Predicting the potential distribution of 12 threatened medicinal plants on the Qinghai-Tibet Plateau (QTP), with a maximum entropy model

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Abstract

Climate change is a vital driver of biodiversity patterns and species distributions, understanding how organisms respond to climate change will shed light on the conservation of endangered species. In this study, the MaxEnt model was used to predict the potential suitable area of 12 threatened medicinal plants in the QTP (Qinghai-Tibet Plateau) under the current and future (2050s, 2070s) three climate scenarios (RCP2.6, RCP4.5, RCP8.5). The results showed that the climatically suitable habitats for the threatened medicinal plants were primarily found in the eastern, southeast, southern and some part of the central regions on the QTP. Moreover, 25% of the threatened medicinal plants would have reduced suitable habitat areas within the next 30-50 years in the different future global warming scenario. Among these medicinal plants, FP (Fritillaria przewalskii) would miss the most habitat (97.1%), while the RAN (Rhododendron anthopogonoides) would miss the least habitat (0.30%). Nevertheless, 41.6% of the threatened medicinal plants showed an increase in their future habitat area because of their physiological characteristics which are more adaptable to a wide range of climate. The climatic suitable habitat for 50% of the threatened medicinal plants would migrate to higher altitudes or higher latitudes regions. This study provides a data foundation for the conservation of biodiversity and wild medicinal plants on the QTP.

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Abstract

Climate change is a vital driver of biodiversity patterns and species distributions, understanding how organisms respond to climate change will shed light on the conservation of endangered species. In this study, the MaxEnt model was used to predict the potential suitable area of 12 threatened medicinal plants in the QTP (Qinghai-Tibet Plateau) under the current and future (2050s, 2070s) three climate scenarios (RCP2.6, RCP4.5, RCP8.5). The results showed that the climatically suitable habitats for the threatened medicinal plants were primarily found in the eastern, southeast, southern and some part of the central regions on the QTP. Moreover, 25% of the threatened medicinal plants would have reduced suitable habitat areas within the next 30-50 years in the different future global warming scenario. Among these medicinal plants, FP (*Fritillaria przewalskii*) would miss the most habitat (97.1%), while the RAN (*Rhododendron anthopogonoides*) would miss the least habitat (0.30%). Nevertheless, 41.6% of the threatened medicinal plants showed an increase in their future habitat area because of their physiological characteristics which are more adaptable to a wide range of climate. The climatic suitable habitat for 50% of the threatened medicinal plants would migrate to higher altitudes or higher latitudes regions.

This study provides a data foundation for the conservation of biodiversity and wild medicinal plants on the QTP.

Keywords: threatened medicinal plants; climate change; suitable habitat; barycenter migration; Qinghai-Tibet Plateau (QTP)

Introduction

The interaction and relationship between plants and climate are hot topics in the fields of botany, ecology, and geography (Jiang & Ni. 2005; Wang & Ni. 2005). Over the past 100 years from the Industrial Revolution to the present, human activities have led to drastic changes in the global climate. According to the fifth report of IPCC (the Intergovernmental Panel on Climate Change), human activities have emitted a large amount of greenhouse gases such as CO_2, leading to an increase in global temperature. From 1880 to 2012, the average global surface temperature increased by 0.85 , and it is projected to increase by 0.3 to 4.8 ° C by the end of the 21st century (2081-2100) compared to the base period (1986-2005) (Hartmann et al. 2013). Under the background of global climate change, climate warming in the coming decades or even centuries may alter the structure and function of terrestrial ecosystems by affecting the distribution of organisms and vegetation composition.

Previous studies have shown that the extinction of some species was resulted from climate change (Sharma et al. 2009), which could lead to the reduction of the suitable distribution area of some species, habitat fragmentation, and accelerated global biodiversity loss (Thomas et al.2004). Endangered plants are a major component of biodiversity in a region, and rare and endangered plants have a high extinction rate and may face the risk of extinction in the coming period if their species numbers continue to decline (Menges 1990). The geographical distribution of species is one of the key geographical characteristics of species, and each species has a specific distribution range in the world. The drawing of species distribution maps is an important means of studying species distribution, and plays a crucial part in analyzing the origin and distribution law of species populations (Zhang & Chen 2003). In order to further protect global biodiversity and prevent further destruction of ecosystems, it is necessary to systematically understand the relationship between the potential geographical distribution areas of species and climate change, as well as the potential geographical distribution areas of species in future climate change scenarios, and propose adaptive protection strategies.

Forecasting the potential distribution of species under current and future climate conditions is mainly based on niche models (Leroy et al. 2013). Niche models can simulate the potential distribution of species using the known distribution points and GIS-based environmental variables, and predict the suitable distribution range and changes of species under future climate change scenarios. At present, there are various species distribution models based on ecological niches (Elith et al. 2006), which have been widely used in predicting suitable distribution areas for endangered plants. For example, the maximum entropy model MaxEnt (Zhang et al. 2023; Zhang and Zhao 2001; Abdelaal et al. 2019; Gao et al. 2022; Ma & Zhang 2012), the ruleset genetic algorithm model GARP (Li et al. 2023), and the BIOCLIM model (Semwal et al. 2021) and so on. Among them, MaxEnt, the maximum entropy model, is an intensively used prediction model in recent years, and its prediction results are the most accurate. Even though the species distribution data information and environmental variables in the distribution area are incomplete, it can precisely predict the potential distribution area of species (Phillips & Dudik 2008; Warren & Seifert 2011). In addition, the stability of the model is good and the predicted results are basically in line with the actual distribution of species (the average AUC value is the largest).

The QTP (Qinghai-Tibetan Plateau) is of great significance for the geographical environment pattern and climate change of China and Asia. It is an important distribution area of terrestrial ecosystems in China and also an important gene pool of biological species worldwide. The QTP is recognized as the "driving force" and sensitive area of global climate change, and its response to "greenhouse gases" is more sensitive than other regions (Pan & Li 1996; Yao et al.2020; Yao et al.2012; Zhang et al. 2020). The QTP is one of the geographical regions with the highest number of medicinal plants in China. There are over 2000 kinds of medicinal plants on the QTP, occupying approximately half of the total number of medicinal plants in China. The unique geographical location and climatic conditions of the QTP had actuated the formation of endemic medicinal plants, and it also had considerably enhanced the richness of medicinal species on the plateau. However, with the continuous development of human society and the increase of population, along with the vigorous development of Tibetan medicine, the Tibetan medicine resources in the QTP have been arbitrarily exploited and plundered for a long time, resulting in the destruction of medicinal vegetation habitats, rapid shrinkage of medicinal plant resources, and some species are on the brink of extinction. In addition, climate change characterized by warming will have a significant impact on the natural environment, ecosystems, and species distribution in this region (Fitzpatrick et al. 2008; Descombes et al. 2015; Allen & Lendemer 2016). In addition, climate change with warming as its main feature will have a huge impact on the natural environment, ecosystem, and species distribution in this region, and some endangered wild medicinal plant resources will face greater threats. Therefore, understanding the potential geographical distribution of threatened species and their suitable habitat status is a prerequisite for effective conservation work (Pearce & Boyce 2006). However, in reality, the geographical distribution data of many species is scarce, especially for endangered medicinal plants in the QTP.

In this study, the distribution areas of suitable habitats for threatened medicinal plants on the QTP were evaluated on spatial and temporal scales by using the MaxEnt model. And the potential impacts of global climate change on endangered medicinal plants on the QTP were evaluated for the first time. The main purpose of this study were: (i) identifying the key areas of suitable habitats for the threatened medicinal plants on the QTP and priority areas for conservation; (ii) estimating the influence of climate change on the suitable habitat of the threatened medicinal plants on the QTP region; (iii) determining the migration direction of suitable habitat for the threatened medicinal plants on the QTP; (iv) comparing changes and trends in future suitable habitat among the different threatened medicinal plants.

2. Materials and Methods

2.1 . Occurrence records of the threatened medicinal plant on the QTP

In this study, 12 native threatened medicinal plants on the QTP were used by consulting the books and database such as "Flora Qinghaiica", "Flora of Tibet", "List of rare and endangered plants in China", "Chinese Red List of species", "List of wild plants under State Key Protection (the first batch)", The IUCN red list of threatened species (*https://www.iucnredlist.org/*), China wild plant conservation association,*https://www.wpca.org.cn/bhml*. Then, these 12 medicinal plants were divided into Critically Endangered (CR), Endangered (EN), Vulnerable (VU) and Near Threatened (NT) levels according to the record of the International Union for Conservation of Nature (IUCN) Red List of Endangered Species (Table 1). Since the NT species is close to or likely to become a threatened category not long in the future, it is included. Organism photographs in the flowering stage of 12 native threatened medicinal plants on the QTP were shown in Figure 1.

The date on the locations of 12 threatened medicinal plants were acquired from field investigation reports from the last 30 years, principally in the specimen libraries, e.g. Chinese Virtual Herbarium (*http://www.cvh.ac.cn/*), Global Biodiversity Information Facility (https://www.gbif.org/), China National Specimen Information Infrastructure (http://www.naii.org.cn), and the reports in literatures. The total occurrence records for these 12 species are 38, 17, 34, 33, 110, 25, 59, 26,72, 64, 37 and 27, respectively (Table S1). We then used ENMTools.pl (https://github.com/danlwarren/ENMTools) to clip occurrence points in order to only one observation was reserved in each 30s grid cell (according with the environment variable data below), to reduce the sampling bias of the data. Finally, all the remaining occurrence records were applied for the ecological niche modeling (ENM) (Table S2).

2.2. Climate Data Collection and Environmental Variables

The correlation and completeness of variables are the key elements of constructing ENM. In this study, we chose three types of environmental variables, including bioclimatic, soil variables and topographical (Table 2). Nineteen bioclimatic and altitude variables were downloaded from WorldClim 1.4 (https://world clim.org) for the current period (1960-1990) at a spatial resolution of 30 arc-seconds (approximately 1 km). Another two topographical variables (slope and aspect) were obtained from Digital Elevation Model using the 3D analyst tools in the software ArcGIS 10.4. We downloaded the eight soil variables from the National Tibetan Plateau Data Center (https://data.tpdc.ac.cn/zh-hans/) based on previous studies (Guo et al. 2019; Li et al. 2021; Ru 2006). Furthermore, the old WorldClim version 1.4 (https://worldclim.org/) was used to obtain projected future climate data. The average values of representative concentration pathways (RCPs) under the future Community Climate System Model (CCSM) were selected to predict the suitable area changes in 2050 and 2070. RCPs include RCP4.5 and RCP6.0 (medium greenhouse gas emissions), and RCP8.5 (high greenhouse gas emissions) (Thomson et al. 2011). However, the available data on the other two types of environmental variables (soil variables and topographical variable) were lack for the future periods according with the same periods. The 12 species are relatively less affected by topography and soil because they are chiefly located in the mountain areas. Therefore, we assumed that these two types of environment variables were constant, as reported in previous studies (Evans et al. 2020; Lv et al. 2021; Zhang et al. 2019).

In order to decrease the autocorrelation between the variable data, ArcGIS software was applied to upload all of the variable data and to execute Pearson correlation analysis on variables by multivariate and band collection statistics (Narkis et al. 2017). For the factor of phase coefficient $|R| > 0.8$ between variables (Figure 2), on the basis of the contribution rate of each environmental variable to the MaxEnt model and the replacement important value, the variables with a larger contribution rate and replacement important value give preference to take part in MaxEnt modeling and prediction, to avoid overfitting (Hill et al.2012). Therefore, different variables were used as the environmental variables for building the distribution model of 12 threatened medicinal plants (Table S3).

2.3. Optimization of Model Parameters

The regularization multiplier and feature class are the two most important parameters for establishing the species distribution model using the MaxEnt version 3.4.4 software. Therefore, we adopted the Kuenm package (https://github.com/marlonecobos/kuenm) to optimize these two parameters in the R version 3.6.3 software (Cobos et al.2019). In the modeling, we used 75% of the data as the training set. A total of 1240 candidate models, with parameters reflecting all combinations of 40 regularization multiplier settings (from 0.1 to 4, the interval is 0.1), and 31 feature class combinations were evaluated (Phillips et al. 2006; Phillips & Dudik 2008).

Model selection was prioritized by statistical significance (partial ROC), predictive power (low omission rate), and complexity (AICc value). First, candidate models were screened and those with statistical significance were retained; second, the set of models were simplified using the omission rate criterion (i.e., <5% when possible); finally, we selected the models with lowest delta AICc values (<2) among the significant and low-omission candidate models (Cobos et al. 2019). The obtained model of each species had different regularization multiplier and feature class parameters (Table 3).

2.4. Species Distribution Model

On the base of the relevant parameter ahead, we established the distribution model of the 12 threatened medicinal plants on QTP with MaxEnt version 3.4.4 and projected it to future periods. In present study, we used 75% of the geographic distribution data as train and 25% of the geographic distribution data to validate the model. Our analysis set 10 replicates and 5000 bootstrap iterations, with default settings for the other parameters (Phillips et al. 2006; Hazzi et al. 2018; Morales et al. 2017; Radosavljevic & Anderson 2014). We used the area under the receiving operator curve (AUC) to estimate model performance (Allouche et al.2006; Swets 1988). The AUC ranged from 0 to 1. The model with AUC value greater than 0.9 was regarded as excellent (Guisan & Thuiller 2005).

Subsequently, we loaded the arithmetic results from MaxEnt into ArcGIS10.4 to execute suitability classification and visualization and thereby generate the potential distribution of 12 threatened medicinal plants. It was vital to select an applicable threshold when shifting the continuous species suitability prediction results into a Boolean classification of suitable and unsuitable habitats. The maximum test sensitivity plus specificity logistic threshold approach was proved to be superior to other threshold division methods (Poirazidis et al. 2019). Then we used the maximum test sensitivity plus specificity threshold as a threshold or "cut-off" value for each scenario, and habitat suitability was divided into four classes: high suitability, moderate suitability, low suitability and unsuitability (Table S4).

2.5. Distribution barycenter migration of threatened medicinal plants

In the case of further investigating the dynamic migration paths of the 12 threatened medicinal plants, we calculated the centroids of the 12 threatened medicinal plants from their current distribution to their future distribution by using a Python-based SDM toolbox (Brown 2014). The analysis centralized the species distribution into an independent central point and established a vector file depicting the magnitude and direction of changes over time (Hu et al. 2015). We observed the distributional shifts by tracking the centroid changes among different SDMs.

3. Results

3.1. Habitat distribution models for the threatened medicinal plants of the QTP

The ROC results showed that the average training AUC value for the 10-replicate runs in current and future surpassed 0.9 in all the threatened medicinal plants on the QTP. Furthermore, the standard deviation (SD) values of 10 repetition runs remained below 0.06 in all the threatened medicinal plants on the QTP (Figure 3). These results indicated that the prediction results of MaxEnt model were accurate and reliable. Thus, we could conduct follow-up analysis.

The models for the present scenario properly predicted the known distribution range of all the threatened medicinal plants on the QTP (Figure 4). As far as CR medicinal plants was concerned, present distribution model predictions result demonstrated that the most suitable habitats for RAL (*Rhodiola alterna*) were similar with the GL (*Gentiana lhassica*), both of which were located in southern and southeast region of QTP, including Shigatse city and Shannan city in Tibet; however, for RAL it was not distributed in the Changdu city of Sichuan Province on the QTP (Figure 4A-B). In addition, the GL had a larger area of high and medium suitable habitat than the RAL (Table S5). The high suitable habitats of the EN medicinal plants, being different to the CR medicinal plants, preferred to inhabit the eastern region on the QTP (Figure 4C-D). These areas include Garze Tibetan Autonomous Prefecture, Ngawa Tibtean Autonomous Prefecture and Maerkang city in Sichuan Province. The high suitable habitats of the VU medicinal plants showed different distribution ranges: FP (*Fritillaria przewalskii*) (Golog Tibtean Autonomous Prefecture in Qinghai Province, Hezuo city in Gansu Province and Maerkang city in Sichuan Province) and RT (*Rheum tanguticum*) were located in the eastern region on the QTP (Golog Tibtean Autonomous Prefecture in Qinghai Province) (Figure 4E-F), while ABR (*Arenaria brevipetala*) mainly distributed in southeast and southern region on the QTP(Shannan and Changdu city in Tibet, Garze Tibetan Autonomous Prefecture, Liangshan yi autonomous prefecture and Ngawa Tibtean Autonomous Prefecture in Sichuan Province) (Figure 4G), and FD (*Fritillaria delavayi*) was found in southern region on the QTP (Garze Tibetan Autonomous Prefecture and Liangshan yi autonomous prefecture in Sichuan Province) (Figure 4H). It was worth noting that ABR (*A. brevipetala*

) had the largest area, 34.5 x 10^4km^2, of high suitable habitat in the threatened medicinal plants (Table S5). Similarly, it had the largest combined area of high and medium suitable habitat. Notably, the RAL (*R. alterna*) had the minimum area, only 8.2x 10^4km^2 and 17.7 x 10^4km^2, of high and medium suitable habitat among the threatened medicinal plants (Table S5).

Among the NT medicinal plants, the largest combine area of high and medium suitable habitat was found in RAN (*Rhododendron anthopogonoides*), with an area of 395.3 x 10^4km^2 (Figure 4K & Supplementary Table 5). And it was mainly found in the eastern, southeastern and southern regions of the QTP, containing Yushu Tibet Autonomous Prefecture in Qinghai Province, Shangri-la city in Yunnan Province, Changdu city and Linzhi city in Tibet and most of region in Sichuan Province. NI (*Notopterygium incisum*) had the second largest combined area of high and medium suitable habitat, with an area of 293.5 x 10^4 km^2, which mainly distributed in the eastern and southeastern regions of the QTP, including Haidong city, Haibei city, Huangnan Tibetan Autonomous Prefecture and Golog Tibetan Autonomous Prefecture in Qinghai Province, Gannan Tibetan Autonomous Prefecture in Gansu Province and Garze Tibetan Autonomous Prefecture, Ngawa Tibetan Autonomous Prefecture in Sichuan Province. The high and medium suitable habitats of AB (*Aconitum brunneum*) were located at eastern region of the QTP, including Gannan Tibetan Autonomous Prefecture in Gansu Province and Ngawa Tibetan Autonomous Prefecture in Sichuan Province. The combined area of high and medium suitable habitat of AE (*Androsace elatior*) was the smallest, only 25.7 x 10^4 km^2, and it was found sporadically on Garze Tibetan Autonomous Prefecture, Ngawa Tibetan Autonomous Prefecture in Sichuan Province.

3.2. Future suitable habitat fluctuations

The results of future climate model prediction showed that the high and medium suitable habitats of GL, RAL, FU, NI and AB expanded in all future climate scenarios with global warming by comparison with contemporary prediction results (Figure 5, Supplementary Figure 1-7 and Supplementary Table 5). Among these medicinal plants, the maximum increasing of high and medium suitability habitats were found in RAL, and the fluctuation ranges were 231.95% ~ 740.04% and 584.78% ~ 810.43%, respectively (Figure 5 and Figure S1), both of which reached a maximum in the RCP 8.5 climate scenario of 2070 (Figure 5 and Figure S1). Notably, the high suitability habitats of LA decreased 48.60% in the RCP8.5 climate scenario of 2070, however, in other future climate scenarios it increased, and reached a maximum of 83.66% in the RCP6.0 in 2050 (Figure 5-B). In addition, high suitability habitats for 25% threatened medicinal plants had a decreased in all future climate scenarios, including FP, RT and RAN (Figure 5). Among these medicinal plants, the high suitable habitat of FP had the largest decrease, and it achieved a maximum of 97.1% in the RCP 8.5 climate scenario of 2070 (Figure 5-F). The medium suitable habitats only for LA had a decreased in all future climate scenarios, with the maximum decrease area of habitat of 74.7% in RCP8.5 of 2070 climate scenarios (Figure S1-F). The high and medium suitable habitat of the remaining medicinal plants decreased or increased in different future climate scenarios (Figure 5 and Figure S1-S7).

3.3. Future migratory trends of the threatened medicinal plants

Barycenter results of the threatened medicinal plants indicated that the GL, LA, FU, RT, FD and NI were likely to migrate northward in the future climatic scenario of global climate change (Figure 6A, C, D, F, H and I). On the contrary, the FP, AB and RAN were inclined to migrate southward in the future distribution model. And, the barycenter of RAL had a trend of eastward migration (Figure 6B), whereas the barycenter of ABR tend to migrate westward in the future climatic scenario of global climate change (Figure 6G). Distance of barycenter migration results indicated that the maximum migration distance of CR medicinal plants were 82 Km and 193 Km, respectively (Table S6). The maximum migration distance of EN medicinal plants were 93 Km and 127 Km, separately (Table S6). As far as VU medicinal plants were concerned, the maximum migration distance of FP, RT, ABR and FD were 83 Km, 166 Km, 68 Km and 69 Km, respectively. Furthermore, the NI, AB, RAN and AE in NT medicinal plants had a maximum migration distance of 378 Km, 121 Km, 367 Km and 101 Km, separately (Table S6). In addition, the elevation of barycenter of LA, FP, RT, ABR, FD, AB and AE were persistently increased due to future climate change (Figure 7). And the FU had a consistently decrease of elevation of barycenter in all future climate scenarios. The elevation of barycenter of the remaining threatened medicinal plants showed increase and decrease in different future climate scenario (Figure 7).

4. Discussion

4.1. Threatened medicinal plants distribution and habitat fluctuations

Combined Maxent model with GIS technology, we predicted potential distribution areas of 12 endangered medicinal plants, and we obtained the spatial distribution pattern and distribution suitability of 12 endangered medicinal plants endemic to the QTP. The AUC values of the models were all more than 0.9, which proved that the prediction results were accurate and could accurately reflect the potential geographical distribution of 12 endangered medicinal plants endemic to the QTP. The results of present suitable habitat distribution models indicated that the low suitability and unsuitability habitats of the threatened medicinal plants were mainly found in the western, northern, northwestern and most part of the central regions on the QTP, while the habits with high and medium suitability were mainly located at the eastern, southeast, southern and some part of the central regions on the QTP. Previous research indicated that the diversity of medicinal plants on the QTP was mainly concentrated in the eastern and southeastern regions, including northwest Yunnan, western Sichuan, and eastern and southeastern Tibet (Fan & Bai 2021; Xing et al. 2023; Song et al. 2023; Chen et al. 2022), which was basically consistent with our results. The rich medicinal plant diversity resources in the eastern and southeastern Tibetan Plateau can be attributed to the complex topographic and geomorphic features (Wu et al. 2022; Li et al. 2015), adequate hydrothermal conditions (Favre et al. 2015), and the relatively stable environment during the ice age in this region compared to the inland regions. Therefore, we proposed to establish protected areas in eastern, southeast and southern regions on the QTP, using the limited protected areas to maximize the protection of more species.

Climate change plays an important role in species distribution. Temperature and precipitation are the main factors that determine the geographical distribution, growth and reproduction of species. Rising temperatures, changes in water conditions, and extreme climate events have caused widespread impacts on biodiversity and species distribution patterns (Wu 2011; Lenoir et al. 2008; Hu et al. 2022; Ma & Sun 2018). At different time periods in the future, the distribution pattern of most plants and animals in the world show a clear trend of migration from low latitude and low altitude areas to high latitude and high-altitude areas, accompanied by varying degrees of reduction or expansion (Parmesan & Yohe 2003; Root et al. 2003). Compared with the present, the potential habitat areas of GL, RAL, FU, NI and AB on the QTP show an overall trend of expansion in the future. By comparing the terrain characteristics, it was found that the expanded suitable habitats were all located in higher altitude mountainous areas. This may be due to climate warming increasing the species richness in the original habitats of these five medicinal plants, resulting in niche overlap and interspecific competition promoting their migration to higher mountainous areas. This is similar to the research results of Jump et al. (2005) and Engler et al. (2011). In addition, under future climate change scenarios, the potential suitable habitats for FP, RT, and RAN are generally showed a decreasing trend, indicating that climate warming will pose a threat to the habitats of these species in the future. Consequently, we considered that the FP, RT and RAN deserved more protection and attention under the global change.

4.2. Trend in migration of barycenter

The results of migration of barycenter showed that about 50% of the threatened medicinal plants on the QTP had a northward migration trend in response to climate change. Meanwhile, the results of barycenter elevation indicated that 58.33% of the threatened medicinal plants on the QTP had a tendency to migrate to higher altitudes in order to alleviate the pressure of climate change. Under different climatic scenarios, the FP and AN of threatened medicinal plants on the QTP tended to continually migrate to lower latitudes. However, in different climate scenarios both of them had an increasing elevation barycenter. We hypothesize that the FP and AN were mainly mitigating the effects of global warming on themselves by moving to higher altitudes. In addition, in the future scenario, the LA, RT and FD have a tendency to migrate to high latitude and high altitude. More and more studies have shown that the distribution pattern of most plants and animals in the world would obviously move from low latitude and low altitude areas to high latitude and high-altitude areas in different time periods in the future. Our findings on endangered medicinal plants on the QTP confirm this perspective. Climate warming has obviously affected the number of plant populations, and the migration of species distribution has led to a decrease in biodiversity at low altitudes and low latitudes, increasing the competition among species at high altitudes and high latitudes, and further increasing the risk of extinction of endangered plants.

In summary, the determination of potential habitats for endangered medicinal plants is of great significance for the collection of wild excellent medicinal provenances and their biological research, and provides basic data for an accurate and comprehensive understanding of the distribution and resource reserves of endangered medicinal plants. The high suitability and suitability areas of 12 endangered medicinal plants can be used as key planning and development areas for the cultivation and planting of endangered medicinal plants in the future. However, this article only used climate factors, soil variables and topographical to simulate the potential geographical distribution areas of the species, and the results obtained may not be suitable for the survival of the species in some areas. In the actual application process, guidance should still be given based on the local hydrological and geological conditions. In future research, more environmental factors such as human interference factors, soil physical and chemical properties, and vegetation type data can be attempted to be added, then conduct on-site experiments at a small scale to better guide its protection, management, and introduction and cultivation. In addition, this article only selected 12 endangered plants as the research object. It is not yet known whether the potential geographical distribution trend of all endangered plants under future climate change conforms to this law. In the future, more rare and endangered plants need to be added for verification to confirm the universality of the research results.

5. Conclusion

The conservation of endangered species is based on a systematic understanding of the relationship between the potential geographical range of species and climate change, and the potential geographical range of species under future climate change scenarios. In this study, the suitable habitats for the threatened medicinal plants on the QTP were found in the eastern, southeast, southern and some part of the central regions on the QTP, containing southeastern region in Tibet Province, eastern and central regions in Qinghai Province and northwestern region in Sichuan Province. In addition, 25% of threatened medicinal plants showed a reduction of the area of suitable habitat in different future scenarios. However, the area of suitable habitat of the 41.6% threatened medicinal plants showed an increase on different degrees due to their more responsive ability to respond to environmental stresses. Among these medicinal plants, the most negatively influenced by climate change is FP, which will miss 97.1% of suitable habitat in 2070 when the carbon emissions are at high (RCP8.5). And, the least negative affected by climate change is RAN, whose area of suitable habitat will increase by 740.04% in 2070 when the carbon emissions are at high (RCP8.5). Then, the suitable habitat for 50% of the threatened medicinal plants would migrate to higher altitudes or higher latitudes regions in the climate change future. Based on these findings, in addition to controlling greenhouse gas emissions, we appealed that the endangered species on the QTP with the reduction of the area of suitable habitat should be given more attention in the conservation measures.

AUTHOR CONTRIBUTIONS

Lucun Yang : Methodology, Software, Investigation, Writing – original draft, Writing – review & editing. **Xiaofeng Zhu** : Software, Investigation. **Wenzhu Song** : Investigation.**Xingping Shi** : Investigation. **Xiaotao Huang** : Supervision, Writing – review & editing

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CONFLICT OF INTEREST STATEMENT

The authors declare there are no conflicts of interest.

DATA AVAILABILITY STATEMENT

We used open-access data from the Global Biodiversity Information Facility database (GBIF, https://www.gbif.org/), Chinese Virtual Herbarium (*http://www.cvh.ac.cn/*),China National Specimen Information Infrastructure (*http://www.naii.org.cn*), WorldClim (http://world clim.org), and National Tibetan Plateau Data Center (https://data.tpdc.ac.cn/zh-hans/).

References

Abdelaal, M., Fois, M., Fenu, G., Bacchetta, G. (2019). Using MaxEnt modeling to predict the potential distribution of the endemic plant Rosa arabica Crep. in Egypt. *Ecological Informatics* , *50* : 68-75.*https://doi.org/10.1016/j.ecoinf.2019.01.003*

Allouche, O., Tsoar, A., Kadmon, R. (2006). Assessing the accuracy of species distribution models: prevalence, kappa and the true skill statistic (TSS). *Journal of Applied Ecology* , *43* (6), 1223-1232. https://doi.org/10.1111/j.1365-2664.2006.01214.x

Allen, J.L., Lendemer, J.C. (2016). Climate change impacts on endemic, high-elevation lichens in a biodiversity hotspot. *Biodiversity and Conservation* , *25* (3), 555-568. https://doi.org/10.1007/s10531-016-1071-4

Brown, J.L. (2014). SDMtoolbox: a python-based GIS toolkit for landscape genetic, biogeographic and species distribution model analyses.*Methods In Ecology and Evolution* , *5* (7), 694-700. https://doi.org/10.1111/2041-210X.12200

Chen, K.Y., Wang, B., Chen, C., Zhou, G.Y. (2022). MaxEnt Modeling to Predict the Current and Future Distribution of *Pomatosace filicula* under Climate Change Scenarios on the Qinghai-Tibet Plateau.*Plants* , *11* : 670. https://doi.org/ 10.3390/plants11050670.

Cobos, M.E., Peterson, A.T., Barve, N., Osorio-Olvera, L. (2019). Kuenm: a R package for detailed development of ecological niche models using Maxent. *PeerJ* , *7* , e6281. https://doi.org/*10.7717/peerj.6281*

Descombes, P., Wisz, M.S., Leprieur, F., Parravicini, V., Heine, C., Olsen, S., Swingedouw, D., Kulbicki, M., Mouillot, D., Pellissier, L. (2015). Forecasted coral reef decline in marine biodiversity hotspots under climate change. *Global Change Biology* , *21* (7), 2479-2487.*https://doi.org/10.1111/gcb.12868*

Elith, J., Graham, C.H., Anderson, R.P., Dudik, M., Ferrier, S., Guisan, A., Hijmans, R.J., Huettmann, F., Leathwick, J.R., Lehmann, A., Li, J., Lohmann, L.G., Loiselle, B.A., Manion, G., Moritz, C., Nakamura, M., Nakazawa, Y., Overton, J.M.M., Peterson, A.T., Phillips, S.J., Richardson, K., Scachetti-Pereira, R., Schapire, R.E., Soberon, J., Williams, S., Wisz, M.S., Zimmermann, N.E. (2006). Novel methods improve prediction of species' distributions from occurrence data.*Ecography* , *29* (2), 129-151. https://doi.org/10.1111/j.2006.0906-7590.04596.x

Engler, R., Randin, C.F., Thuiller, W., et al. (2011). 21st century climate change threatens mountain flora unequally across Europe.*Global Change Biology* , *17* (7), 2330-2341.https://doi.org/10.1111/j.1365-2486.2010.02393.x

Evans, A., Janssens, S. & Jacquemyn, H. (2020). Impact of climate change on the distribution of four closely related Orchis (Orchidaceae) species. *Diversity* , *12* (8), 312-324.*https://doi.org/10.3390/d1208 0312*

Fitzpatrick, M.C., Gove, A.D., Sanders, N.D., Dunn, R.R. (2008) Climate change, plant migration, and range collapse in a global biodiversity hotspot: The Banksia (Proteaceae) of Western Australia. *Global Change Biology* , *14* , 1337-1352.*http://doi.org/10.1111/j.1365-2486.2008.01559.x.*

Fan, Z., Bai, X. (2021). Scenarios of potential vegetation distribution in the different gradient zones of Qinghai-Tibet Plateau under future climate change. *Science of the Total Environment* , 796, 148918. https://doi.org/*10.1016/j.scitotenv.2021.148918*

Favre, A., Packert, M., Pauls, S.U., Jahnig, S.C., Uhl, D., Michalak, I., Muellner-Riehl, A.N. (2015). The role of the uplift of the Qinghai-Tibetan Plateau for the evolution of Tibetan biotas.*Biology of Reproduction*

, *90* , 236–253. https://doi.org/10.1111/brv.12107

Gao, X.X., Liu, J., Huang, Z.H. (2022). The impact of climate change on the distribution of rare and endangered tree *Firmiana kwangsiensis* using the Maxent modeling. *Ecology and Evolution* , 12(8), e9165. *https://doi.org/10.1002/ece3.9165*

Guo, Y., Li, X., Zhao, Z. & Nawaz, Z. (2019). Predicting the impacts of climate change, soils and vegetation types on the geographic distribution of *Polyporus umbellatus* in China. *Science of the Total Environment* , 648, 1-11.*https://doi.org/10.1016/j.scito tenv.2018.07.465*

Guisan, A., Thuiller, W. (2005). Predicting species distribution: offering more than simple habitat models. *Ecology Letters* , 8(9), 993-1009. https://doi.org/10.1111/j.1461-0248.2005.00792.x

Hartmann, D.L., Klein-Tank, A.M.G., Rusticucci, M. (2013). Chapter 2: observations: atmosphere and surface[R]//Stocker, T.F., Qin, D., Plattenr, G-K,et al. IPCC, 2013: climate change 2013: the physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press 39.

Hazzi, N.A., Moreno, J.S., Ortiz-Movliav, C., Palacio, R.D. (2018). Biogeographic regions and events of isolation and diversification of the endemic biota of the tropical Andes. *Proceedings of the National Academy of Sciences* , *115* (31), 7985-7990.*https://doi.org/10.1073/pnas.1803908115*

Hill, M.P., Hoffmann, A.A., Mccoll, S.A., Umina, P.A. (2012). Distribution of cryptic blue oat mite species in Australia: Current and future climate conditions. *Agricultural and Forest Entomology* , 14, 127-137.*https://doi.org/10.1111/j.1461-9563.2011.00544.x*

Hu, X.G., Jin, Y.Q., Wang, X.R., Mao, J.F., Li, Y. (2015). Predicting impacts of future climate change on the distribution of the widespread conifer *platycladus orientalis* . *PloS One* , *10* (7), e0132326. https://doi.org/10. 1371/journal.pone.0132326

Hu, H.W., Wei, Y.Q., Wang, W.Y., Suonan, J., Wang, S.X., Chen, Z., Guan, J.H., Deng, Y.F. (2022). Richness and distribute on of endangered orchid species under different climate scenarios on the Qinghai-Tibetan Plateau. *Frontiers in Plant Science* , *13* , 948189. *https://doi.org/10.3389/fpls.2022.948189*

Jiang, X., Ni, J. (2005). Species-climate relationships of 10 desert plant species and their estimated potential distribution range in the arid lands of northwestern China. *Chinese Journal of Plant Ecology, 29* (1): 98-107. https://doi.org/*10.17521/cjpe.2005.0013*

Jump, A.S.,Penuelas, J. (2005). Running to stand still: adaptation and the response of plants to rapid climate change. *Ecology Letters* ,*8* (9), 1010-1020. *https://doi.org/10.1111/j.1461-0248.2005.00796.x*

Leroy, B., Paschetta, M., Canard, A., Bakkenes, M., Isaia, M., Ysnel, F. (2013). First assessment of effects of global change on threatened spiders: potential impacts on *Dolomedes plantarius* (Clerck) and its conservation plants. *Biological Conservation* , *161* (5), 155-163.*https://doi.org/10.1016/j.biocon.2013.03.022*

Lenoir, J., Gegout, J.C., Marquet, P.A., Ruffray, P.D., Brisse, H. (2008). A Significant Upward Shift in Plant Species Optimum Elevation During the 20th Century. *Science* , 320, 1768-1771. https://doi.org/10.1126/science.1156831

Li, G.D., Xiong, Y., Zhong, X.M., Song, D.D., Kang, Z.J., Li, D.J., Tang, J.H., Wang, Y.P., Wu, L. (2023). Changes in overwintering ground of small yellow croaker (*Larimichthys polyactis*) based on MaxEnt and GARP models: A case study of the southern Yellow Sea stock.*Journal of Fish Biology* , *102* (6), 1358-1372. https://doi.org/10.1111/jfb.15383.

Li, K.D., Zhang, G.F., Zhang, Y. & Griffith, M.P. (2021). A noteworthy case of rewilding Chinese yew from a garden population in eastern China.*PeerJ* , 9, e12341.https://doi.org/10.7717/peerj.12341

Li, S., Currie, B.S., Rowley, D.B., Ingalls, M. (2015). Cenozoic paleoaltimetry of the SE margin of the Tibetan Plateau: constraints on the tectonic evolution of the region. *Earth And Planetary Science Letters*

, *432* , 415e424.

Lv, T., Harris, A.J., Liu, Y., Liu, T., Liang, R., Ma, Z. & Su, X. (2021). Population genetic structure and evolutionary history of*Psammochloa villosa* (Trin.) Bor (Poaceae) revealed by AFLP marker. *Ecology and Evolution* ,*11* (15), 10258-10276.*https://doi.org/10.1002/ece3.7831*

Ma, S.M., Zhang, M.L. (2012). Phylogeography and conservation genetics of the relic *Gymnocarpos przewalskii* (Caryophyllaceae) restricted to northwestern China.*Conservation Genetics* , 13, 1531–1541. *http://doi.10.1007/s10592-012-0397-z.*

Ma, B., Sun, J. (2018). Predicting the distribution of *Stipa purpurea* across the Tibetan Plateau via the MaxEnt model. *BMC Ecology* , 18, 10. http://doe.10.1186/s12898-018-0165-0.

Menges, E.S. (1990) Population viability analysis for an endangered plant. *Conservation Genetics* , *4* (1): 52-62.*https://doi.org/10.1111/j.1523-1739.1990.tb00267.x*

Morales, N.S., Fernández, I.C., Baca-González, V. (2017). MaxEnt's parameter configuration and small samples: are we paying attention to recommendations? A systematic review. *PeerJ* , 5, e3093.*https://doi.org/10.7717/*p eerj.3093

Narkis, M.S., Fernandes, C.I., Victoria, B-G. (2017). MaxEnt's parameter configuration and small samples: Are we paying attention to recommendations? A systematic review. *PeerJ* , 5, e3093. https://doi.org/10.7717/peerj.3093

Pan, B.T., Li, J.J. (1996). Qinghai-Tibetan Plateau: A Driver and Amplifier of the Global Climatic Change. III. The effects of the uplift of Qinghai-Tibetan Plateau on Climatic Changes. *Journal of Lanzhou University (Med Sci)* , *32* (1), 108-115. http://doi.org/10.13885/j.issn.0455-2059.1996.01.024

Parmesan, C., Yohe, G. (2003). A globally coherent fingerprint of climate change impacts across natural systems. *Nature* ,*421* (6918), 37-42. https://doi.org/10.1038/nature01286.

Pearce, J., Boyce, M. (2006). Modelling distribution and abundance with presence-only data. *Journal of Applied Ecology* , 43, 405-412. https://doi.org/10.1111/j.1365-2664.2005.01112.x

Phillips, S.J., Dudík, M. (2008). Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Ecography* ,*31* (2):161-175.*https://doi.org/10.1111/j.0906-7590.2008.5203.x*

Phillips, S.J., Anderson, R.P., Schapire, R.E. (2006). Maximum entropy modeling of species geographic distributions. *Ecological Modelling* , *190* (3-4), 231-259.*https://doi.org/10.1016/j.ecolmodel.2005.03.026*

Phillips, S.J., Dudík, M. (2008). Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Ecography* ,*31* (2), 161-175. https://doi.org/10.1111/j.0906-7590.2008.5203.x

Poirazidis, K., Bontzorlos, V., Xofis, P., Zakkak, S., Xirouchakis, S., Grigoriadou, E., Kechagioglou, S., Gasteratos, I., Alivizatos, H., Panagiotopoulou, M. (2019). Bioclimatic and environmental suitability models for capercaillie (Tetrao urogallus) conservation: Identification of optimal and marginal areas in Rodopi Mountain-Range National Park (Northern Greece). *Global Ecology and Conservation* , 17, e00526. https://doi.org/10.1016/j.gecco.2019.e00526

Radosavljevic, A., Anderson, R.P. (2014). Making better MAXENT models of species distributions: complexity, overfitting and evaluation.*Journal of Biogeography* , *41* (4), 629-643. https://doi.org/10.1111/jbi.12227

Ru, W.M. (2006). Study on the ecology of endangering plant *Taxus chinensis* var. *mairei* . Shanxi University.

Root, T.L., Price, J., Hall, K.R., Schneider, S.H., Rosenzweig, C., Pounds, A. (2003). Fingerprints of global warming on wild animals and plants. *Nature* , 421, 57-60. https://doi.org/10.1038/nature01333.

Semwal, D.P., Pandey, A., Gore, P.G., Ahlawat, S.P., Yadav, S.K., Kumar, A.V. (2021). Habitat prediction mapping using BioClim model for prioritizing germplasm collection and conservation of an aquatic cash crop '*makhana*' (*Euryale ferox* Salisb.) in India. *Genetic Resources and Crop Evolution* , 68, 3445-3456.*https://doi.org/10.1007/s10722-021-01265-7*

Sharma, E., Chettri, N., Tsering, K,. et al. Climate change impacts and vulnerability in the eastern Himalayas. Kathmandu: International Centre for Integrated Mountain Development, 2009.

Song, D., Li, Z., Wang, T., Qi, Y., Han, H., Chen, Z. (2023). Prediction of Changes to the Suitable Distribution Area of *Fritillaria przewalskii* Maxim. in the Qinghai-Tibet Plateau under Shared Socioeconomic Pathways (SSPs). *Sustainability* , 15, 2833. https://doi.org/10.3390/su15032833

Swets, J.A. (1988). Measuring the accuracy of diagnostic systems.*Science* , *240* (4857), 1285-1293.*https://doi.org/10.1126/science.3287615*

Thomas, C.D., Cameron, A., Green, R.E., Bakkenes, M., Beaumont, L.J., Collingham, Y.C., Erasmus, B.F.N., Siqueira, M.F., Grainger, A., Hannah, L., Hughes, L., Huntley, B., Jaarsveld, A.S., Midgley, G.F., Miles, L., Ortega-Huerta, M.A., Peterson, A.T., Phillips, O.L. & Williams, S.E. (2004). Extinction risk from climate change. *Nature* , *427* , 145-148. https://doi.org/10.1038/nature02121

Thomson, A.M., Calvin, K.V., Smith, S.J., Kyle, G.P., Volke, A., Patel, P., Delgado-Arias, S. & Bond-Lamberty, B. (2011). RCP4.5: a pathway for stabilization of radiative forcing by 2100. *Climatic Change* , 109, 77-94. https://doi.org/10.1007/s1058 4-011-0151-4

Warren, D.L., Seifert, S.N. (2011). Ecological niche modeling in Maxent: the importance of model complexity and the performance of model selection criteria. *Ecological Applications* , 21(2), 335-342.*https://doi.org/10.1890/10-1171.1.*

Wang, J., Ni, J. (2006). Review of modelling the distribution of plant species. *Chinese Journal of Plant Ecology* , *30* (6), 1040-1053. https://doi.org/*10.17521/cjpe.2006.0133*

Wu, S.D., Wang, Y., Wang, Z.F., Shrestha, N. & Liu, J.Q. (2022). Species divergence with gene flow and hybrid speciation on the Qinghai–Tibet Plateau. *New Phytologist* , *234* , 392-404. https://doi.org/10.1111/nph.17956

Wu, J.G. (2011). The potential effects of climate change on the distributions of 7 plants in China. *Guihaia* , 31(5), 595-607. http://doi.org/10.3969/j.issn.1000-3142.2011.05.008

Xing, Y., Shi, J., De, K., Wang, X., Wang, W., Ma, Y., Zhang, H., He, M., Liu, Q. (2023). The Current Distribution of *Carex alatauensis*in the Qinghai–Tibet Plateau Estimated by MaxEnt. *Agronomy* ,*13* , 564. https://doi.org/10.3390/ agronomy13020564

Yao, T., Thompson, L., Chen, D., Zhang, Y., Wang, N., Zhao, L., Che, T., Xu, B., Wu, G., Zhang, F.J.Bn. (2020). Third Pole climate warming and cryosphere system changes. 69, 1.

Yao, T., Thompson, L.G., Mosbrugger, V., Zhang, F., Ma, Y., Luo, T., Xu, B., Yang, X., Joswiak, D.R., Wang, W.J.E.D. (2012). Third pole environment (TPE). *Environmental Development* , 3, 52-64.*https://doi.org/10.1016/j.envdev.2012.04.002*

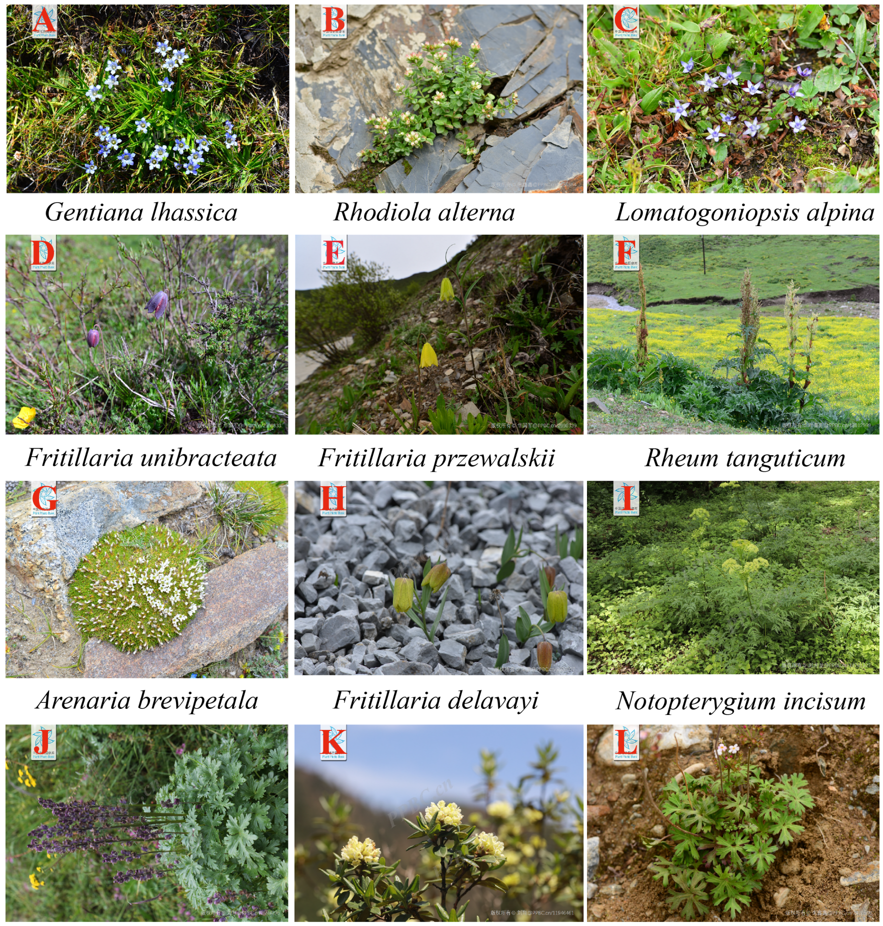
Zhang, W.J., Chen, J.K. (2003). Research progress of species distribution. *Biodiversity* , *11* (005), 364-369.

Zhang, Q, Shen, X., Jiang, X., Fan, T., Liang, X., Yan, W. (2023). MaxEnt Modeling for Predicting Suitable Habitat for Endangered Tree*Keteleeria davidiana* (Pinaceae) in China. *Forests* ,*14* , 394.*https://doi.org/10.3390/f14020394.*

Zhang, H., Zhao, H.X. (2001). Study on rare and endangered plants under climate: maxent modeling for identifying hot spots in northwest China.*Cerne* , *27* , e-102667. *https://doi.org/10.1590/01047760202127012667*

Zhang, G.Q., Yao, T.D., Xie, H.J., Yang, K., Zhu, L.P., Shum, C.K., Bolch, T., Yi, S., Allen, S., Jiang, L.G., Chen, W.F., Ke, C.Q. (2020). Response of Tibetan Plateau lakes to climate change: trends, patterns, and mechanisms. *Earth-Science Reviews* , *208* , 103269. https://doi.org/10.1016/j.earscirev.2020.103269

Zhang, Z.X., Capinha, C., Usio, N., Weterings, R., Liu, X., Li, Y.M., Landeria, J.M., Zhou, Q. & Yokota, M. (2019). Impacts of climate change on the global potential distribution of two notorious invasive cray fishes. *Freshwater Biology* , 65(3), 353-365. https://doi.org/10.1111/ fwb.13429



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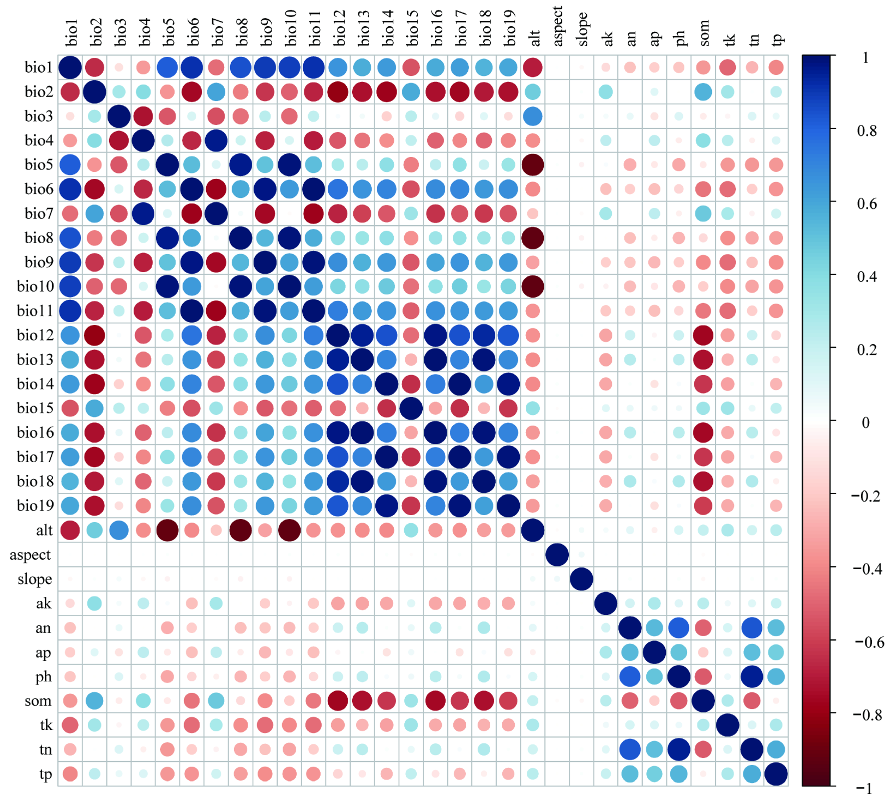
Aconitum brunneum *Rhododendron anthopogonoides* *Androsace elatior*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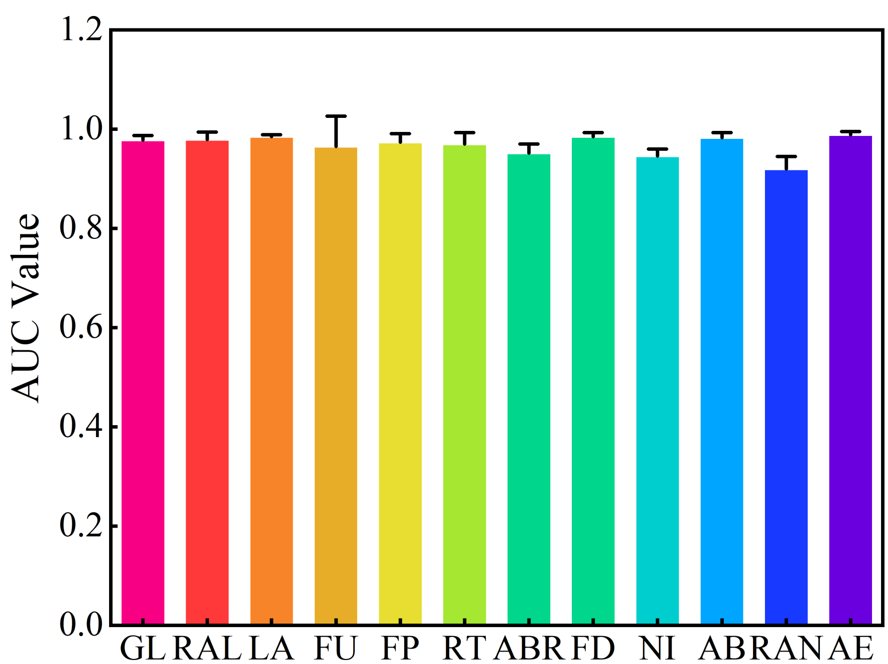
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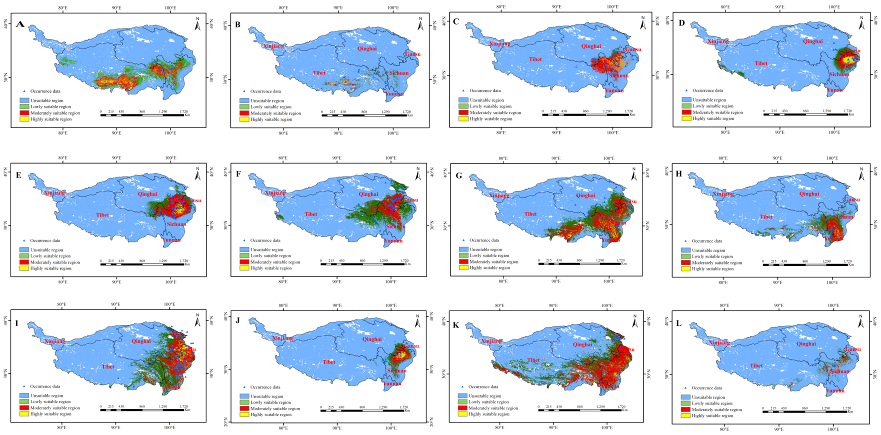
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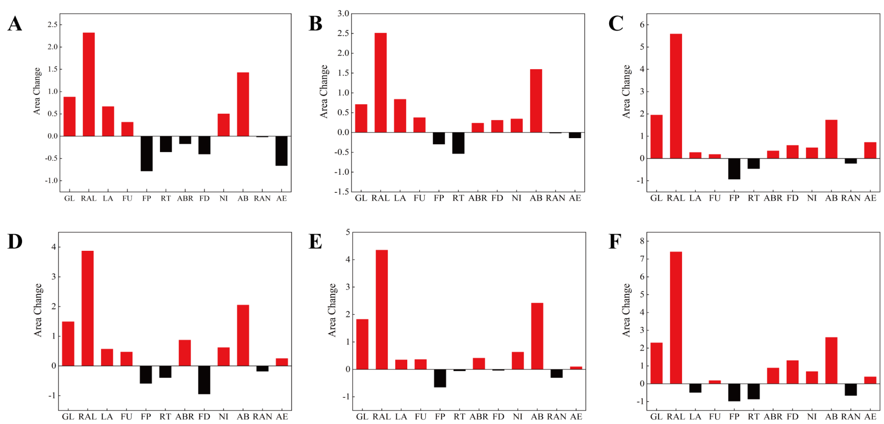
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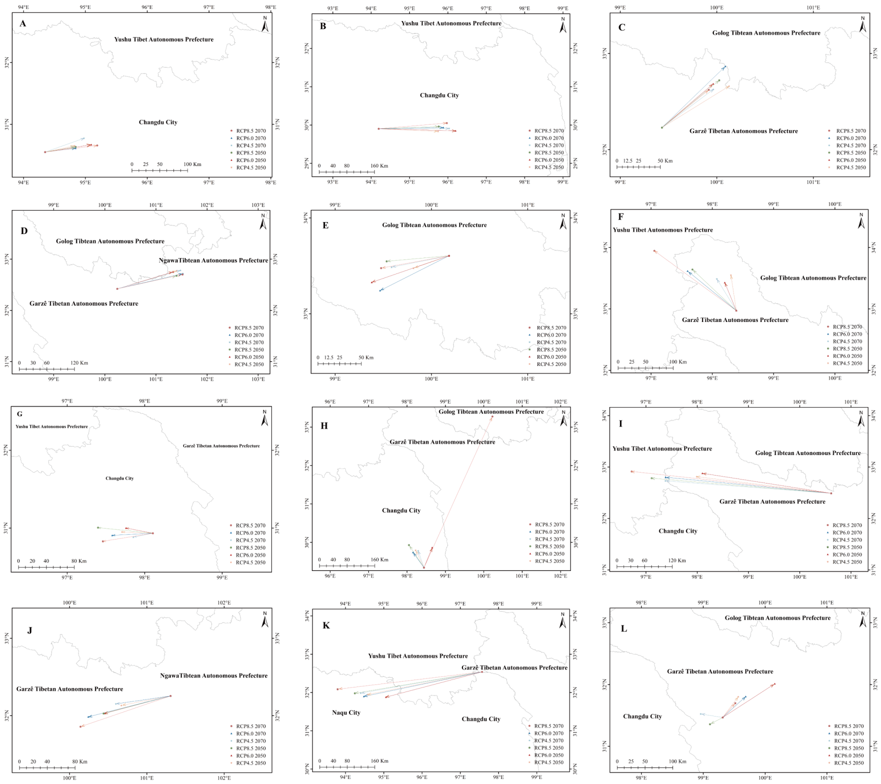

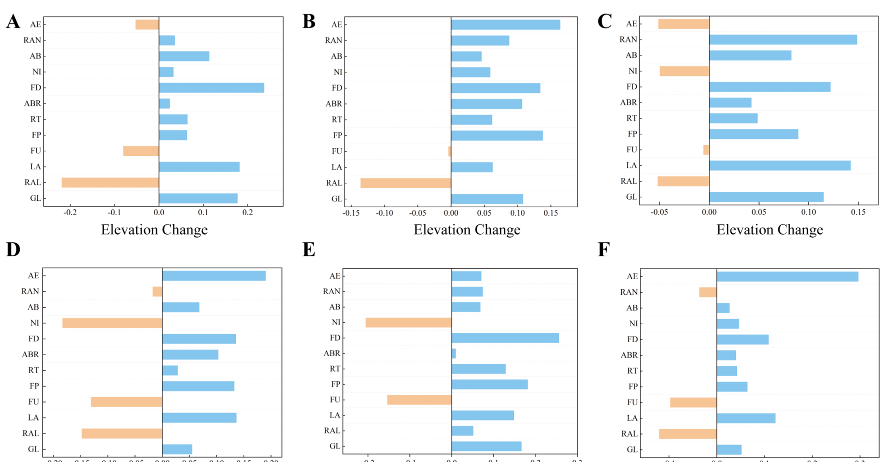

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