# DISTRIBUTION OF CLIMATIC SUITABILITY OF *PELLIONIA SCABRA* BENTH. (*URTICACEAE*) IN CHINA

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**Abstract.** *Pellionia scabra* Benth. (PSB), a traditional Chinese medicinal plant, is widely used as folk treatment for rheumatic diseases. Assessing the impact of climate change on habitat suitability is critical for PSB resource utilization and ecological conservation. In this study, the maximum entropy model (MaxEnt) and the Geographic Information System (ARCGIS) were applied to predict the distribution of PSB, and the contribution of variables was evaluated using Jackknife test. The area under the receiver operating characteristic curve (AUC) of the PSB geographic distribution model reached a very good standard, indicating that the model prediction results can be used in this study. The potential distribution of PSB was mainly in Guangxi, Guangdong, Fujian, Hunan, Jiangxi, Zhejiang, Taiwan, Chongqing, Guizhou, southeast of Sichuan, southwest of Hubei, and south of Anhui (adaptability index > 0.5). The comprehensive analysis of the contribution rate of climatic factors and jackknife experiment showed that the precipitation of driest quarter (35.4%), precipitation of driest month (25.0%), annual precipitation (11.4%), mean diurnal range (7.9%) and precipitation of wettest quarter (3.9%) were the most important factors affecting the potential distribution of PSB.
**Keywords:** *Maxent, ARCGIS, climate change, geographic information system, traditional Chinese medicine, Jackknife test*

## Introduction

*Pellionia scabra* Benth. (PSB) is plant species under the family Urticaceae. *P. scabra* is also known as alias rock amaranth (Hunan) and *Pellionia scabra* (Taiwan) (Liu, 2001; Yang et al., 1996). It is widely distributed in south China, southwest China, central China, east China, Taiwan China, Vietnam and Japan and is found at 300-1200 m above sea level (Wang et al., 2013). In the Chinese folk, this species is mainly used for the treatment of eye red swelling and pain, toothache, contusion sore furuncle swelling and pain, burns and scald, snake bites, trauma bleeding and other diseases (Wang et al., 2013). In recent years, PSB has been clinically used to treat patients with coronary heart disease and further found to have a good effect on the treatment of patients with hyperlipidemia (Zhu et al., 1994). Due to the important medicinal properties of this species, the wild resources of PSB have been greatly depleted, and the natural habitat of these plants may be gradually reduced due to climate change. Most previous studies have focused on its taxonomy (Lin et al., 2002), while others have focused on its chemical and nutritional composition (Wang et al., 2013; Zhu et al., 1994). However, so far, there has been little ecological research on the conservation and utilization of PSB resources.

In recent years, with the great promotion of ecological restoration, more stakeholders have begun to pay attention to the utilization and planting of species resources.


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Therefore, the research on the potential distribution and prediction of species resources has become necessary. The working principle of MaxEnt model is to determine the ecological niche occupied by species based on the known distribution information and ecological environmental factor variables, to predict the potential geographical distribution model of species (Ye et al., 2021; Song et al., 2020; Ji et al., 2021). Compared with Climax, Garp, Bioclim, Domain and other models, MaxEnt is the most widely used software to predict the potential distribution of species. At the same time, combined with the calibration, reclassification, modeling, and display functions of Arcgis, the ecological suitability map of species can make the potential geographical distribution of species more accurate, intuitive and specific (Zhang et al., 2021a; Zhuo et al., 2020; Wang et al., 2019; Li et al., 2022).

This study combines the MaxEnt model and Arcgis software to evaluate the suitable distribution areas of PSB under different climatic conditions. The objectives of the study were to (1) investigate the important climatic factors affecting the distribution of PSB; (2) analyse the data calculated by MaxEnt model in combination with ArcGIS10.5 analysis and mapping functions, and to comprehensively evaluate the suitable distribution areas of PSB in China. The results of the study can provide reference for the exploitation and utilization of PSB as traditional Chinese medicine and environmental resource management.

## Materials and methods

### *Species data source*

The distribution information of *P. scabra* was obtained from the Chinese Virtual Herbarium (http://www.cvh.ac.cn), the China National Nature Reserve Specimen Resource Sharing Platform (http://www.papc.cn/), and the field survey (*Fig. 1*), excluding the repeated longitude and latitude coordinates. A total of 67 PSB distribution information were collected, as shown in *Figure 2*. The data is divided into three columns by species name, longitude, and latitude, and stored in ".csv" format.

### *Climatic factor data*

Climatic factors data from Worldclim website (https://www.worldclim.org/data/index.html), which mainly includes BIO1 (Annual Mean Temperature), BIO2 (Mean Diurnal Range), BIO3 (Isothermality), BIO4 (Temperature Seasonality), BIO5 (Max Temperature of Warmest Month), BIO6 (Min Temperature of Coldest Month), BIO7 (Temperature Annual Range), BIO8 (Mean Temperature of Wettest Quarter), BIO9 (Mean Temperature of Driest Quarter), BIO10 (Mean Temperature of Warmest Quarter), BIO11 (Mean Temperature of Coldest Quarter), BIO12 (Annual Precipitation), BIO13 (Precipitation of Wettest Month), BIO14 (Precipitation of Driest Month), BIO15 (Precipitation Seasonality), BIO16 (Precipitation of Wettest Quarter), BIO17 (Precipitation of Driest Quarter), BIO18 (Precipitation of Warmest Quarter), BIO19 (Precipitation of Coldest Quarter) were accessed which has a total of 19 comprehensive climatic factors were included in the study. The above 19 comprehensive climate factor data were imported into ArcMap10.5 and stored in ".asc" format with the Species Distribution Model (SDM) Toolbox. The vector maps of administrative departments and provincial boundaries in China were used for basic map analysis by the National basic geographic information system, and the suitability distribution maps of species were generated by ArcMap10.5.


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***Figure 1.*** *Pellionia scabra Benth. collected in the wild*


***Figure 2.*** *Distribution map of Pellionia scabra Benth*

### *Maximum entropy model*

The ".csv" format of PSB distribution and 19 integrated climatic factors data were imported into MaxEnt3.3.3. 25% species distribution points were set as the test date, and the remaining 75% was the training date. The maximum number of iterations was $10^6$, and the model operation was repeated 10 times. According to the response curve, receiver-operating characteristic (ROC) and area under the receiver operating characteristic curve (AUC) were used to test the accuracy of MaxEnt model prediction results, jackknife method was used to test the weight, and other parameters were default software values.


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### *Reliability and accuracy analysis*

ROC curve is a highly recognized indicator for predicting and evaluating the potential distribution of species. AUC value is the area value under the ROC curve, which is used to evaluate the fitting degree of the model in species distribution prediction. When the AUC value ranges from 0.9 to 1, the model performance was excellent, 0.8–0.9 was very good, 0.7–0.8 was good, 0.6–0.7 was fair and 0.5–0.6 was poor.

### *Screening of climatic factors*

The distribution prediction results of MaxEnt simulation were imported into ArcMap for superposition operation, and the PSB climatic suitability zoning map based on dominant factors was drawn. According to the concept of ecological similarity and the reclassification function of ArcMap, manual classification was carried out, and finally four grade regions were divided, including high suitability area (≥50%), medium suitability area (30%-50%), low suitability area (10%-30%) and non-suitability area (≤10%).

## Results

### *Accuracy evaluation*

The prediction accuracy of the model is measured by value of AUC, which ranges from 0 to 1. The value of AUC is proportional to the strength of the model's judgment ability. The average training data of ROC curve of MaxEnt model is 0.976, greater than 0.9, and tends to 1, indicating that the PSB growth environment suitability calculated by MaxEnt model has high accuracy and reliability. As shown in *Figure 3*.


***Figure 3.*** *ROC curve of Maxent model for Pellionia scabra Benth.*


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### *Main climatic factors*

Climatic factors are the key to the quality formation of medicinal plants, and their selection will affect the accuracy prediction of the model. A total of 19 climatic factors were established in this model. After 10 calculations of MaxEnt model, there were 16 climatic factors with contribution rate remaining, and 9 climatic factors with contribution rate > 1% were selected for analysis. The total contribution rate of nine climatic factors was 96.7%, including precipitation of driest quarter (bio17), precipitation of driest month (bio14), annual precipitation (bio12), mean diurnal range (bio2), mean temperature (bio10), precipitation of wettest quarter (bio16), mean temperature of wettest quarter (bio8), temperature seasonality (bio4) and isothermality (bio3). The results are shown in *Table 1*. As can be seen from the jackknife analyses (*Fig. 4*), the weight order of each climatic factor on PSB distribution is as follows: precipitation of driest quarter (bio17), precipitation of driest month (bio14), annual precipitation (bio12), precipitation of coldest quarter (bio19), mean diurnal range (bio2), precipitation of wettest quarter (bio16), precipitation of wettest month (bio13), temperature annual range (bio7), precipitation of warmest quarter (bio18), min temperature of coldest month (bio6), mean temperature of driest quarter (bio9), annual mean temperature (bio1), Mean temperature of coldest quarter (bio11). After comprehensive analysis of the contribution rate of climatic factors and the results of jackknife analyses, the intersection part of climatic factors is taken. The influencing factors were precipitation of driest quarter (35.4%), precipitation of driest month (25.0%), annual precipitation (11.4%), mean diurnal range (7.9%) and precipitation of wettest quarter (3.9%). The cumulative contribution rate was 83.6%, and they were the main climatic factors affecting PSB suitability.

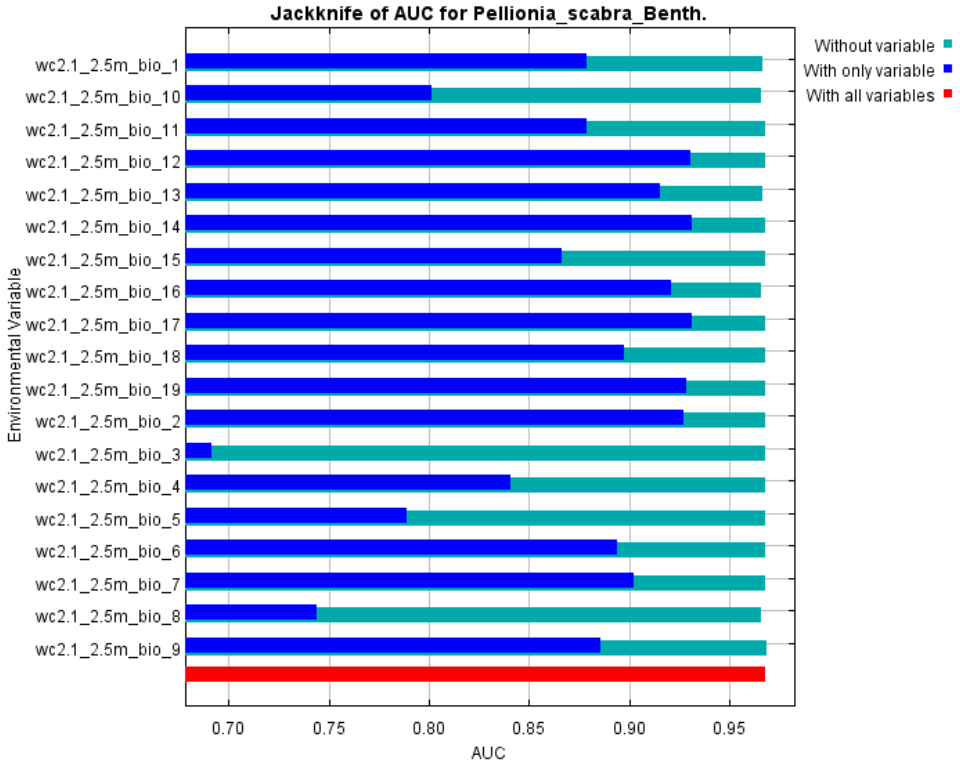


***Figure 4.*** *Results of the jackknife test of variables' contribution in modelling potentive distribution of Pellionia scabra Benth.*


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***Table 1.*** *Climatic factors affecting the distribution of Pellionia scabra Benth.*

| Factors | Name | Percent contribution (%) |
|---|---|---|
| bio17 | Precipitation of driest quarter | 35.4 |
| bio14 | Precipitation of driest month | 25.0 |
| bio12 | Annual precipitation | 11.4 |
| bio2 | Mean diurnal range (mean of monthly (max temp - min temp)) | 7.9 |
| bio10 | Mean temperature | 7.1 |
| bio16 | Precipitation of wettest quarter | 3.9 |
| bio8 | Mean temperature of wettest quarter | 3.6 |
| bio4 | Temperature seasonality (standard deviation ×100) | 1.6 |
| bio3 | Isothermality (bio2/bio7) (×100) | 1.1 |

## *Climatic suitability zoning*

The results of MaxEnt model operation were imported into ArcGIS10.5 software to obtain the climatic suitability of PSB, as shown in *Figure 5*. As can be seen from *Figure 5*, the distribution of PSB is mainly concentrated in the south of the Yangtze River, and the most suitable distribution areas include Guangxi, Guangdong, Fujian, Hunan, Jiangxi, Zhejiang, Taiwan, Chongqing, Guizhou, southeast of Sichuan, southwest of Hubei, and south of Anhui (*Table 2*).

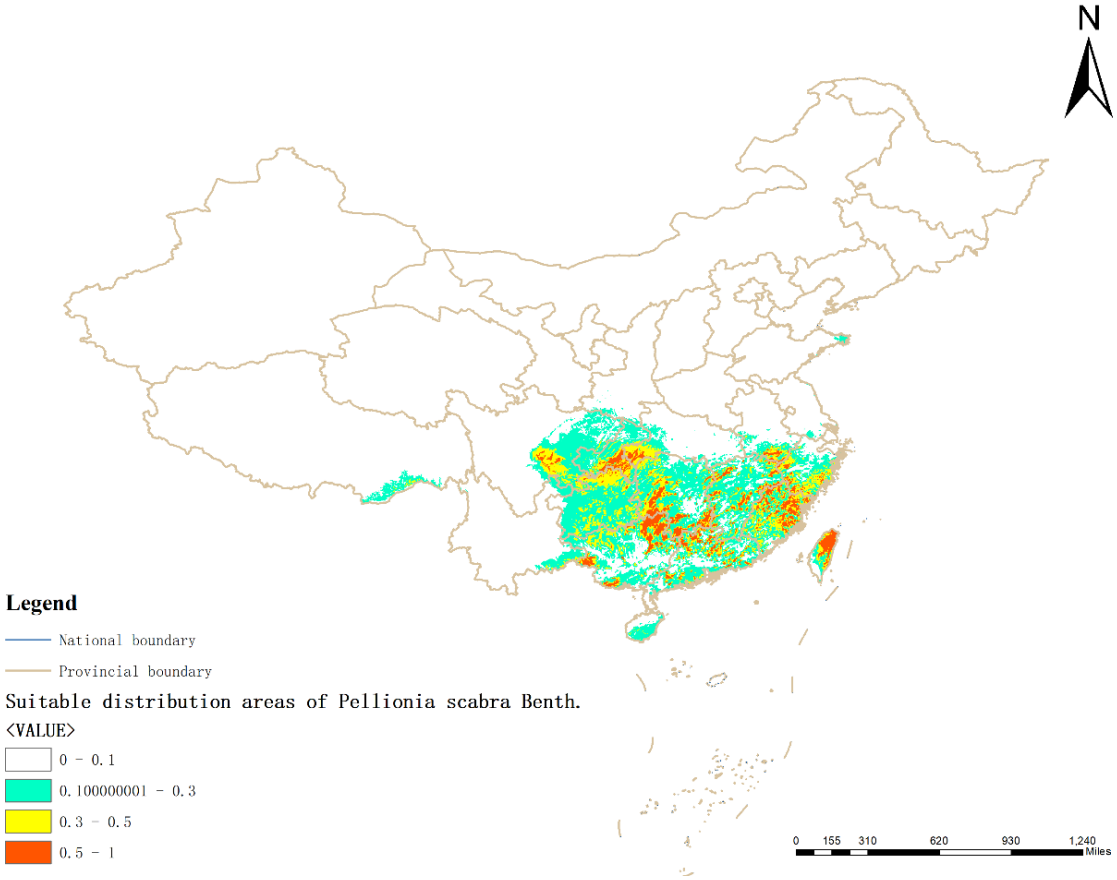


***Figure 5.*** *Pellionia scabra Benth. climatic suitability distribution area*


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***Table 2.*** *Climatic suitability distribution area of Pellionia scabra Benth. in China*

| Province | Climatic suitability distribution area |
|---|---|
| Guangxi | Guilin, Liuzhou, Baise, Chongzuo, Fangchenggang, Hezhou, Guigang, Yulin, Laibin, Hechi, Nanning |
| Guangdong | Shaoguan, Qingyuan, Zhaoqing, Heyuan, Maoming, Yangjiang, Jiangmen, Chaozhou, Shantou, Jieyang, Shanwei, Huizhou, Meizhou, Shenzhen, Dongguan |
| Fujian | Ningde, Nanping, Fuzhou, Shanming, Putian, Zhangzhou, Longyan, Quanzhou |
| Hunan | Yueyang, Zhuzhou, Chenzhou, Yongzhou, Hengyang, Huaihua, Jishou, Zhangjiajie, Shaoyang, Changde |
| Jiangxi | Jiujiang, Shangrao, Jingdezhen, Pingxiang, Yichun, Ganzhou, Fuzhou, Yingtan |
| Zhejiang | Hangzhou, Quzhou, Lishui, Wenzhou, Taizhou, Ningbo |
| Taiwan | Keelung, Taipeh, Ilan, Taoyuan, Hsinchu, Miaoli, Taichung, Nantou, Hualien, |
| Chongqing | Qianjiang, Youyang, Xiushan, Shizhu, Fengdu, Fuling, Nanchuan, Jiangjin, Wansheng, Qijiang, Pengshui, Wulong |
| Sichuan | Luzhou, Yibin, Neijiang, Leshan, Meishan, Ziyang, Yaan, Chengdu |
| Hubei | Enshi |
| Guizhou | Zunyi, Tongren, Qiandongnan |
| Anhui | Chizhou, Xuancheng, Huangshan |

## Discussion

MaxEnt model can find the maximum entropy of species distribution rule through incomplete information of species distribution (Phillips et al., 2006; Zhang et al., 2021b; Shogren et al., 2020), so as to predict the existence probability of species and determine the distribution area of species. In general, the sample quantity and sample on the space distribution of the directly related to the accuracy of the model prediction results and reliability (Cao et al., 2021), the more sample size model prediction results more accurate, but studies show MaxEnt model rules of procedure in the small sample size in the process of the simulation can offset excessive fitting trend (Zhao et al., 2018; Xu et al., 2022; Li et al., 2020), showing the predictions of a high quality. In this study, MaxEnt model was used to analyse the 67 distribution points of PSB, 25% of which were the test date and the remaining 75% were the training date. The adoption of the above approach was mainly based on a large number of literature studies (Cao et al., 2021; Xu et al., 2022; Zhan et al., 2022; Shi et al., 2021), which yielded conclusions with a high degree of accuracy and feasibility. Furthermore, the area under the subject operating characteristic (ROC) curve (AUC) provides a further measure of the accuracy of the model predictions. The accuracy test of the ROC curve shows that the AUC value is higher than 0.9, indicating that the model has a good prediction effect on PSB distribution area and has high reliability (Kottas et al., 2014). The jackknife experiment of MaxEnt model and the analysis of the response curve of climatic factors showed that precipitation (precipitation of driest quarter, precipitation of driest month, annual precipitation, Precipitation of Wettest Quarter) and temperature (mean diurnal range) are the main climatic factors affecting the difference of PSB's geographical spatial distribution, which is consistent with PSB preferring to live in shady places and near small streams.

ArcGIS analysis shows that PSB is mainly distributed in the Yangtze River basin and the provinces south of the Yangtze River, including Guangxi, Guangdong, Guizhou,


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southeastern Sichuan, Hunan, Jiangxi, southern Anhui, Zhejiang, Fujian, and Taiwan, in agreement with the descriptions in Flora of China. However, there are still some differences between the predicted distribution area and the actual distribution area of PSB. The results show that the low suitability area of PSB is widely distributed, especially in the south and southeast of Tibet, the south and east of Jiangsu, and the east of Shandong, which is larger than the current known distribution area of PSB.

PSB is a kind of common subshrub plant, which mainly grow in the valley stream or forest, and has unique application value in water environment protection and medicine. Based on our findings, this method can be used to predict the potential distribution of other medicinal plants, providing a valuable tool for species conservation and distribution. However, there are still some aspects of this study that need improvement. First, the potential distribution area predicted by the model may overestimate the actual ecological position of the species. This is because the species may not be able to spread to potential areas due to human disturbance, topographic barriers and species competition. Secondly, ecological factors other than those selected in this study may also influence the distribution range of PSB. Finally, a combination of an appropriate increase in sample size and field surveys would make the study of PSB regionalisation more comprehensive and reasonable.

## Conclusions

Based on the results and discussions presented above, the conclusions are the following:

(1) MaxEnt and Arcgis were used to model the climatic suitability of PSB, and correlation analysis was conducted on 19 climate factor variables. 5 climatic factors such as precipitation of driest quarter (bio17), precipitation of driest month (bio14), annual precipitation (bio12), mean diurnal range (bio19) and precipitation of wettest quarter (bio2), contributed more to the prediction results of PSB distribution. The cumulative contribution rate was 83.6%, and they were the main climatic factors affecting PSB suitability.

(2) PSB suitable areas in China are mainly distributed in Guangxi, Guangdong, Fujian, Hunan, Jiangxi, Taiwan, Chongqing, Guizhou. Southeast of Sichuan, Southwest of Hubei, and South of Anhui. Low suitability areas are distributed in Hainan, southern Shaanxi, southern and eastern Jiangsu, southeastern Yunnan, northeastern Sichuan, western Hunan, southern and southeastern Xizang, southwestern Anhui, and eastern Shandong.

(3) Of course, in practice, the distribution areas of plants need further field surveys. the prediction accuracy of the MaxEnt model increases with the sample size and eventually stabilises, so to improve the accuracy of the model prediction results, the sample size should be appropriately selected according to the differences of different species, and the sample size and the number of ecological factors should be appropriately increased.

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