# Postprint: Simulation of Geographic Distribution of Locusta migratoria Outbreaks in China and Analysis of Bioclimatic Factors

**Authors:** Zhang Jie, Yang Zhang, Zhao Zhenyong, Li Min

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## Abstract

Locusta migratoria (Linnaeus), belonging to the family Oedipodidae and genus Locusta Linnaeus, is a major transcontinental agricultural pest. In China, it mainly includes L.migratoria manilensis (Meyen), [WTBX]L.migratoria[WTBZ] (Linnaeus), and L.migratoria tibetensis Chen. Understanding the geographic spatial distribution of locust disasters and predicting their potential suitable distribution areas is of great significance for the comprehensive prevention and control of locust disasters in China. By integrating geographic information records of disaster occurrences for the three Chinese locust types with biotic and environmental factor parameters, and applying the Maximum Entropy model (MaxEnt) and Geographic Information System (GIS) technology, we conducted simulation, prediction, and analysis of the spatial gradient patterns of geographic distribution, disaster risk probability, and risk levels for the three locust disasters in China at a 3 km × 3 km scale, and analyzed the key bioclimatic environmental factors affecting the distribution. The results showed that the simulated geographic distribution of locust disaster risk areas was highly consistent with historical records, and ROC testing indicated that the MaxEnt model has extremely high prediction reliability. The total areas of disaster risk zones for the three locust types—L.migratoria manilensis, [WTBX]L.migratoria[WTBZ], and L.migratoria tibetensis—in China were 315.87×104 km2, 395.80×104 km2, and 125.00×104 km2, respectively, accounting for 33.43%, 41.96%, and 13.25% of the national territory. The disaster risk areas of L.migratoria manilensis and [WTBX]L.migratoria[WTBZ] had a spatial overlap of 75.8×104 km2, mainly distributed in China' s agro-pastoral ecotone and areas to the south. The geographic gradients and distribution patterns of the disaster risk areas for the three locust types highly coincided with China' s three major natural geographic regions, and their geographic distribution patterns exhibited significant spatial heterogeneity in longitudinal and latitudinal gradients. Jackknife tests indicated that differences in the dominant bioclimatic impact factors among the three locust disasters led to significant differences in their geographic distribution patterns, indicating that the probability of locust disaster outbreaks is simultaneously constrained by both the adaptation of different locust species to climatic environments and geographic spatial isolation. The research results can provide a reference basis for cross-regional integrated prevention and control throughout the entire process, regional networked monitoring and joint control, and comprehensive management of locust disasters in China.

## Full Text

## Preamble

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**Authors:**
ZHANG Jie[1], ZHANG Yang[2], ZHAO Zhen-yong[3], LI Min

**Affiliations:**
[1] Poyang Lake Research Center, Jiangxi Academy of Sciences, Nanchang 330096, Jiangxi, China
[2] College of Resource and Environment, Fujian Agriculture and Forestry University, Fuzhou 350002, Fujian, China
[3] State Key Laboratory of Oasis Ecology and Desert Environment, Xinjiang Institute of Ecology and Geography, CAS, Urumqi 830011, Xinjiang, China
Nanchang First Specialized Secondary School, Nanchang 330013, Jiangxi, China

**Abstract:**

The migratory locust plague is one of the most persistent and damaging natural hazards in China. *Locusta migratoria* (Linnaeus) is the most widespread locust species and poses a significant threat to agricultural production, livelihoods, and food security. In this study, based on historical reported occurrence data of locust disasters, we applied MaxEnt niche models to predict and analyze the distribution area of locust outbreak risk for three main species of migratory locust in China. The Asian migratory locust (*Locusta migratoria migratoria* (Linnaeus)), the Oriental migratory locust (*Locusta migratoria manilensis* (Meyen)), and the Tibetan migratory locust (*Locusta migratoria tibetensis* Chen) were mapped at 3 km × 3 km resolution, and the degree of outbreak risk was evaluated. The results of the migratory locust plague probability modeling display a heterogeneous distribution of locust disaster risk probability in China. The area of low to high risk for the three locust species is 3,158,667 km$^2$, 3,958,002 km$^2$, and 1,250,037 km$^2$ respectively, accounting for 33.43%, 41.96%, and 13.25% of China' s total land area respectively. The disaster risk areas of *L. m. migratoria* and *L. m. manilensis* have a spatial overlap of 757,890 km$^2$, mainly distributed in the farming-pastoral ecotone and the southern region of China. The geographic patterns of the spatial distribution of locust outbreak risk for the three species along latitudinal and longitudinal gradients are highly consistent with the three major natural geographical areas in China. The predicted results were tested by ROC curves using suitability indexes (AUC), with the mean AUC across eight different spatial scales ranging from 0.924 to 0.987. The Jackknife test analysis reveals the linkages between locust infestation risk and main environmental factors, and the results show that the difference in dominant influence factors among the three migratory locust species leads to significant differences and heterogeneity in geographical distribution patterns in China. The results demonstrate that the probability of locust disaster outbreak is simultaneously restricted by the adaptability of different migratory locust species to the climate environment and their geographical space isolation. This study will provide vital information to help manage and control the outbreak risk of the migratory locust disaster.

**Keywords:** migratory locust plague; disaster outbreak risk; geographical distribution; suitability; MaxEnt

## 1 Introduction

*Locusta migratoria* (Linnaeus) belongs to the order Orthoptera, family Oedipodidae, genus *Locusta* Linnaeus. It is a globally distributed agricultural pest that causes severe damage to crops [2-3]. In China, the migratory locust has three subspecies: *L. m. manilensis* (Meyen), *L. m. migratoria* (Linnaeus), and *L. m. tibetensis* Chen [1-3]. The locust exhibits phase polyphenism, with solitary and gregarious phases showing significant differences in morphology, physiology, and behavior [4]. The gregarious phase forms large swarms that can migrate long distances, causing widespread agricultural damage.

Historical records show that locust plagues have frequently occurred in China, with the farming-pastoral ecotone and regions below 200 m elevation being particularly vulnerable [1-13]. Previous studies have analyzed the numerical taxonomy and relationships among different geographic populations of *L. migratoria* phase solitaria in China [13-14]. The spatial distribution of locust disasters is influenced by environmental factors such as climate, vegetation, and topography [15-17]. Temperature and precipitation are key climatic factors affecting locust development and population dynamics [18-21].

### 1.1 Data Collection and Processing

**1.1.1 Locust Disaster Data** Historical locust disaster data were obtained from the "Historical Atlas of Natural Disasters in China" (1:4,000,000 scale) and related literature. Using Adobe Illustrator CS6 and CorelDRAW X5, the data were digitized and processed in ESRI ArcGIS 9.1.

**1.1.2 Environmental Variables** Nineteen bioclimatic variables (BIO01-BIO19) were selected from the WorldClim database at 30-second spatial resolution, along with altitude (ALT) data. These variables represent annual trends, seasonality, and extreme environmental conditions affecting locust distribution. The correlation between variables was analyzed to avoid multicollinearity, and variables with correlation coefficients less than 0.8 were retained for modeling.

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## 2 Methods

### 2.1 MaxEnt Modeling

The MaxEnt (Maximum Entropy) model was used to predict the potential geographic distribution of locust disaster risk. The model was run with 75% of occurrence points for training and 25% for testing, with 10-fold cross-validation. The regularization multiplier was set to 1.0, and the maximum number of iterations was 500.

### 2.2 Model Evaluation

Model performance was evaluated using the area under the receiver operating characteristic curve (AUC). Jackknife tests were performed to assess variable importance. The final risk maps were classified into four categories: low risk (0-0.25), moderate risk (0.25-0.5), high risk (0.5-0.75), and very high risk (0.75-1.0).

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## 3 Results

### 3.1 Spatial Distribution Patterns of Locust Disaster Risk

The predicted risk distribution shows distinct geographic patterns for the three locust subspecies. The *L. m. migratoria* risk area covers 3,158,667 km² (33.43% of China' s land area), *L. m. manilensis* covers 3,958,002 km² (41.96%), and *L. m. tibetensis* covers 1,250,037 km² (13.25%). The overlap between *L. m. migratoria* and *L. m. manilensis* risk areas is 757,890 km², primarily located in the farming-pastoral ecotone and southern China.

The geographic range of *L. m. migratoria* extends from 101.08°E to 122.46°E and 18.25°N to 42.09°N, covering major agricultural regions including the North China Plain, Yangtze River Basin, and Northeast China. The *L. m. manilensis* range spans 73.88°E to 132.91°E and 18.36°N to 49.22°N, while *L. m. tibetensis* is restricted to the Tibetan Plateau region between 73.96°E-132.76°E and 32.86°N-49.22°N.

### 3.2 Latitudinal and Longitudinal Gradient Analysis

Risk probability shows significant variation along latitudinal and longitudinal gradients [FIGURE 3]. For *L. m. migratoria*, risk probability peaks at 77.5×10 km$^2$ between 93.36°-116.56°E ($R^2 = 0.98$, $P < 0.001$) and at 92.6×10 km$^2$ between 32.36°-37.56°N ($R^2 = 0.92$, $P < 0.01$). For *L. m. manilensis*, the highest risk occurs between 78.76°-104.76°E and 27.16°-37.97°N. The *L. m. tibetensis* risk is concentrated between 93.36°-116.56°E and 32.36°-37.56°N, with a peak contribution of 91.72% to the total risk area.

### 3.3 Environmental Factor Contributions

Jackknife analysis reveals that different environmental factors dominate for each subspecies [TABLE 4]. For *L. m. migratoria*, the top five contributing factors are: BIO06 (Mean Temperature of Wettest Quarter) at 27.5%, BIO18 (Precipitation of Warmest Quarter) at 19.5%, BIO03 (Isothermality) at 10.2%, BIO07 (Temperature Annual Range) at 7.5%, and BIO04 (Temperature Seasonality) at 7.2%, cumulatively explaining 71.92% of the model.

For *L. m. manilensis*, the dominant factors are BIO16 (Precipitation of Wettest Quarter) at 21.0%, BIO04 at 19.4%, BIO12 (Annual Precipitation) at 13.0%, BIO19 (Precipitation of Coldest Quarter) at 11.8%, and BIO13 (Precipitation Seasonality) at 6.8%, together accounting for 72.73% of the contribution.

For *L. m. tibetensis*, altitude (ALT) is the most important factor (57.6%), followed by BIO03 (23.9%), BIO09 (Mean Temperature of Driest Quarter), BIO18, and BIO15 (Precipitation Seasonality), with the top five factors explaining 91.7% of the model.

### 3.4 Model Validation

The mean AUC values across eight spatial scales range from 0.924 to 0.987, indicating excellent model performance. The Jackknife tests confirm that the models are robust and not overfitted.

## 4 Discussion

This study demonstrates that migratory locust disaster risk in China is heterogeneously distributed, with distinct geographic patterns for each subspecies. The differences in dominant environmental factors—temperature and precipitation variables for *L. m. migratoria* and *L. m. manilensis*, and altitude for *L. m. tibetensis*—reflect their adaptation to different ecological zones.

The substantial overlap (757,890 km$^2$) between *L. m. migratoria* and *L. m. manilensis* risk areas highlights the need for integrated management strategies in the farming-pastoral ecotone. The high-risk areas identified correspond to regions with suitable climate conditions, adequate vegetation, and appropriate elevation for locust breeding and development.

The MaxEnt model proved effective for predicting locust disaster risk, with AUC values consistently above 0.92. However, the model could be further improved by incorporating dynamic environmental data and human activity factors. Future research should focus on real-time monitoring and early warning systems based on these risk maps.

The results provide crucial information for targeted surveillance and preventive control measures, particularly in high-risk zones. Understanding the species-specific environmental drivers enables more efficient allocation of management resources and development of region-specific control strategies.

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