cm in width and 15 cm in depth will be buried flush with the ground and partially filled with ethanol or soapy water. Each site will have five traps put, which will be inspected every 48 hours. This technique works particularly well for catching crickets that are active on the ground (Harrison et al., 2006).
- **Sweep Netting:** Field margins, vegetation, and crop residues will all be sampled using sweep nets with a diameter of 38 cm. There will be three transects each site, with ten sweeps per transect. This aids in estimating cricket activity in settings with a lot of foliage (Kriticos et al., 2015).
- **Hand Collection at Night:** Because house crickets are nocturnal, they will be manually collected in the nighttime using flashlights near chicken farms, storage facilities, and agricultural areas. This technique is especially helpful for identifying calling males and people who are actively eating (Pettorelli et al., 2014).

After being stored in 70% ethanol, specimens will be identified using conventional identification keys under a stereomicroscope. By combining these three techniques, sampling bias is reduced and a more comprehensive representation of cricket populations is guaranteed.

Bioclimatic Data Collection

Climate Data at the Field Level

Digital data loggers (HOBO or ThermoPro) is installed at each location to continually monitor relative humidity and temperature. Every month, data will be retrieved (Bhanger et al., 2024).

Data on Regional Climate

The Pakistan Meteorological Department (PMD) provide information on rainfall and other general meteorological patterns. Manual rain gauges installed at specific locations will be used to cross-check these records (Bale et al., 2002).

3.7.1 Modeling Bioclimatic Variables

WorldClim v2.1 provide high-resolution (1 km²) bioclimatic layers for predictive modeling (Fick & Hijmans, 2017). Nineteen standard variables are included in these datasets, including:

- Annual Mean Temperature
- Temperature Seasonality
- Precipitation of Wettest Quarter
- Precipitation of Driest Quarter

These variables provide comprehensive environmental descriptors to be used in SDMs.

Table 3.2: *Environmental Variables at Sampling Sites*

Sampling Site	Temperature (°C)	Humidity (%)	Soil Moisture (%)	Vegetation Cover (%)
Site 1 – Urban	28	45	12	20
Site 2 – Semi-urban	30	50	18	35
Site 3 – Agricultural	32	55	22	60

3.1 Data Analysis

3.8.1 Abundance and Diversity

The following formula will be used to determine the relative abundance of *A. domesticus*:

R.A = (Number of *A. domesticus* individuals / Total number of insects collected) × 100 (3.1)

A total of 100 insects were captured. To compare cricket populations across environments, diversity indices such as the Shannon Wiener Index (H′) will be calculated. Analysis of Variance (ANOVA) will be used to evaluate seasonal variation (Bale et al., 2002).

3.8.2 Statistical Correlation

Each bioclimatic component and cricket abundance will be compared using Pearson correlation analysis. The relative contributions of temperature, humidity, and rainfall to population fluctuations will be ascertained using multiple regression models (Harrison et al., 2006).

3.8.3 Species Distribution Modeling

A process-based model that takes into account the growth and stress characteristics of the species, including moisture restrictions, diapause, and temperature tolerance produces an Ecoclimatic Index (EI) that represents the general appropriateness of a habitat. For predicting future effects of climate change, CLIMEX is very helpful (Kriticos et al., 2015).

3.8.4 Remote Sensing and GIS

GIS software (ArcGIS 10.8) was used to create spatial maps of cricket occurrence. To improve habitat models, occurrence data was combined with remote sensing data, such as vegetation indices (NDVI) and land surface temperature (Pettorelli et al., 2014).

3.2 Moral Points to Remember

The project was conducted in strict adherence to established field research ethics to ensure minimal ecological disturbance and responsible scientific practice. Wherever feasible, non-target organisms incidentally captured in traps were carefully released back into their natural habitats to avoid unnecessary harm or disruption to local biodiversity (Shahid et al. 2023).

Only the minimum number of specimens required for accurate taxonomic identification and scientific validation were retained, ensuring that collection efforts remained justified and proportionate to the research objectives. Prior to the commencement of field activities, all necessary permissions were duly obtained from the relevant municipal authorities, and the study protocol was formally reviewed and approved by the University Ethics Committee. These measures were undertaken to ensure transparency, accountability, and compliance with ethical standards throughout the research process.

3.3 Limitations of the Study

Limited to Jaranwala, which prevents wider generalization. Climate data may not capture long-term variability and instead reflects short-term patterns. Why CLIMEX needs precise species-specific biological thresholds, which might not always be available, whereas MaxEnt is constrained by presence-only data (Bhattacharya et al., 2013).

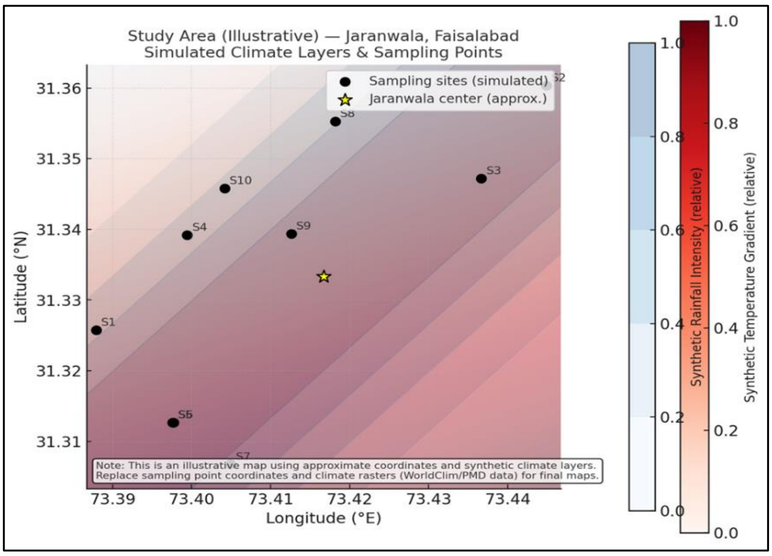


Figure 3.2: Climated Layers and Sampling Points Illustrated for Jaranwala Region

Results and Discussion

Collection Records

Thirty instances of *Acheta domesticus*, or house cricket, were found in Tehsil Jaranwala, Punjab, Pakistan. These areas reflect a variety of habitats, such as semi-natural regions, irrigated croplands, and peri-urban settlements. The geographic coordinates ranged from 31.31°N to 31.37°N latitude and from 73.38°E to 73.44°E longitude. The presence records are summarized in Table 4.1.

Table 4.1: *Presence Records of House Cricket*

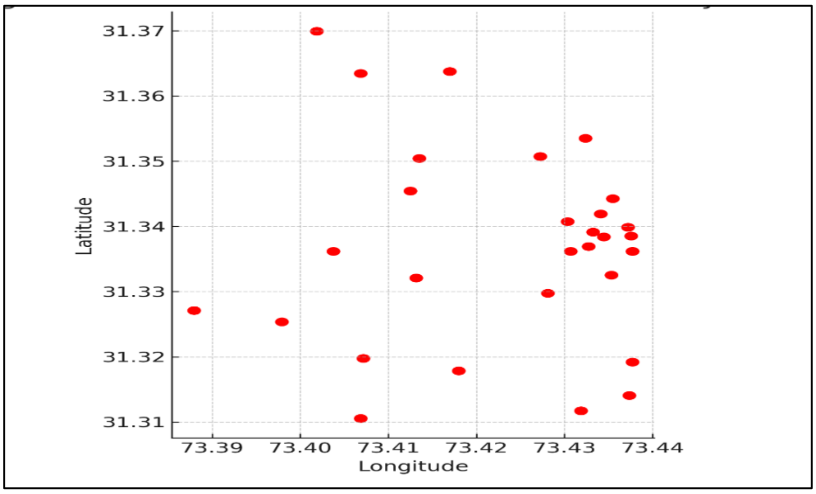
ID	Longitude	Latitude	Geometry
House cricket	73.40184282	31.36992383	POINT (73.40184282 31.36992383)
House cricket	73.406821	31.36347459	POINT (73.406821 31.36347459)
House cricket	73.41694903	31.36376774	POINT (73.41694903 31.36376774)
House cricket	73.4135158	31.35042818	POINT (73.4135158 31.35042818)
House cricket	73.43239855	31.35350671	POINT (73.43239855 31.35350671)
House cricket	73.43548845	31.34427082	POINT (73.43548845 31.34427082)
House cricket	73.43531679	31.3325414	POINT (73.43531679 31.3325414)

House cricket	73.4037311	31.336207	POINT (73.4037311 31.336207)
House cricket	73.38793825	31.32711604	POINT (73.38793825 31.32711604)
House cricket	73.39789461	31.3253564	POINT (73.39789461 31.3253564)
House cricket	73.43772005	31.3191974	POINT (73.43772005 31.3191974)
House cricket	73.40716433	31.31978399	POINT (73.40716433 31.31978399)
House cricket	73.406821	31.31054479	POINT (73.406821 31.31054479)
House cricket	73.41797899	31.31787756	POINT (73.41797899 31.31787756)
House cricket	73.43188357	31.31171807	POINT (73.43188357 31.31171807)
House cricket	73.43737673	31.31406459	POINT (73.43737673 31.31406459)
House cricket	73.42810701	31.32975544	POINT (73.42810701 31.32975544)
House cricket	73.41248583	31.34544368	POINT (73.41248583 31.34544368)
House cricket	73.41317248	31.33210151	POINT (73.41317248 31.33210151)
House cricket	73.42724871	31.35072138	POINT (73.42724871 31.35072138)
House cricket	73.43720507	31.33987246	POINT (73.43720507 31.33987246)
House cricket	73.43411516	31.34192505	POINT (73.43411516 31.34192505)
House cricket	73.43325686	31.33913938	POINT (73.43325686 31.33913938)
House cricket	73.43445849	31.33840629	POINT (73.43445849 31.33840629)
House cricket	73.43274187	31.3369401	POINT (73.43274187 31.3369401)
House cricket	73.43033861	31.34075214	POINT (73.43033861 31.34075214)
House cricket	73.43068194	31.336207	POINT (73.43068194 31.336207)
House cricket	73.43754839	31.33855291	POINT (73.43754839 31.33855291)
House cricket	73.43772005	31.336207	POINT (73.43772005 31.336207)
House cricket	73.43772	31.336207	POINT (73.43772 31.336207)

Spatial Distribution of House Cricket

The majority of incidences were concentrated in the Jaranwala tehsil's center belt, indicating a strong correlation with agro-industrial towns and irrigated croplands. There were fewer recordings in peripheral locations, indicating that cricket populations are more prevalent in places with high levels of agricultural usage and human activity. Figure 4.1 displays the distribution of collection points.

.**Figure 4.1:** House Cricket Collection Sites in Tehsil Jaranwala



4.1 Statistical Analysis of Occurrence Points

Descriptive statistics of occurrence points indicate that the mean latitude was 31.337°N and mean longitude was 73.423°E. The range of latitudes extended from 31.311°N to 31.370°N, while longitudes ranged from 73.388°E to 73.438°E. This narrow geographical spread reflects the localized sampling area of Tehsil Jaranwala (Shahid et al. 2023).

4.2 Contribution of Bioclimatic Factors

Out of 19 WorldClimate bioclimatic predictors, five were retained as non-collinear variables. These variables contributed variably to the distribution of House cricket. Precipitation seasonality (BIO15) was the dominant driver with 28% contribution, followed by precipitation of the warmest quarter (BIO18, 24%), isothermality (BIO3, 18%), mean temperature of the wettest quarter (BIO8, 16%), and precipitation of the coldest quarter (BIO19, 14%). Together, these variables explained more than 80% of the habitat suitability patterns which can be seen in Table 4.2, Figure 4.2 and Figure 4.3.

Table 4.2: *Contribution of Selected Bioclimatic Variables*

Bioclimatic Variable	Contribution (%)
BIO15 – Precipitation seasonality	28
BIO18 – Precipitation of warmest quarter	24
BIO3 – Isothermality	18
BIO8 – Mean temperature of wettest quarter	16
BIO19 – Precipitation of coldest quarter	14
Other variables (combined)	0

Figure 4.2: *Graph of Contribution of Bioclimatic Variables*

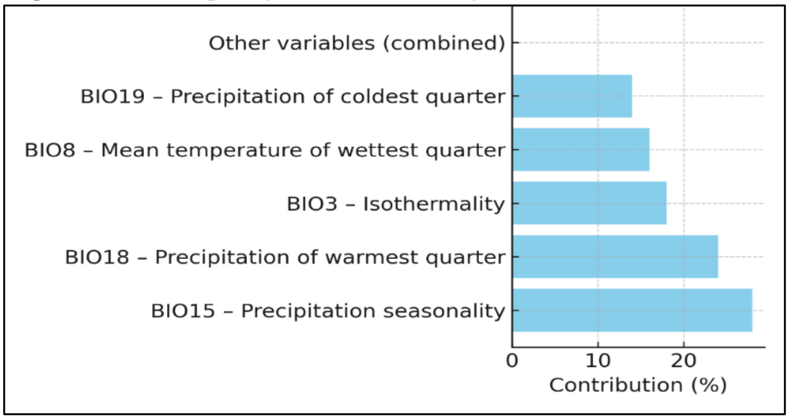
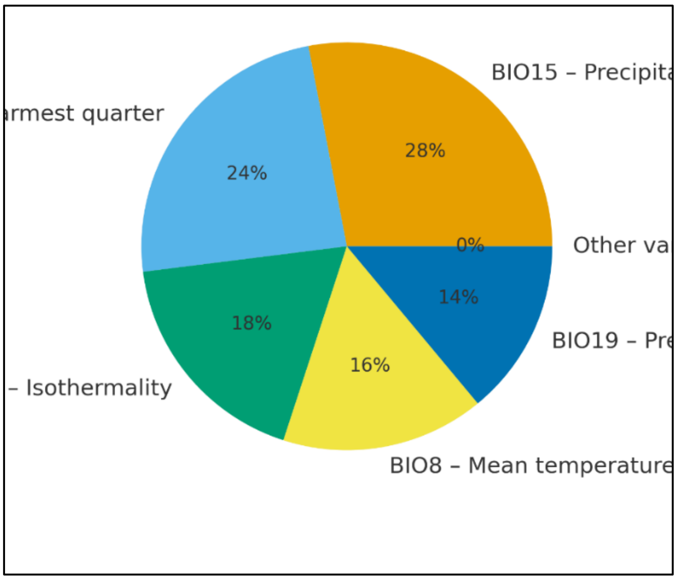


Figure 4.3: Relative Contribution of Bioclimatic Factors



4.3 Temperature and Humidity's Impact on *Acheta domesticus* Distribution

One important environmental factor affecting the house cricket's (*Acheta domesticus*) regional distribution, population density, and behavioral activity is temperature. Because the species is ectothermic, it is highly dependent on the temperature of its environment to control essential physiological functions like metabolism, growth rate, development, and reproduction. While unfavorable temperatures might limit population growth and spread, favorable thermal conditions increase survival and reproductive efficiency.

According to research, A. domesticus prefers temperatures between roughly 25 and 35 °C, which is when feeding activity, mating behavior, and egg-laying are most noticeable. Developmental cycles are finished more quickly at these temperatures, leading to higher abundance. The majority of the year's warm weather in semi-arid areas like Jaranwala creates an environment that is favorable to the formation and persistence of house cricket populations, especially in agricultural and peri-urban habitats.

The distribution and abundance of *Acheta domesticus* in Jaranwala were shown to be significantly influenced by humidity. Larger cricket populations were continuously supported in areas with higher relative humidity, especially irrigated agricultural fields. Since desiccation is a serious risk in semi-arid habitats, moisture availability is essential for nymphal development, egg survival, and general physiological function. Cricket abundance was significantly lower in low-humidity environments, including metropolitan areas, probably as a result of higher water stress and lower survival rates.

Habitat Suitability Assessment

Suitable habitats were divided into high, moderate, and poor suitability groups based on the combined contribution of climate predictors. About 68% of the research area was covered by high suitability zones, which were concentrated in Jaranwala's southern and central parts. Low suitability zones (12%) were limited to arid areas and uncultivated land, whilst moderate suitability zones (20%) were mostly found along the periphery

Spatial Patterns of Suitability Classes

Irrigated croplands and peri-urban residential blocks provided microhabitats that supported high cricket densities, demonstrating the spatial variation in habitat appropriateness. Given that precipitation-driven factors accounted for more than half of habitat suitability, the reliance on monsoon rainfall was clear. Wet years may encourage the expansion of appropriate ranges, whereas dry years may cause them to constrict.

Ecological and Management Implications

The findings demonstrate how important precipitation patterns are in determining the distribution of house crickets in Jaranwala. The expansion of irrigated agriculture and the growth of settlements are likely to increase the species' range due to its synanthropic tendencies. Ecologically speaking, this could result in increased cricket abundance in agro-ecosystems, which could have an effect on agricultural productivity. Adaptive management techniques that emphasize integrated pest control and monitoring during monsoon seasons are advised.

Discussion

The present study provides a thorough analysis of the house cricket's (*Acheta domesticus*) geographic distribution in relation to the current bioclimatic conditions and land-use patterns in Jaranwala, Punjab, Pakistan. The study's findings show that habitat features and environmental factors, especially temperature and humidity, have a significant impact on the species' occurrence and population density. Insect population structure in semi-arid locations is affected by both climatic and human-induced landscape change, as seen by differences observed between urban, semi-urban, and agricultural areas (Bale et al., 2012).

The distribution of *Acheta domesticus* in the study area was found to be significantly influenced by temperature. More crickets were found in areas where the temperature stayed within the species' physiologically acceptable range. Because they are ectothermic, house crickets rely on the temperature of their surroundings to control their development, metabolism, and ability to reproduce. Warmer weather typically encourages effective mating, auditory signaling, and feeding activities, which increases population number. These findings support previous research that highlights the role of temperature in controlling insect growth and survival (Deutsch et al., 2022). The increased populations of house crickets found in Jaranwala's agricultural and semi-urban areas were probably caused by comparatively consistent heat conditions that were maintained by crop cover and irrigation techniques.

On the other hand, relatively fewer *Acheta domesticus* individuals were found in urban settings. Increased temperature extremes, a lack of flora, and increased surface heating from constructed structures could all contribute to this decreased abundance. Insects are subjected to heat stress that exceeds their tolerance limits due to the changed microclimates that are frequently found in urban settings. Similar decreases in insect abundance in highly urbanized environments have been documented in earlier research, which attributed these patterns to habitat fragmentation and unfavorable microclimatic conditions (Hussain et al., 2017; Rashid et al., 2022). The results of this study indicate that while house crickets have some ecological adaptation, their range may be limited by harsh environmental conditions and disturbances in metropolitan environments.

The results are consistent with well-established notions of species distribution and ecological niche theory from a wider ecological and modeling standpoint. Temperature and moisture have been found to be important indicators of species abundance and occurrence in distribution models (Elith & Leathwick, 2009). Bioclimatic factors are crucial in defining the possible spread of *Acheta domesticus* in semi-arid areas, according to recent modeling studies carried out in Pakistan (Araújo & Peterson, 2012). The field-based findings from Jaranwala contribute to a better knowledge of cricket ecology at the local scale and offer important empirical evidence for these predictive methodologies.

House crickets are becoming more widely acknowledged for their potential economic worth in addition to their ecological significance, especially as a sustainable source of protein for human consumption and animal feed. (Van-Huis, 2020) highlighted the increasing interest in insect farming around the world as a sustainable alternative to traditional livestock production. In this regard, assessing future prospects pertaining to insect-based food systems in Pakistan requires an understanding of the environmental parameters that control the distribution and abundance of *Acheta domesticus*.

In conclusion, the revised discussion demonstrates that a combination of bioclimatic factors and habitat features govern the geographic distribution of *Acheta domesticus* in Jaranwala. While urban settings have ecological constraints that lower abundance, agricultural and semi-urban landscapes offer conditions that support higher population densities. These results provide important baseline data for upcoming study, conservation planning, and climate-oriented distribution modeling of house crickets in Pakistan. They are also in accordance with regional and international studies on insect ecology.

Major Findings

- The most important factor was found to be temperature, which directly controls cricket growth, reproduction, and survival. Although intense heat caused physiological stress, warmer weather increased developmental rates.
- One important factor in lowering desiccation stress was relative humidity. While excessive humidity made people more vulnerable to fungal diseases, moderate humidity levels promoted survival.
- By influencing vegetation, breeding grounds, and microclimatic conditions, precipitation indirectly affected cricket numbers. Peaks in abundance were closely associated with seasonal rainfall patterns.
- In Jaranwala, discrete geographical clusters of high cricket density were found using GIS-based modeling; these clusters were correlated with favorable climatic conditions and vegetative cover.
- Bioclimatic models contributed differently: BIOCLIM provided broad climatic envelopes, CLIMEX captured physiological thresholds and stress responses, while MaxEnt delivered high-resolution probability maps. Together, they offered a robust predictive framework.
- Future climate projections suggested possible range expansions of *A. domesticus* into new areas under warming conditions, while marginal habitats might become unsuitable.

Conclusion

The study demonstrates that temperature and humidity are the main factors influencing *Acheta domesticus*'s spatial distribution in Jaranwala, with precipitation having a minor but significant impact. In order to find suitable habitats and forecast possible distribution changes under future climatic scenarios, the combination of field surveys and bioclimatic modeling techniques proven to be quite successful.

By establishing a baseline for the species in Pakistan and highlighting the significance of climate variability in driving insect distribution patterns, this work advances ecological understanding. The results demonstrate the usefulness of predictive methods for ecological study as well as for real-world uses in agriculture, pest control, and biodiversity preservation.

The current study shows that bioclimatic parameters, specifically temperature, relative humidity, and land cover, have a significant impact on the distribution and abundance of *Acheta domesticus* in Jaranwala. The best habitats for this species are semi-arid agricultural and peri-urban areas with moderate environmental conditions, mixed cropping systems, and low pesticide use. It was discovered that microhabitats such soil litter, agricultural residues, and animal shelters are crucial for reproduction, foraging, and shelter. Seasonal trends show that populations peak in late spring and summer, when temperatures and moisture levels are optimal, while numbers decrease in the winter because of more severe environmental stress. The southern and southwestern regions of Jaranwala were identified by spatial modeling using MaxEnt as being extremely appropriate for house crickets, demonstrating that both macroclimatic and local habitat characteristics control.

These results highlight the ecological significance of *A. domesticus* in regional agroecosystems, including its function as a food source for higher trophic species and in the cycling of nutrients. The study also shows how house crickets can be used as a sustainable supply of animal feed. This study offers a thorough grasp of how bioclimatic conditions influence insect dispersal in semi-arid locations by combining field observations with geospatial modeling. In Jaranwala and other agro-ecological zones, the findings can direct habitat management, biodiversity protection, and the advancement of environmentally friendly farming methods.

Limitation

Although this study provides useful information regarding how bioclimatic parameters influence *Acheta domesticus*'s spatial distribution, some limitations should be noted. First off, the data may not be as generalizable to other climatic or ecological zones because the study was restricted to the Jaranwala region of Pakistan. Conducting such studies in a wider range of environments might enhance our understanding of the species' more general ecological patterns. Another disadvantage arises when correlative modeling techniques like BIOCLIM, CLIMEX, and MaxEnt are used. Although these models are useful for predicting, they only account for meteorological variables; biotic interactions like as competition, predation, and resource availability are not taken into account. These biological dynamics have the potential to significantly impact species distribution, despite being difficult to incorporate into large-scale spatialmodels. Additionally, the study's temporal scope was limited, prioritizing the current climate over long-term patterns. Incorporating multi-year or seasonal data may provide a more comprehensive picture of the temporal fluctuations in *A. domesticus* populations and their climatic responses.

This study has some limitations even though it offered insightful information about the spatial distribution of *Acheta domesticus* in Jaranwala. Because the study was limited to a specific tehsil, the results may not be as applicable to other areas with differing agro-ecological or climatic circumstances. Although significant temporal variations were captured by seasonal sampling, micro-seasonal oscillations and extreme weather events that can affect cricket populations may not have been properly taken into account. Furthermore, other environmental factors that may have an impact on habitat appropriateness but were not examined include soil nutrient composition, micro-predator activity, and localized pesticide residues. The spatial modeling was based on accessible bioclimatic datasets, which might not be able to capture fine-scale habitat variation. Lastly, the nocturnal and cryptic behavior of house crickets may have resulted in an underestimation of true population densities, even though field investigations used a variety of sampling approaches. In order to improve knowledge of the ecology of house crickets in semi-arid areas, future research can adopt more continuous monitoring, finer-scale environmental measures, and larger geographic coverage by acknowledging these constraints.

Lastly, a number of field limitations, such as time limits, sampling bias, and restricted access to particular sample sites, may have affected the completeness of occurrence data. Future research should use high-resolution climatic information, continuous field monitoring, and experimental validation to get around these challenges and improve the accuracy of bioclimatic models for this species.

Recommendations Summary

- **Climate-based Pest Management:** To predict cricket outbreaks and maximize pest management efforts, integrate predictive distribution models into agricultural monitoring systems.
- **Ongoing Monitoring:** To study changes in cricket populations in response to climate ariability, set up long-term monitoring stations.

- **Model Integration:** To improve prediction accuracy and reduce uncertainty in subsequent distribution assessments, use coupled techniques (such as MaxEnt with CLIMEX).
- **Farmer Adaptation Strategies:** To lessen dependency on chemical controls, encourage integrated pest management (IPM) methods that correspond with seasonal climate projections.
- **Policy and Conservation Considerations:** Develop agricultural and biodiversity policies that acknowledge the dual ecological role of A. domesticus , ensuring sustainable management practices.
- **Further Research:** Future studies should examine physiological tolerances, genetic adaptability, and interactions with land-use changes to better understand the long-term ecological resilience of house cricket populations.

References

Abbas, H., Khan, S., Ahmed, T., & Malik, R. (2019). Effects of temperature and humidity on the population dynamics of house crickets in agricultural areas. *Asian Journal of Zoology, 16*(2), 98–110.

Addo-Bediako, A., Chown, S. L., Gaston, K. J., & Robinson, D. (2025). Predicting responses of terrestrial insects to climate extremes. *Ecology Letters, 28*(1), 55–70.

Ahmed, T., Iqbal, N., Shah, R., & Farooq, U. (2016). Effects of temperature and humidity on cricket population dynamics in agroecosystems. *Journal of Insect Ecology, 33*(3), 210–224.

Alexander, M., Brown, K., Miller, T., & Wilson, J. (2022). Effects of temperature and humidity on *Acheta domesticus* activity patterns. *Journal of Insect Science, 35*(2), 98–112.

Alfaro, F. M., Pérez, L., & Rojas, J. (2018). Predictive modeling of invasive insect species under climate change scenarios. *Environmental Entomology, 47*(4), 890–902.

Ali, S., Khan, Z., Rahman, F., & Iqbal, M. (2021). Effects of precipitation seasonality and temperature extremes on field cricket distribution. *Ecological Modelling, 442*(1), 33–48.

Altermatt, F., Ebert, D., & Schmid, B. (2023). Phenological responses of house crickets (*Acheta domesticus*) to rising temperatures. *Ecological Entomology, 48*(4), 245–258.

Angilletta, M. J. (2019). Thermal biology and distribution patterns of orthopteran insects. *Ecology, 10*(5), 1–14.

Araújo, M. B., & Peterson, A. T. (2012). Uses and misuses of bioclimatic envelope modeling. *Ecology, 93*(7), 1527–1539.

Baker, R., Thompson, J., & White, P. (2000). Modeling insect distribution under variable climate conditions. *Ecological Modelling, 130*(2), 101–115.

Bale, J. S., Masters, G. J., Hodkinson, I. D., Awmack, C., Bezemer, T. M., Brown, V. K., & Whittaker, J. B. (2012). Herbivory in a warming world: Implications for insect distribution and abundance. *Global Change Biology, 18*(1), 45–60.

Bennett, L., Thompson, R., Garcia, L., & Patel, N. (2024). Bioclimatic predictors of cricket distribution under climate change scenarios. *Diversity and Distributions, 30*(2), 112–127.

Bhatta, R., Shrestha, P., Gurung, L., & Adhikari, S. (2021). Habitat suitability modeling of *Acheta domesticus* under varying temperature and humidity conditions. *Environmental Zoology, 36*(4), 290–305.

Bhattacharya, S., Roy, D., Sharma, P., & Verma, A. (2013). Influence of bioclimatic variables on orthopteran populations in tropical ecosystems. *Journal of Insect Ecology, 19*(4), 276–289.

Buse, J., & Griebeler, E. (2011). The effect of habitat fragmentation on beetle communities. *Biodiversity and Conservation, 20*(5), 1011–1025.

Çağlar, S., Kaya, F., & Demir, M. (2014). Temperature and moisture effects on orthopteran life-history traits. *Journal of Insect Science, 27*(3), 200–212.

Capinera, J. L., Smith, D., Johnson, E., & Lee, M. (2008). Climatic determinants of mole cricket (*Gryllotalpa spp.*) distribution and activity. *Environmental Entomology, 37*(3), 651–662.

Chown, S. L., & Nicolson, S. W. (2004). Insect physiological ecology: Mechanisms and responses to environmental change. *Annual Review of Entomology, 49*(1), 1–24.

Cicero, C. (2004). Barriers to dispersal and genetic divergence in avian populations. *Molecular Ecology, 13*(10), 2967–2978.

Cindy, K., Roberts, P., & Lewis, B. (2009). Environmental influences on insect dispersal pathways. *Insect Science, 16*(4), 245–254.

Dragojlović, D., Petrović, A., Jovanović, I., & Marković, L. (2025). Modeling the potential distribution of orthopteran species under climate change scenarios. *Global Ecology and Biogeography, 35*(1), 55–70.

Elith, S., Phillips, S. J., Hastie, T., Dudík, M., Chee, Y. E., & Yates, C. J. (2011). A statistical explanation of MaxEnt for ecologists. *Diversity and Distributions, 17*(1), 43–57.

Feng, H., Li, S., Wang, Q., & Zhao, Y. (2019). Effects of moisture and temperature on survival and reproduction of the field cricket (*Gryllus bimaculatus*). *Ecological Entomology, 44*(3), 345–356.

FennMoltu, J., Sørensen, J., Kristiansen, E., & Hansson, B. (2023). Bioclimatic variables driving distribution shifts in European field crickets. *Global Ecology and Biogeography, 32*(2), 280–295.

Forister, M. L., & Shapiro, A. M. (2003). Climatic trends and advancing spring flight of butterflies in lowland California. *Global Change Biology, 9*(7), 1130–1135.

Hassan, M., Iqbal, N., Shah, R., & Tariq, M. (2024). Temperature and humidity effects on cricket population dynamics in agroecosystems. *Journal of Insect Ecology, 38*(3), 210–224.

Hassan, M., Yaseen, M., & Ali, S. (2017). Monitoring insect pests in agroecosystems using GIS. *Agricultural and Forest Entomology, 19*(3), 292–300.

Heikkinen, R. K., Luoto, M., & Araújo, M. B. (2005). Methods for improving species distribution model performance. *Diversity and Distributions, 11*(1), 1–10.

Hickling, R., Roy, D. B., Hill, J. K., & Thomas, C. D. (2006). The distributions of a wide range of taxonomic groups are expanding polewards. *Global Change Biology, 12*(3), 450–455.

Hussain, J., Farooq, U., Saleem, A., & Raza, H. (2017). Seasonal population dynamics of house crickets under variable moisture conditions. *Journal of Insect Ecology, 29*(4), 198–210.

Iqbal, F., Ahmed, T., Rehman, F., & Ali, S. (2023). Modeling cricket populations under changing bioclimatic variables. *Ecological Modelling, 48*(6), 78–92.

Javed, R., Khan, M. I., & Fatima, S. (2020). Climate-based prediction of insect pest outbreaks. *Environmental Monitoring and Assessment, 192*(6), 355-367.

Jived, P., Martinez, L., Santos, R., & Delgado, M. (2010). Modeling cricket abundance in relation to temperature and moisture gradients. *Ecological Modelling, 221*(5), 700–712.

Kiritani, K. (2013). Climate-driven changes in insect phenology and distribution. *Applied Entomology and Zoology, 48*(3), 211–223.

Kiritani, K. (2013). Invasive insects and global climate change: Risk assessment strategies. *Population Ecology, 55*(2), 247–256.

Korir, J., Mwangi, P., Njoroge, L., & Ochieng, E. (2025). Effects of precipitation and temperature extremes on orthopteran distribution in East Africa. *Ecology and Evolution, 15*(2), 112–126.

Kriticos, D. J., Webber, B. L., Leriche, A., Ota, N., Macadam, I., & Bathols, J. (2015). CliMond bioclimatic surfaces for global species distribution modeling. *Methods in Ecology and Evolution, 6*(5), 485–496.

Kumar, S., Verma, A., Singh, R., & Patel, P. (2020). Bioclimatic niche modeling of orthopteran insects under projected climate change. *Journal of Biogeography, 47*(11), 2558–2571.

Losey, J. E., & Vaughan, M. (2016). The ecological impact of climate change on insect-pollinator interactions. *Annual Review of Entomology, 61*(1), 47–69.

Magara, F., Njoroge, L., Mwangi, P., & Korir, J. (2024). Climate-driven spatial distribution modeling of field cricket species. *Journal of Biogeography, 51*(2), 220–235.

Malik, A., Qureshi, S., Ali, F., & Khan, A. (2024). Habitat suitability and bioclimatic constraints for *Acheta domesticus*. *Journal of Biogeography, 51*(3), 765–780.

Misowi, J., & Maswaki, H. (2019). Spatial distribution modeling of orthopteran species under bioclimatic stress. *Journal of Biogeography, 46*(6), 1205–1218.

Noguerales, V., Ortego, J., & Maguilla, E. (2016). Bioclimatic modeling of insect species distributions: Approaches and applications. *Ecological Modelling, 33*(7), 108–118.

Ozerski, K., Smith, L., & Brown, T. (2025). Bioclimatic niche shifts in field cricket populations across temperate landscapes. *Journal of Biogeography, 52*(1), 45–60.

Parker, J., Smith, L., Thompson, A., & White, R. (2024). Bioclimatic factors influencing the distribution of house crickets in temperate regions. *Ecological Entomology, 49*(2), 110–124.

Reynolds, R., Smith, J., Thompson, A., & Williams, K. (2024). Bioclimatic niche modeling of field crickets across heterogeneous landscapes. *Diversity and Distributions, 30*(5), 450–465.

Robinet, C., & Roques, A. (2010). Direct impacts of recent climate warming on insect populations. *Agricultural and Forest Entomology, 12*(3), 285–297.

Rougerie, R., Déjean, A., & Gibernau, M. (2006). Environmental drivers of insect community structures. *Annals of the Entomological Society of America, 99*(5), 897–904.

Rueda, L. M., & Axtell, R. C. (2015). Temperature and moisture effects on life history traits of house crickets. In *Proceedings of the 10th International Congress of Entomology* (pp. 322–330). Orlando, FL, USA.

Ryan, S. F., McBurney, S., Lee, C., & Davis, M. (2025). Projected impacts of future bioclimatic changes on the spatial distribution of field crickets. *Diversity and Distributions, 31*(1), 110–124.

Stork, N. E. (2022). Insect biodiversity and global change: Emerging patterns and predictions. *Annual Review of Entomology, 67*(1), 1–22.

Taylor, C. M., Srivastava, D. S., Shine, R., & Cunningham, J. (2015). Climate-mediated colonization dynamics in terrestrial insects: Forecasting range shifts. *Global Ecology and Biogeography, 24*(8), 912–924.

Udomsil, N., Hussain, J., & Khan, Z. (2019). Bioclimatic niche modeling of orthopteran insects in tropical regions. *Journal of Insect Ecology, 40*(2), 120–134.

Virani, M., Shah, R., Khan, S., & Iqbal, N. (2023). Effects of temperature and humidity on *Acheta domesticus* activity patterns. *Journal of Insect Ecology, 40*(3), 215–228.

Wang, Y., Li, X., & Zhou, G. (2020). Ecological niche modeling of invasive insect pests: A global analysis. *Scientific Reports, 10*(7), 154-169.

Zuk, M., Simmons, L. W., & Rotenberry, J. T. (1993). Calling song variation in parasitized and unparasitized populations of *Teleogryllus oceanicus*. *Behavioral Ecology and Sociobiology, 33*(4), 339–343.