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Research Article

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The Potential Geographic Analysis and Prediction of *Acer tataricum* subsp. *Ginnala* in China

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Abstract

As a versatile and highly ornamental tree species, *Acer tataricum* subsp. *ginnala* is widely distributed in the contemporary ages (1950-2000). Predicting its potential geographic distribution not only has great significance for its protection, but also provides theoretical support for forecasting other endangered species geographic distribution. In this study, MaxEnt model combined the GIS spatial analysis techniques were used to predict the potential geographic distribution of *Acer tataricum* subsp. *ginnala* from the 2030s to the 2070s. The reasons for the changes of geographic distribution were analyzed based on the future climate characteristics of China. The present results showed that *Acer tataricum* subsp. *ginnala* had different levels of distribution in China from 2030s to 2070s. The geographic distribution of *Acer tataricum* subsp. *ginnala* was mainly in the Northeast and North China. However, the mainly geographic distribution of *Acer tataricum* subsp. *ginnala* had changed because of the effects of temperature, precipitation and other climatic factors. In special, the distribution was moved to eastern parts of Shandong, parts of Hubei, the bordering parts of Jiangsu and Anhui provinces. *Acer tataricum* subsp. *ginnala* suitable areas in the country had shown a obviously reduction trend with the advance of years, And the future climate of China will be not conducive to the growth of *Acer tataricum* subsp. *ginnala*. The information got in this study will be usefull for the *Acer tataricum* subsp. *ginnala* protection in China.

Keywords

Acer tataricum subsp. ginnala; MaxEnt models; Predict potential distribution; GIS; Geographic distribution

Introduction

The maximum theory is proposed in the middle of the twentieth century. Based on the principle [1,2], Steven Phillips programmed MaxEnt software by using JAVA language to predict the potential geographic distribution of species. Maxent took the data of the two groups in the operation process: the growing longitude and latitude of target species and the environmental variables of target area, main climate data [3]. The MaxEnt model predicted the possible distribution of the species in the target area according to the distribution of species and the real environment variables of distribution area. There are several domestic and foreign softwares currently to predict the distribution of many species, such as GARP and CLIME [4]. These softwares have relatively high requirements for isolation, and the experimental operation is also complex [5-7]. MaxEnt is superior to other software due to its simple operation, and it can still obtain satisfactory results even in the condition of incomplete data [8-10]. The MaxEnt model has been widely applied to predict the potential distribution of species. Many scholars have successfully predicted the potential distribution on plant, animal and microorganism by it. The method laid the foundation for the protection of animals and plants, and prevented the invasion of harmful species [11]. MaxEnt model is used to simulate the potential distribution of Gymnocarpos przewalskii in the northwest region of China [12]. Currently, by using trace points, natural environment and spatial data of human disturbance, the habitat suitability of golden monkey in the Qinling Mountains was evaluated [13]. It also was used to predict the potential distribution of 5 quarantine pathogens causing maize downy mildew in China [14]. Therefore, MaxEnt model will be useful for predicting the potential geographic distribution of *Acer tataricum* subsp. *ginnala* in China.

Acer tataricum subsp. *ginnala* is a kind of large perennial deciduous shrubs or small arbor in aceraceous family [15], with the resistant ability of cold, barren shelter, drying, strong disease and strong adaptability. It often grows below 800 metres above sea level on the sunny slopes or riparian wet grassland, and scatters or comes into jungle. *Acer tataricum* subsp. *ginnala* is favorable fragrant ornamental tree [16]. The gallic acid in leaves is widely used in medicine, dyes, chemicals etc. The latest research showed the drug made of gallic acid as raw material could inhibit the the growth or apoptosis of tumor cell [17], therefore gallic acid was used for anti-cancer. It is due to the importance of *Acer tataricum* subsp. *ginnala* in all areas that it is becoming a wide concern. At present, the research of *Acer tataricum* subsp. *ginnala* mainly focuseed on the phenotypic diversity [18], genetic diversity [19], callus tissue cultivating and the determination of gallic acid [20]. There is few information about the potential geographic distribution of *Acer tataricum* subsp. *ginnala* in China. This study takes *Acer tataricum* subsp. *ginnala* as the research object and predicts the potential distribution area in different climate conditions of the contemporary (1950-2000) and future (30s, 40s, 50s, 60s, 70s). All has been done to provide scientific reference for formulating protection strategy and a theoretical basis for the prediction and protection of endangered plants in the future.

Materials and Methods

The distribution data collection

110 *Acer tataricum* subsp. *ginnala* existing distribution points were collected from its known distribution range in this paper. Distribution data sources include: (1) field investigation; (2) literature database (Springer, Wiley InterScience, Chinese HowNet, ScienceDirect); (3) Chinese digital herbarium (http://www.cvh.org.cn/cms/); (4) the global biodiversity information network (Global Biodiversity Information Facility, GBIF; http://www.gbif.org). Part of the distribution record only refers to places description without providing the latitude and longitude data. In this case, the latitude and longitude coordinates were obtained by means of Google Earth v7.0.

According to the requriement of MaxEnt 3.3.3a the actual distribution of *Acer tataricum* subsp. *ginnala* was stored as format

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file with suffix name (CSV) by knowing distribution points, longitude and latitude order.

Meteorological data collection

The process took meteorological data affecting the distribution of plants as variables, including average annual temperature, seasonal variations of temperature, annual temperature change range, the highest points of the hottest month, the lowest temperature of the coldest month, annual precipitation, monthly precipitation, the precipitation in the driest month, 19 bio meteorological variables and altitude (Table 1). The contemporary(1950-2000) climate data and altitude data was collected from WorldClim (http://www.worldclim.org) and the climate data and altitude data of the next 50 years (the 30s, 40s, 50s, 60s, and 70s in the 21st Century) from the CCAFS.

Analysis method

Enter the distribution and environmental data into MaxEnt. Then adjust it according to the actual distribution quantity, select 25% of distribution randomly as a test set (test data), keep the remaining as training set (training data). Put the rest parameter settings for software default with the output format of ASCII raster layers. Import the layers into ArcGIS then analyse and process the date. The prediction results of the model were evaluated by ROC curve. The area under the curve (AUC) ranging from 0 to 1 was used as the model to predict the effect. The greater the value is, the better the prediction model is. The prediction model was established with the environmental distribution variables by using MaxEnt software, and then we used it to calculate the suitable probability of *Acer tataricum* subsp. *ginnala* in China (index). The analysis results were the output format of ASCII raster layer and then transformed into Arc-GIS v7.5 to get the distribution of *Acer tataricum* subsp. *ginnala* in the world. Then Chinese administrative map was overlaid to get *Acer tataricum subsp. ginnala* prediction distribution map in China

Results

Select the environment variables

After a series of jackknife screening, 6 environmental factors mainly influencing *Acer tataricum* subsp. *ginnala* distribution were found: the average monthly precipitation in wet (140 mm) with the contribution rate of 30.2% (Figure 1A), the seasonal variation coefficient of temperature (8500 to 10000) with the contribution rate of 25.8% (Figure 1B), the annual average temperature (10 ~ 15 degrees) with the contribution rate of 17.5% (Figure 1C), the average temperature in dry season (0 ~ 6 degrees) with the contribution rate of 10.5% (Figure 1D), the average precipitation in wet season(1300 mm) with the contribution rate of 10.1% (Figure 1E), the highest temperature in the hottest month (27 ~ 31 degrees) with the contribution rate of 3.7% (Figure 1F). The cumulative contribution of 6 environmental factors was 97.8%. The top three of contribution rate (precipitation in the wettest month, seasonal temperature variation coefficient, the average annual temperature) were probably the primary climatic conditions that determine the geographic distribution of *Acer tataricum* subsp. *Ginnala.*

Prove the prediction results

The operation results of MaxEnt model could automatically generate ROC curve [21]. The ROC curve *of Acer tataricum* subsp. *ginnala* prediction results, the average AUC value of the training data and test data were all above 0.90, which prove high accuracy for the prediction of the potential distribution of *Acer tataricum* subsp. *ginnala*

Potential geographic distribution forecast map of *Acer ginnala*

The geographic distribution (Mainly geographic distribution, Moderately geographic distribution and lowly geographic distribution) of *Acer tataricum* subsp. *ginnala* was wide in contemporary (1950-2000) China (Figure 2). It included: (1) the northwest including Gansu, southern Ningxia, southern Shaanxi, the northern part of the area; (2) the North China including Beijing, Tianjin, Hebei, most of Shanxi, parts of bordering of Shanxi, Southeast Inner Mongolia and Shaanxi; (3) the East China including Shandong, Anhui, most part of Jiangsu; (4) the Northeast China including Liaoning, Jilin and much of the southern area of Heilongjiang; (5) the Central China including Henan, Hubei, Northwestern Hunan and Northern Jiangxi area; (6) the Southwest areas including northern Guizhou, eastern Chongqing and Sichuan. Among these areas, mainly geographic distribution was distributed in Western of Liaoning, Eastern Hebei and Tianjin, Beijing. Moderately geographic distribution was located in central Hebei, parts of Eastern Inner Mongolia and Shandong North area.

From the distribution map in the 30's (Figure 3), the whole distribution area of *Acer tataricum* subsp. *ginnala* did not change much, but there were signs of geographic distribution going southward. Specifically, the distribution area in the northern part of Inner Mongolia and the Heilongjiang were reduced, while in the southern region of Sichuan, Guizhou, Hunan, Jiangxi expanded significantly. Mainly geographic distribution also transfered from western Liaoning, Eastern Hebei to Eastern Shandong, small parts of central Hubei, small parts of the bordering of central Jiangsu and Anhui. Moderately geographic distribution was mainly in Western Liaoning, Eastern Hebei and Shandong, the central region of Hubei.

In the distribution map of the 40's (Figure 3), the overall distribution range of *Acer tataricum* subsp. *ginnala* had a signs

Table 1: The main meteorological factors affecting the distribution of plants.

Date Titles	Name
bio1	Annual Mean Temperature
bio 2	Mean Diumal Range(Mean of monthly (max temp-min temp))
bio 3	Isothermality (BIO2/BIO7)(*100)
bio 4	Temperature Seasonality(standard deviation*100)
bio 5	Max Temperature of Warmest Month
bio 6	Min Temperature of Coldest Month
bio 7	Temperature Annual Range (BIO5-BIO6)
bio 8	Mean Temperature of Wettest Quarter
bio 9	Mean Temperature of Driest Quarter
bio 10	Mean Temperature of Warmest Quarter
bio 11	Mean Temperature of Coldest Quarter
bio 12	Annual Precipitation
bio 13	Precipitation of Wettest Month
bio 14	Precipitation of Driest Month
bio 15	Precipitation Seasonality(Coefficient of Variation)
bio 16	Precipitation of Wettest Quarter
bio 17	Precipitation of Driest Quarter
bio 18	Precipitation of Warmest Quarter
bio 19	Precipitation of Coldest Quarter
bio 20	Altitude

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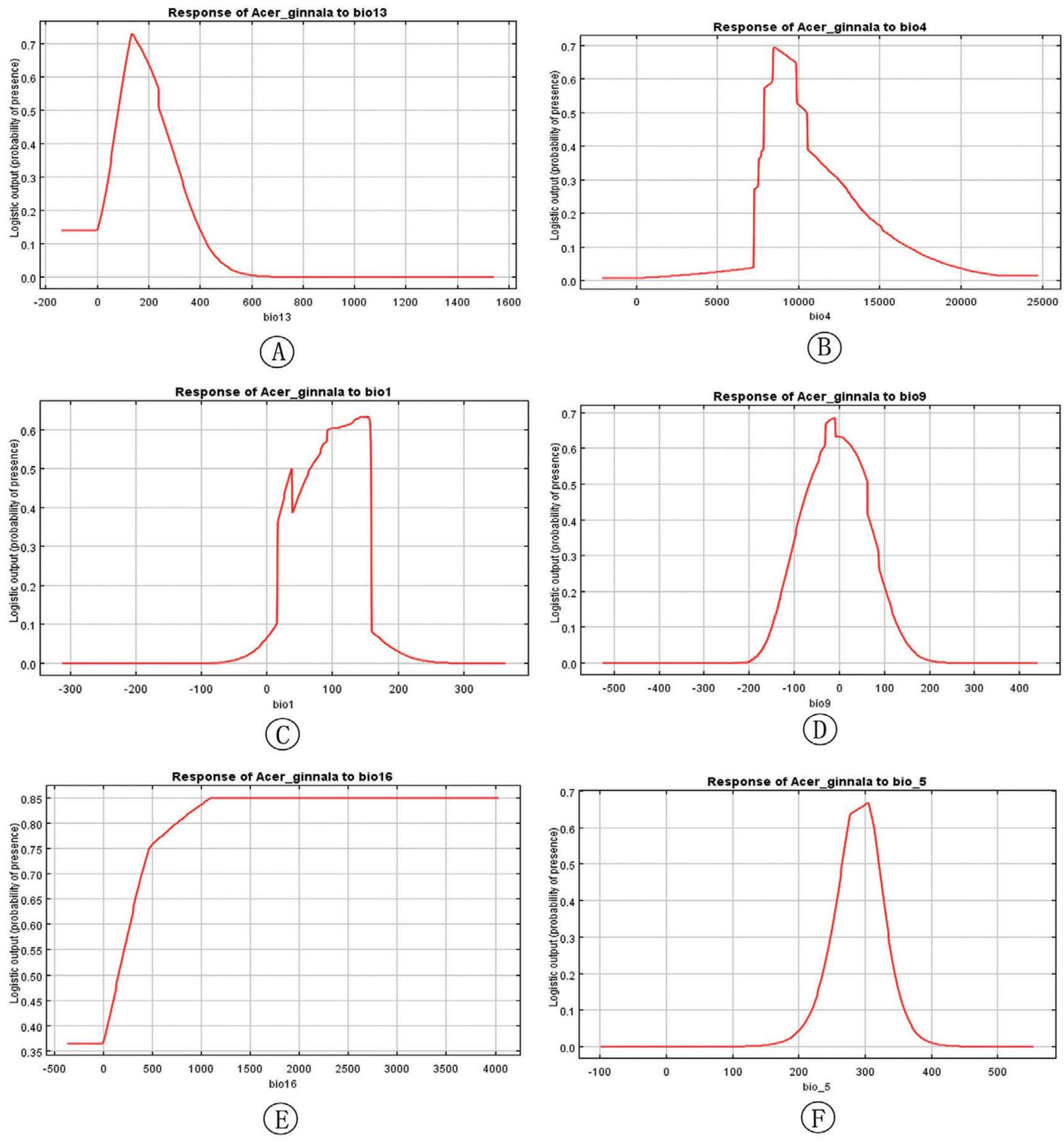

Figure 1: Six main climate factors response curve.

of expanding. Specifically, the suitable area expanded to different degree in Inner Mongolia, Heilongjiang, Hunan and Jiangxi, and also appeared in Zhejiang. Among these areas, mainly geographic distribution located western Liaoning, eastern Shandong, and southeastern Shaanxi, central Hubei minority area. Moderately geographic distribution covered the eastern regions of Inner Mongolia and most of central Hubei.

The distribution map of the 50's (Figure 3) showed there was the trend of reducing for *Acer tataricum* subsp. *ginnala* geographic distribution. Specifically, it decreased in Inner Mongolia, Heilongjiang, Guizhou, Shanxi, Shaanxi and significantly in Sichuan, while it was expanding in Hunan, Jiangxi, Fujian province. Mainly geographic distribution was located in small parts of central Shandong, part of the bordering regions of Liaoning and Hebei. Moderately geographic distribution was only in Hubei, Jiangxi, Shandong, Liaoning, Hebei.

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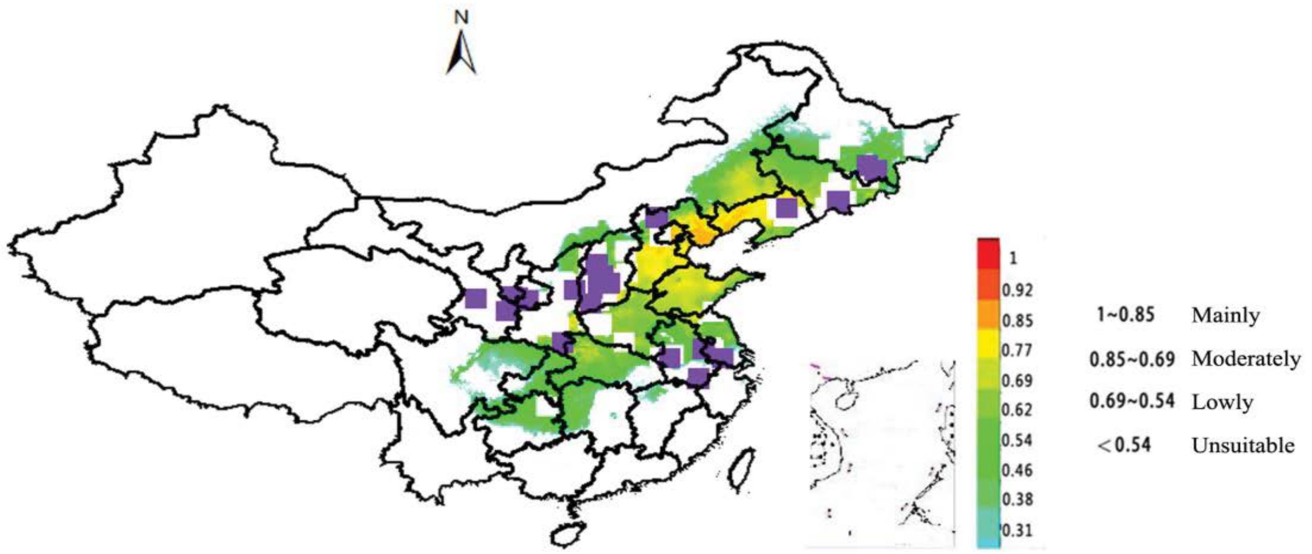

Figure 2: The geographic distribution of *Acer tataricum* subsp. *ginnala* in contemporary China.

In the 60's distribution map (Figure 3), *Acer tataricum* subsp. *ginnala* geographic distribution significantly reduced. The specific situation was the Inner Mongolia, Shaanxi, Sichuan, Chongqing, Guizhou, Hunan, Jiangxi were no longer suitable areas for *Acer tataricum* subsp. *ginnala*. In Jilin, Hebei, Shanxi, Hubei, the geographic distribution was significantly reduced. The geographic distribution in Heilongjiang also transfered to the east. Mainly geographic distribution almost disappears. Moderately geographic distribution was only small parts of central and Northeast of China,

Compared with the 60's, the distribution map of 70's (Figure 3) also showed *Acer tataricum* subsp. *ginnala* geographic distribution remained a reduce tendency. Specifically, Zhejiang and Fujian were not geographic distribution for *Acer tataricum* subsp. *ginnala* . The geographic distribution in Heilongjiang, Jilin, and the eastern region of Hubei were furtherly reduced, while Chongqing, Guizhou, the western region of Hubei were becoming the geographic distribution. The mainly geographic distribution was still not visible. Moderately geographic distribution was Hebei, Shandong, and little parts of Shaanxi and Henan border.

The regional distribution of *Acer tataricum* subsp. *ginnala* in China from contemperary years (1950-2000) to the 30s of the 21st Century showed the signs of going southward, especially the mainly geographic distribution migrated to eastern Shandong and most of Jiangsu from western Liaoning and eastern Hebei. In the 40s, the mainly geographic distribution of *Acer tataricum* subsp. *ginnala* was obviously reduced. It distributed only in the eastern parts of Shandong and Liaoning. In the 50s, *Acer tataricum* subsp. *ginnala* geographic distribution had an obvious decreasing trend, and the mainly geographic distribution also decreased slightly. The mainly geographic distribution was only in Shandong, little parts of Henan and Liaoning border area. Compared with 50s, *Acer tataricum* subsp. *ginnala* geographic distribution was much smaller in the 60's, and the mainly geographic distribution almost disappeared. In the 70s, it was still in decline compared to the 60's. Different provinces have different degrees of reduction, and the mainly geographic distribution was still not visible.

The change trend of the climatic factors

The climate conditions of *Acer tataricum* subsp. *ginnala* geographic distribution was compared in this study. The annual average temperature in 2050s increased by about 3 degrees Celsius (Table 2), the precipitation of wettest month remained unchanged, the seasonal temperature variation coefficient increased by about 450-1700 (Table 2). While in 70's, the annual average temperature dropped by 0.3 degrees Celsius and the rainfall did not change obviously (Table 2). The seasonal variation coefficient of temperature declined to 6327-14895 (Table 2). Compared with the contemporary, the annual average temperature was still rising 3 degrees Celsius or so (Table 2), and the precipitation of the wettest month expanded the scope of 104-305mm (Table 2), the seasonal variation coefficient of temperature turned close to the scope of contemporary. On the whole, the overall climate characteristics of the future was that temperature was rising and rainfall was decreasing from now to the middle of this century. By the end of this century the temperature decrease slightly and the rainfall remained the same as the middle by the end of this century.

The result of climate factor ' change on geographic distribution

The mainly geographic distribution of contemporary was concentrated in the areas of North China and part of western Liaoning. Because the climate of the North China belonged to temperate monsoon climate. During 1950~2000, the annual average temperature in North China was 6~13 degrees Celsius (Figure 4), and the annual average temperature was rising in nearly 50 years [22]. Light and heat resources were abundant among these years [23,24]. Western Liaoning Province was temperate monsoon climate. The precipitation of wettest month was 120~190 mm (Figure 6) and the annual average temperature at 6.3~9.8 degrees (Figure 4). All of these climatic conditions of these areas were close to the optimum climatic factors of *Acer tatarricum* subsp. *ginnala*, so they growed concentratedly in these areas.

The whole area of *Acer tataricum* subsp. *ginnala* did not change much in 30's compared to that in contemporary time, but there

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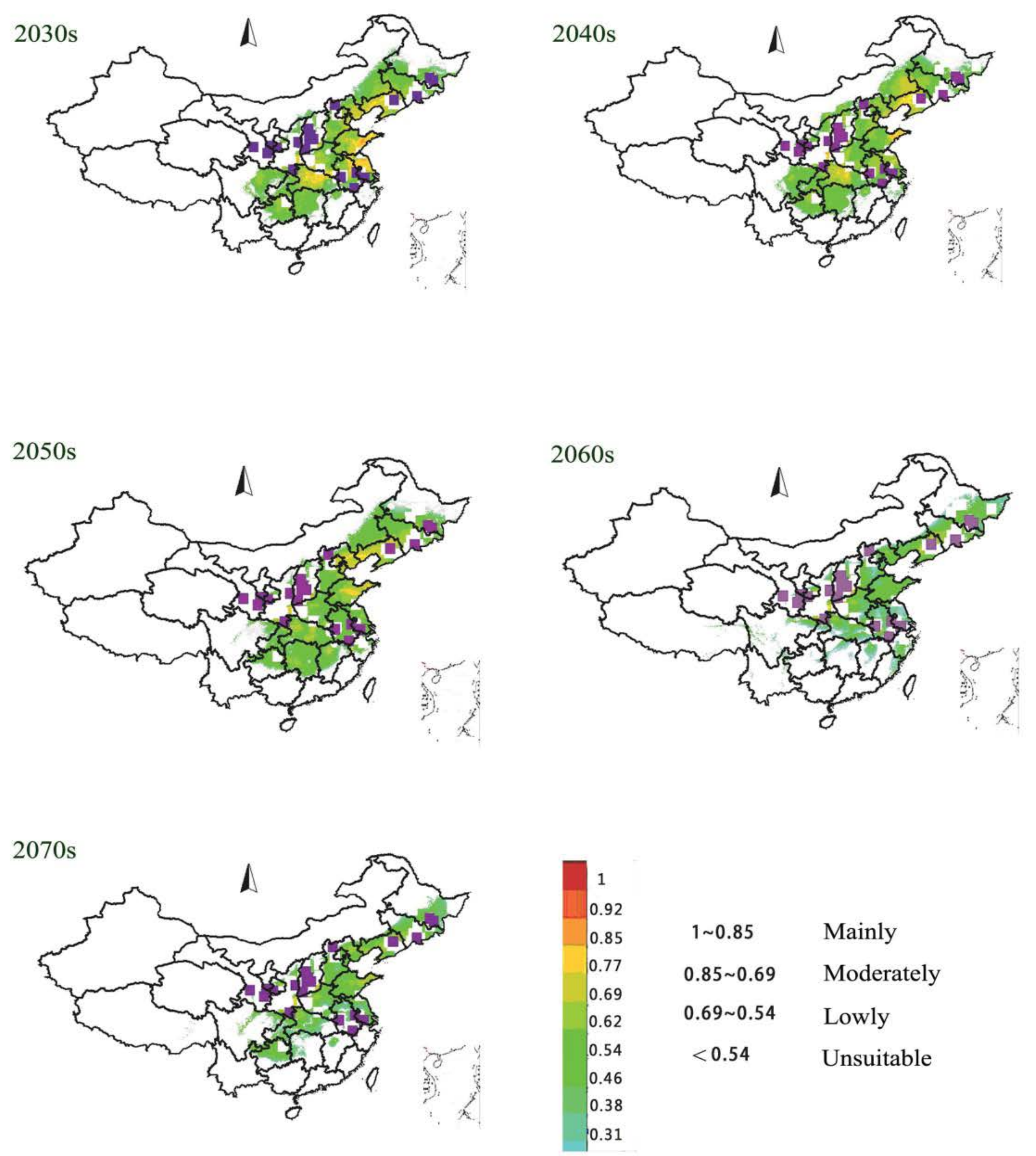

Figure 3: The geographic distribution of *Acer tataricum* subsp. *ginnala* in the future of China.

were signs of geographic distribution moving towards the south. The mainly geographic distribution moved from western Liaoning and central Hebei to Eastern Shandong, small parts of central Hubei and parts of the bordering area of central Jiangsu and Anhui. It is noted that in the 30's climatic conditions did not change much, so the whole geographic distribution maintained a stable state. The transfer of mainly geographic distribution may result from the changes of several major factors in these areas. For example, the weather may be warm and precipitation may increase in the future in Northeast area. However the increase of precipitation was not enough to offset the expend caused by enhanced evaporation and transpiration, it is not conducive for centralized growth of *Acer tataricum* subsp. *ginnala*.

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Table 2: Based on RCP45 scenario *Acer tataricum* subsp. *ginnala* suitable areas within the provincial climate factor changes.

Climatic factors	**Decade**		
	contemporary	**2050s**	**2070s**
Annual Mean temperature	3. 3-19. 5	6. 2-21. 9	5. 8-21. 6
Temperature Seasonality	6505-14980	6969-16680	6327-14895
Precipitation of Wettest Month	122-292	103-294	104-305

Note: RCP45 came from the intergovernment panel on climate change (IPCC5), published in the future climate change scenarios.

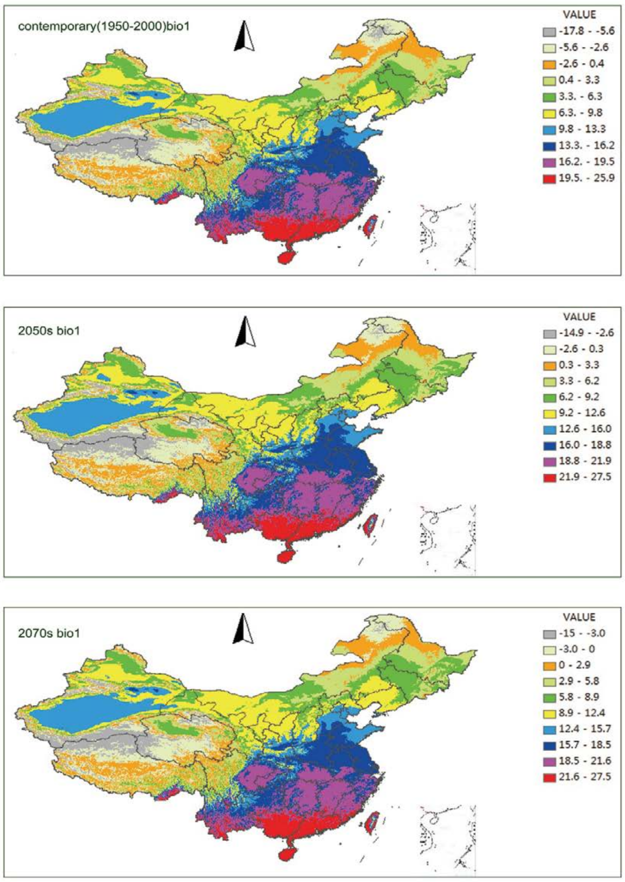

Figure 4: The changing trend of bio1 in contemporary (1950-2000), 2050 (average for 2041-2060), 2070 (average for 2061-2080).

The distribution area moved to more suitable area. While, in the warming region of the northeast, such as Liaoning [25], the minimum temperature increased and precipitation rised, which may provide wet environment to a certain extent for the growth of *Acer tataricum* subsp. *ginnala*. Liaoning was therefore the mainly geographic distribution for *Acer tataricum* subsp. *ginnala*.

From 40s to 60s *Acer tataricum* subsp. *ginnala* geographic distribution was significantly reduced, and the mainly geographic distribution area almost disappeared. In the mainly geographic distribution (Western Liaoning, southeastern Shaanxi and Eastern Shandong), the annual average temperature risesed by 3 degrees celsius (Figure 4). In addition, rainfall was below that in the contemporary (1950-2000) in these areas. Temperature increase was conducive to improving the conditions of heat current, but the reduction of precipitation could not compensate water evaporation caused by enhanced transpiration. Seasonal variation coefficient of temperature was higher than that of *Acer tataricum* subsp. *ginnala* suitable interval in 10376-13011(Figure 5). The climate was not suitable for *Acer tataricum* subsp. *ginnala* to grow beacuse of these changes. The mainly geographic distribution almost disappeared. From the overall trend in the 70s, the mainly geographic distribution was still shrinking, but the dropping rate was relatively slow than in the 60s. it can be seen that in suitable planting areas the overall annual average temperature was lower than that in the 50s, dropping by 0.3~0.5 degrees (Figure 6), and the precipitation of the wettest month increases in different degrees. All of these held back the reduction trend of the *Acer tataricum* subsp. *ginnala* geographic distribution caused for lack of water in the 50s and 60s. Meanwhile the seasonal variation coefficient of temperature was 8809-12433 (Figure 5) which was close to the *Acer tataricum* subsp. *ginnala* suitable interval. It was probably the reason why the geographic distribution do not continue to shrink in 70s.

Discussion

This study collected future climate data and species actual distribution points combining Maxent to predict the suitable areas of *Acer tataricum* subsp. *ginnala* in the future. Meanwhile, converting the future climate data into visual images to analyze the reasons for distribution of *Acer tataricum* subsp. *ginnala* firstly.

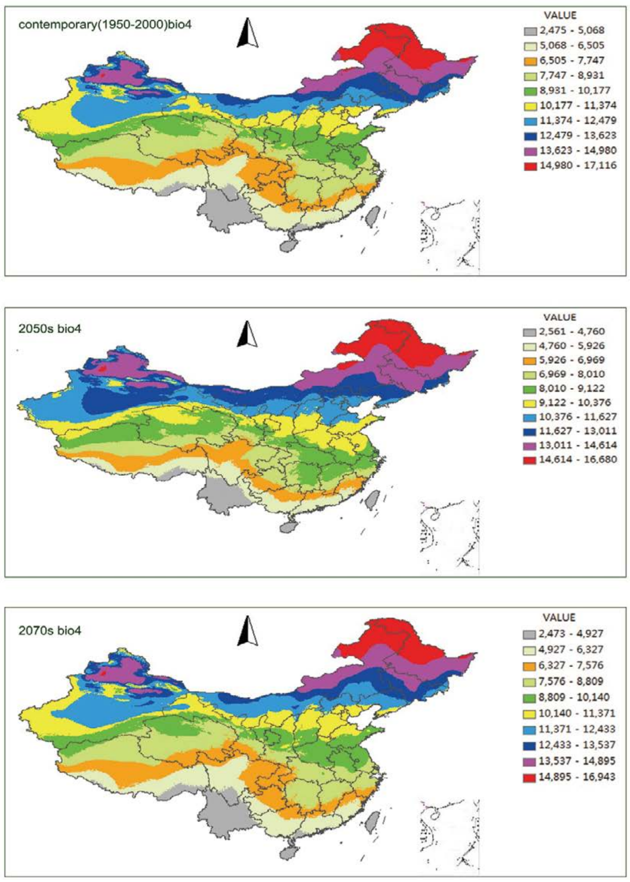

Figure 5: The changing trend of bio4 in contemporary (1950-2000), 2050 (average for 2041-2060), 2070 (average for 2061-2080).

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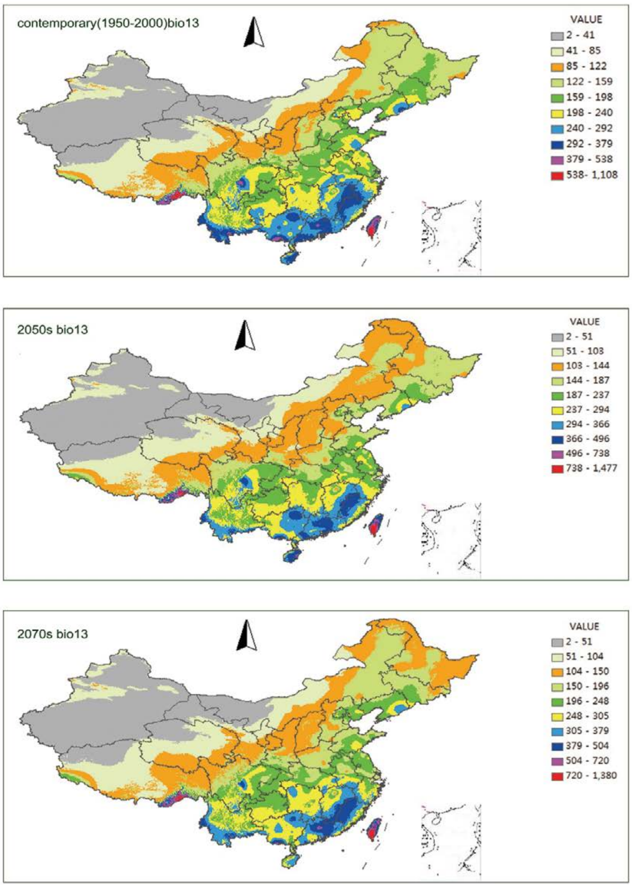

Figure 6: The changing trend of bio13 in contemporary (1950-2000), 2050 (average for 2041-2060), 2070 (average for 2061-2080).

For the next 50 years, the distribution of *Acer tataricum* subsp. *ginnala* was in a reducing state, especialy in Inner Mongolia and Gansu where the distribution area may disappear. The possible reasons were as follow: (1) In the future 30 years, the temperature in the northwest region would generally increase [26], while the precipitation would show the trend of volatility increase [27], but the drought in the millennial scale trend would intensify [28], the desert area would increase, the shortage of water resources and drought would come about. All of these may seriously hinder the growth of *Acer tataricum* subsp. *ginnala*. (2) With the different width of temperature increasing in winter and summer, the annual range of temperature may decrease in Western Sichuan and Guizhou plateau area of Southwest China [29]. In 2040, southwest rainfall rate beginned to increase by 5%~10%, where was not suitable for *Acer tataricum* subsp. *ginnala* to grow. (3) Besides, the human activities would cause extensive damage to vegetation and stream flow, and severe drought may damage the habitat of *Acer tataricum* subsp. *ginnala*. (4) Low seed setting rate and pest diseases may also lead to the decline of *Acer tataricum* subsp. *ginnala* genetic diversity, which may be not beneficial to the expansion of *Acer tataricum* subsp. *ginnala* population.

The prediction of *Acer tataricum* subsp. *ginnala* geographic distribution in the study has a certain deviation with the actual distribution area. Plant suitable environment variables may also be related with vegetation types, soil types and other factors. This study selected 19 biological climate and altitude variables, which may bring some errors to the model prediction [30]. In addition, the geographic distribution in theory is no longer suitable for the survival of the species. Due to the low resolution ratio global climate model resolution and the uncertain future human activity emission scenario [31], there may also exist uncertain future climate data that also affected the accuracy of MaxEnt model. In the subsequent studies, if there is more distribution and diverse environmental data, the prediction results will be more accurate.

Conclusion

At present, although the *Acer tataricum* subsp. *ginnala* geographic distribution spreads widely in China, While with the advance of years, the future climate of China will be not conducive to the growth of *Acer tataricum* subsp. *ginnala*, and suitable areas in the country had shown an obviously reduction trend. In view of its unique biological, economic, ornamental value, and the decreasing trend of the most suitable growth range in this research, part areas of *Acer tataricum* subsp. *ginnala* may disappear in future. If effective protective measures are not taken timely, Acer ginala may be extinct in the future. The information suppported in this study may be useful for the protection of *Acer tataricum* subsp. *ginnala*.

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