Maximum entropy niche-based modeling (Maxent) of potential geographical distributions of *Lobesia botrana* (Lepidoptera: Tortricidae) in China

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Abstract. *Lobesia botrana* (Denis & Schiffermüller, 1775) (Lepidoptera: Tortricidae) is one of the most destructive pests of grape in the Palearctic region. The potential geographical distribution of this pest is important to agriculture security. In this study, Maxent and ArcGIS were used to project the potential geographical distribution of *L. botrana* in China under the current climate. The result indicated that *L. botrana* was suitable in most parts of middle and southern China and the Maxent model was highly accurate for the AUC value of 0.970. Jackknife analysis revealed that low temperature influence the potential distribution of *L. botrana*. This study would be a decision-support of surveillance and quarantine measures.

Keywords: *Lobesia botrana*, potential geographical distribution, Maxent, ArcGIS

Introduction

The grape berry moth, *Lobesia botrana* (Lepidoptera: Tortricidae) is an important pest of vineyards in many countries of the world [1,2]. It was first described in 1775 in Vienna, from samples collected in Italy. At present, it has spread to several European countries, North and West Africa and the Middle East. It was introduced into Japan before 1974 and recently into Chile [2]. In September 2009, it was reported for the first time from Napa County, CA in North America [3]. It is considered an economic pest of grape because the damage to the grape yield is twofold, direct damage by larvae feeding on all parts of the flower cluster in early spring, on green berries in mid summer, and on ripening fruit in late summer continuing through harvest, and indirect damage by fungi and bacterial growth [4]. In response to differences of climate, the number of generations completed by *L. botrana* within a year differs geographically. In general, two generations occur annually in northern areas of Europe, such as Austria, Germany, Switzerland and northern France, whereas three generations occur in southern Europe, including Mediterranean countries [5,6]. High temperature and low humidity provide optimal conditions for *L. botrana*, while rainy in conjunction with low temperature conditions seem to reduce the frequency of mating and, subsequently, egg production [7]. Optimal conditions for its activity occur at temperatures over 20°C and at 40%-70% relative humidity [8]. The Chinese government classified *L. brotrana* as one of the quarantine pests [9,10]. Although to date there is no distribution of *L. brotrana* is unknown in China, the potential risk of it spreading from its original introduction [2] or being repeatedly introducted into China is increasing as the international grape trade increases. It is important to predict the potential geographical distribution of *L. brotrana* in China, which will present a decision-support of surveillance and quarantine measures.

There are several methods to predict the potential geographical distribution of organisms. The most commonly used methods are secological niche model such as CLIMEX, GARP and Maxent[11]. Maxent is a machine learning method, which estimates the distribution of a species by finding the probability dispersal of maximum entropy, subject to constraints representing incomplete information about the distribution. The constraints are the expected value of each environmental variable that should match its average over sampling locations derived from environmental layers. The algorithm evaluates the suitability of each grid cell as a function of environmental variables of that cell [12]. Maxent has been extensively used though it was just recently released [13-19]. In this study, Maxent software is used to predict the potential geographical distribution of *L. botrana* in China.

1. Material and Method

1.1 Material

1.1.1 Occurrence Data of *L. botrana*

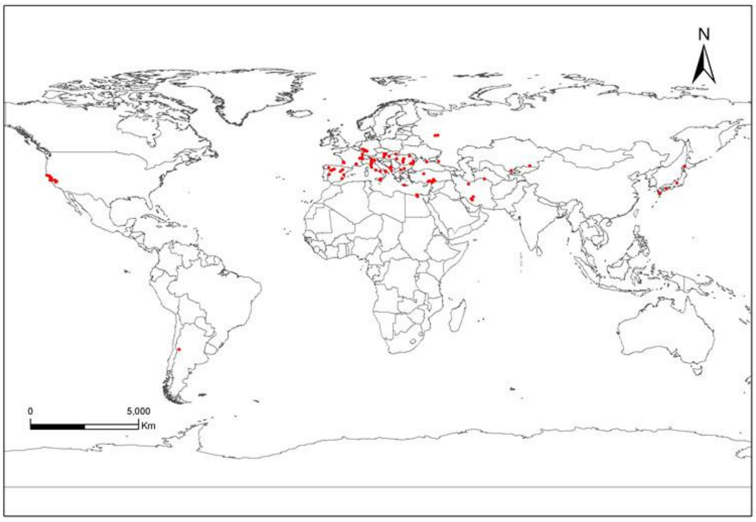

Fig. 1. The known distributions of *Lobesia botrana* in the world

The species distributional data are gathered from literature published, the specimen records in the museum or herbarium, and authoritative electronic resources. In addition, the data are also obtained through on-the-spot investigation [20]. In this study, the data came from the distribution of papers published abroad [21-30]. Localities were geo-referenced based either on coordinates provided directly in papers or on the official gazetteers (GeoNet, http://gnswww.nga.mil/geonames/GNS/index.jsp). The 95 unique records in Fig. 1 were obtained after checking the location. According to Maxent software requirements, the reference points were saved in csv format by species name, longitude, and latitude in order.

1.1.2 Software Tools

Maxent: Downloaded from http://www.cs.princeton.edu/~schapire/maxent/, ver. 3.3.3e.
ArcGIS: Purchased by the Plant Quarantine and Invasion Biology Laboratory of China Agricultural University (CAUPQL), ver. 9.3.

1.1.3 Environmental Variables

Nine biological climate variables (Table 1) were used as the main environmental data forprediction. The climate data with a resolution of 5arc-minutes in 1950-2000 were downloaded from http://www.diva-gis.org/climate.htm, and converted to asc format according to Maxent software requirements.

Table 1. Environmental variables used in potential distribution prediction of *L. botrana*

Environmental variables	
BIO6	Min temperature of coldest month
BIO19	Precipitation of coldest quarter
BIO11	Mean temperature of coldest quarter
BIO18	Precipitation of warmest quarter
BIO8	Mean temperature of warmest quarter
BIO2	Mean diurnal range
BIO4	Temperature seasonality
BIO3	Isotherm
BIO1	Annual mean temperature

1.1.4 Basic Geographic Data

The 1:400 million maps of national boundaries and province boundaries used in this paper were downloaded from the national fundamental geographic information system (http: // nfgis.nsdi.gov.cn/).

1.2 Methods

The distributional and environmental data were imported into the Maxent, and 75% of the distribution points were selected at random as the training dataset, the remaining points as the test dataset. Other parameters were the software defaults. The analysis resulted in the logistic format were outputted by ASCII type of file. The file was imported into ArcGIS and showed the results map. ArcGIS was also used to show the known distributions of *L. botrana* in the world.
The predicted results were usually classified based on the suitable values. The area under the curve (AUC) were directly calculated by Maxent. In addition, Maxent has a jackknife option through which

the importance of individual environmental variables can be estimated (Fig. 4).

2. Results and Analysis

We graphed the potential geographical distribution of *L. botrana* in China under current climate conditions (Fig. 2). In the predicted results, the appropriate values of known regions of occurrence were more than 0.006; the values of Hokkaido in Japan were 0.107, It was reported that this pest had occurred in this region [31]; the values of the regions all had severe occurrences were more than 0.17. Therefore, the suitable area was divided into 4 grades.

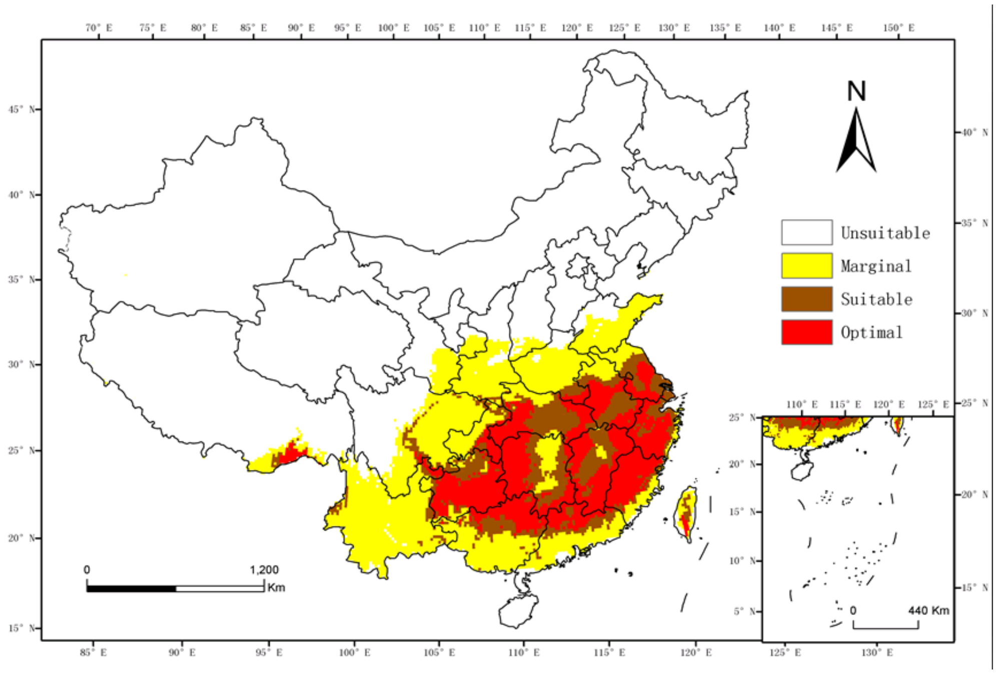

Fig. 2. The potential geographical distribution of *Lobesia botrana* in China under current climate conditions, as modeled using Maxent. White = unsuitable (Appropriate value≤0.006); yellow = marginal (0.006<Appropriate value≤0.1); brown = suitable (0.1<Appropriate value≤0.17) and red = optimal (0.17<Appropriate value≤1).

Optimal regions: middle and southern Jiangsu, Zhejiang and Anhui; eastern and western Hubei; Jiangxi except northern region; northern Guangdong and Guangxi; eastern and southern Guizhou; western Hunan; southeastern Chongqing and Tibet; southern Henan and Taiwan.

Suitable regions: Southeastern and western Jiangsu; Northern Zhejiang and Guizhou; Mid south parts of Anhui and Hubei; Eastern and middle Hunan; Middle Taiwan, Guangdong and Guangxi; Eastern and western Yunnan; a small portion of Sichuan; Shanghai.

Marginal regions: Northern Jiangsu, Anhui and Hubei; Southern Shaanxi, Shanxi, Fujian, Guangdong and Guangxi; Eastern Gansu; Middle Hunan and Henan; eastern and western Yunnan and Sichuan; Northwestern Chongqing; Southeastern Tibet; Shandong except northern regions; most parts of Taiwan.

Maxent is a new software, which predicts the geographical distribution of species, AUC values are regularly used to evaluate the ability of the models to predict independent test points accurately. AUC values of 0.5–0.7 are usually taken to indicate low accuracy. Values of 0.7–0.9 indicate useful applications, and values > 0.9 indicate high accuracy [32].The AUC value reached 0.970 in this study (Fig. 3), indicating that the Maxent model performed well and that its predictions of the potential distribution of *L. botrana* were highly accurate.

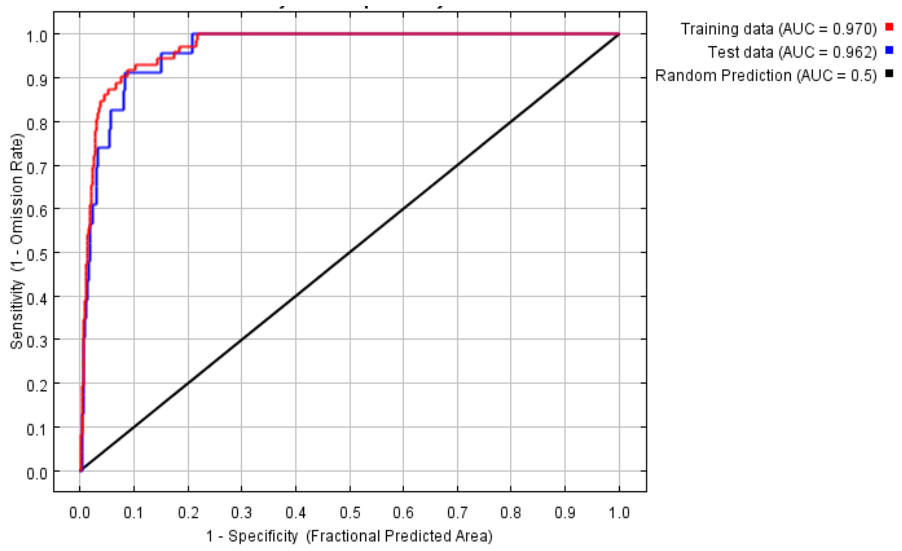

Fig. 3. Sensitivity vs. 1-Specificity for *Lobesia botrana*

3. Discussion

In order to make more accurate predictions using the Maxent model, we required a certain amount of accurate and representative geographical distribution of species known point data, but also needed to select the key environmental variables to establish a relatively accurate model. The foundation depends on having a good knowledge of the biological and ecological characteristics of species [33].

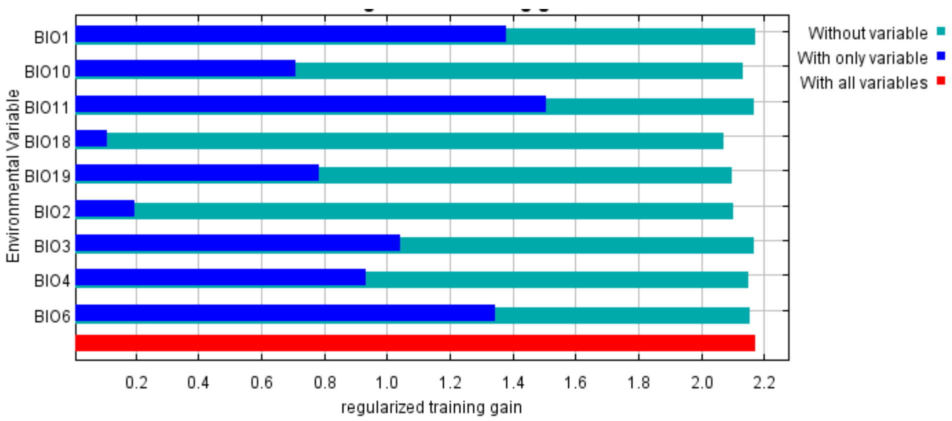

Fig.4. Jackknife test for environmental variable significance performed by Maxent

From Fig. 4, the environmental variable with the highest value is the mean temperature of coldest quarter, which contains the most valuable information. The Maxent background showed the min temperature of coldest month had some information which other variables did not have. This meant low temperatures had a great influence on the occurrence of this pest, which was consistent with previous studies, and also indicated that the study selected the correct environmental variables.The main host of *L. botrana* is grape which grows in most part of our country, so *L. botrana* is easy to establish itself once introduced into China. Therefore, the following management measures should be strengthened: (i) Fruit or planting material from areas where the pest has occurred should require a licensing system and strictly quarantined to prevent future spread of this pest; (ii) the regions predicted to be suitable for *L. botrana* should be monitored more rigorously to strengthen quarantine; (iii) long-term monitoring system should be established and the monitoring results should be reported regularly.

The process of invasive species entering and establishing in a new region is complex. In this study, we just considered the altitude and climate factors in environmental variables. Soil type, vegetation and climate warming on the distribution of this pest have not been considered for lack of corresponding digital base map. More research on the influence of environmental variables on survival of *L. botrana* are needed.

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