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Bioclimatic Modeling of the Potential Distribution of the Western Tien-Shan Endemic *Tulipa kaufmanniana* Regel (Uzbekistan, Kazakhstan)

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Abstract

The article analyzes the natural distribution area of the species *Tulipa kaufmanniana* Regel using the programs of type MaxEnt and ArcGis, the endemic of Central Asia (past, current, future). According to the results of the study, it is proved that the main distribution of the species coincides with the boundaries of the areali Tien-Shan mountain system (Uzbekistan, Kazakhstan). It is noted that the climatic factors that are optimal for the species are sufficient temperature and annual precipitation.

Keywords

T. kaufmanniana Regel, Tien-Shan, Endemic, Modeling, TASH, MaxEnt, Uzbekistan, Kazakhstan

1. Introduction

The Central Asian region is one of the centers of origin of the species *Tulipa* L. [1] [2] [3]. *Tulipa* L. has a vast habitat throughout Eurasia, extending from the northern regions of Portugal and Africa to the west, southeast to the islands of Japan [4]. Most of the world's most exquisitely cultivated tulips are native to Central Asia. About 70 species of the genus grow in Central Asia, more than half of which are considered as endemic [5] [6] [7]. There are 34 species of the genus in Uzbekistan, 37 species in Kazakhstan, 22 species in Kyrgyzstan, 24 species in Tajikistan and 16 species in Turkmenistan [8] [9].

Tulipa kaufmanniana Regel in Tashkent and Namangan regions: grows solitary or in small tufts on rocky soils from the foothills to the upper parts of (lower part of the pasture) Ugom, Piskom, Qorjantov, Chatkal, Qurama ridges and is considered a declining endemic plant in Western Tien Shan, therefore included in the Red Data Book with the 3rd status [10]. Today, as a result of global climate change, especially the sharp rise in air temperature it is important to assess and to conduct regular monitoring of the current state of rare and endangered species in the world. At the same time, there is an increase in anthropogenic impacts on plant communities and rare plants.

In this article, the potential distribution area of *T. kaufmanniana* Regel, which is rare for the flora of Central Asia, is also modeled over several periods (low, current and future) in order to determine the impact of climate change on the species population. These analyses were performed on the basis of samples stored in the National Herbarium Fund (TASH), international GBIF data and the results of field research.

The results of field studies show that the representatives of the genus are spring ephemeroids with a very short growing season. The vegetation period of the representatives of the genus is 120 - 140 days. The object of study *T. kaufmanniana* Regel was scientifically described in 1877 by E. Regel. One of the unique features of the species is its widespread use in selection work. The world-famous Dutch tulips are the descendants of *T. kaufmanniana* Regel (**Figure 1**).

In recent years, the use of modern methods in the analysis of botanical research has also become a tradition. In particular, a number of studies have been conducted on the population of species and the prediction of their habitats. One such method is the modern MaxEnt (Maximal Entropy) program.

2. Material and Methods

The object of study is *T. kaufmanniana* Regel. Predictive analyzes were performed on the basis of samples taken from the database of the National Herbarium (TASH) of the Institute of Botany of the Academy of Sciences of the Republic of Uzbekistan and the Global Biodiversity Information Facility (GBIF, https://www.gbif.org/) [11-12].

MaxEnt method was studied by S.J. Phillips *et al.*, [13] [14] and is now one of the most effective methods in modeling species distribution. This method is based on the creation of a generalized climate envelope using the climatic data of the points about where the species is recorded. BIOCLIM was developed by H. Nix and is widely used to create a climate profile of species and determine their potential habitats.

3. Result and Discussion

To date, Tulipa L. in Uzbekistan a lot of research has been carried out on the study of types of cenopopulations [15] [16]. A total of 96 points were obtained on the basis of TASH and GBIF data in the analysis (**Table 1**).

(a)

(b)

Figure 1. *T. kaufmanniana* in different conditions. (a) National herbarium (TASH); (b) Natural populations.

Table 1. Number of herbarium specimens and sources from which they were obtained.

Ridge	Administrative territories	Number of coordinates	Sources of information
Tien-Shan	Uzbekistan	87	TASH
	Kazakhstan	9	GBIF

From the points it can be seen that the main distribution are of the species is an important criterion in the prediction of endemic species and in the development of strategies to reduce this risk (**Figure 2**).

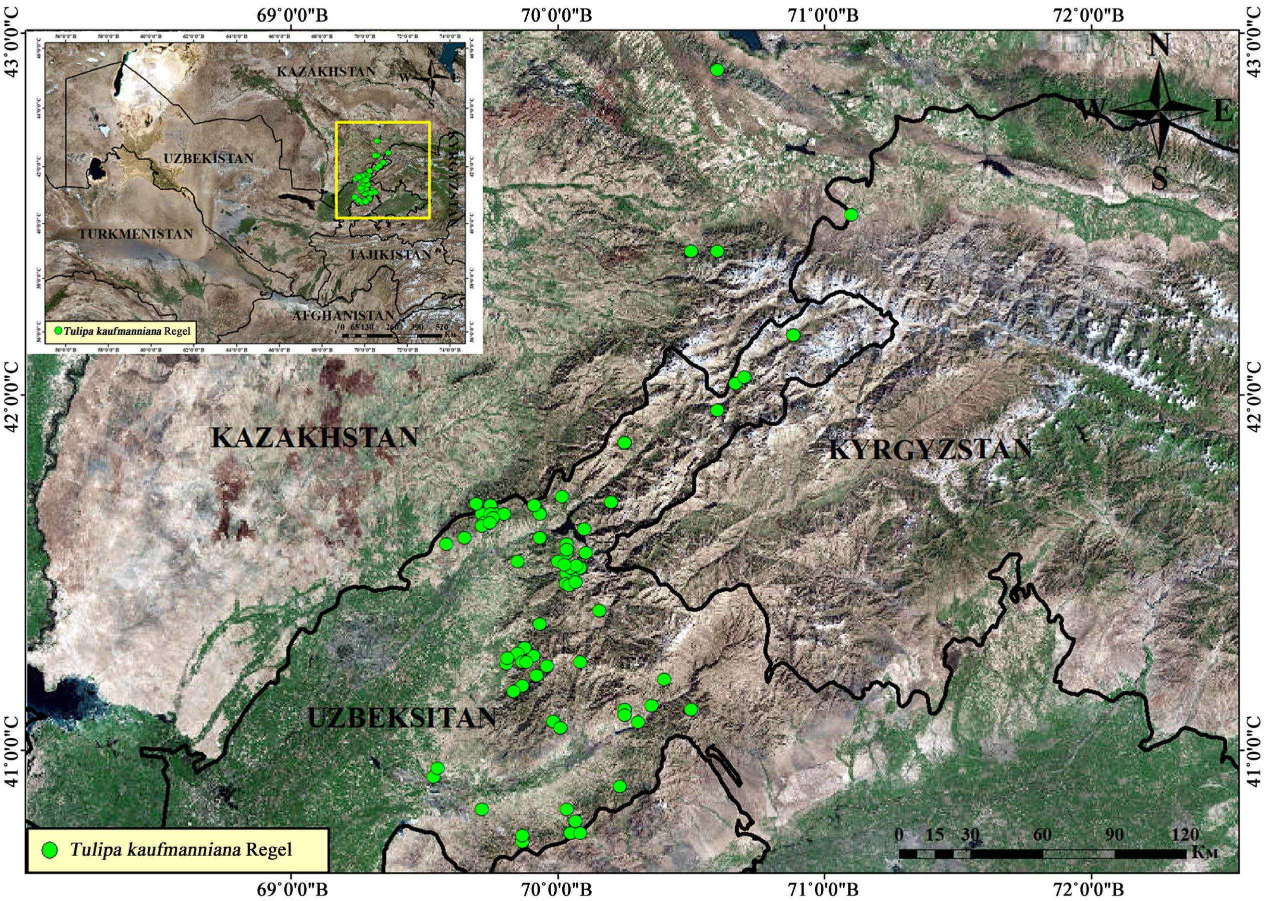


Figure 2. The natural distribution area of the species.

Climate change is one of the main factors affecting the range of the species, and international government experts have noted that the average global temperature will rise by 1.4˚C - 5.8˚C between 1900 and 2100. Today, climate change is having an impact on species adaptation and development. In the coming years, species modeling analyzes will play an important role in current and future analyzes. The developed models play a crucial role in predicting the risk of future biodiversity loss and in shifting strategies to reduce this risk. Prediction of species distribution areas for high-probability climate scenarios is based on MaxEnt and 19 BIOCLIM (**Table 2**) trends from World Clim 2.1 (https://www.worldclim.org/) [17].

When performing analyses using each method, specific criteria are important. In particular, during the study, growth coefficient of the modeling results of the species was defined from 0 to 1. In this appendix, the high range of the species is described in "red", the areas with low distribution are described in "yellow", the areas with low probability of distribution and almost no chance of occurrence are described in "light and dark blue". Other colors have an average rating (**Figure 3**).

According to the spread of climate change scenarios in PAST—in the recent past (1970-2000), Current—in the present and Future—in the future SSPs585 (2050) region with convenient climatic conditions for optimal growth of the *T. kaufmanniana* Regel can be seen in the Western Tien Shan. It is and endemic

Table 2. Trends in bioclimatic variability.

Bio 1	**Annual mean temperature**	**˚C**
Bio 2	Mean diurnal range (max. Temp –min. temp)	˚C
Bio 3	Isothermality (Bio2/Bio7) × 100	
Bio 4	Temperature seasonality (SD × 100)	˚C
Bio 5	Max temperature of warmest month	˚C
Bio 6	Min temperature of coldest month	˚C
Bio 7	Temperature annual range (Bio5-Bio6)	˚C
Bio 8	Mean temperature of wettest quarter	˚C
Bio 9	Mean temperature of driest quarter	˚C
Bio 10	Mean temperature of warmest quarter	˚C
Bio 11	Mean temperature of coldest quarter	˚C
Bio 12	Annual precipitation	mm
Bio 13	Precipitation of wettest month	mm
Bio 14	Precipitation of driest month	mm
Bio 15	Precipitation seasonality (Coefficient of variation)	
Bio 16	Precipitation of wettest quarter	mm
Bio 17	Precipitation of driest quarter	mm
Bio 18	Precipitation of warmest quarter	mm
Bio 19	Precipitation of coldest quarter	mm
Elev	Elevation	m

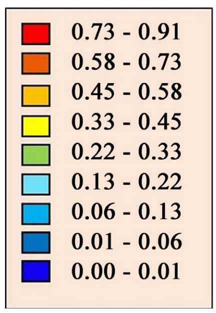
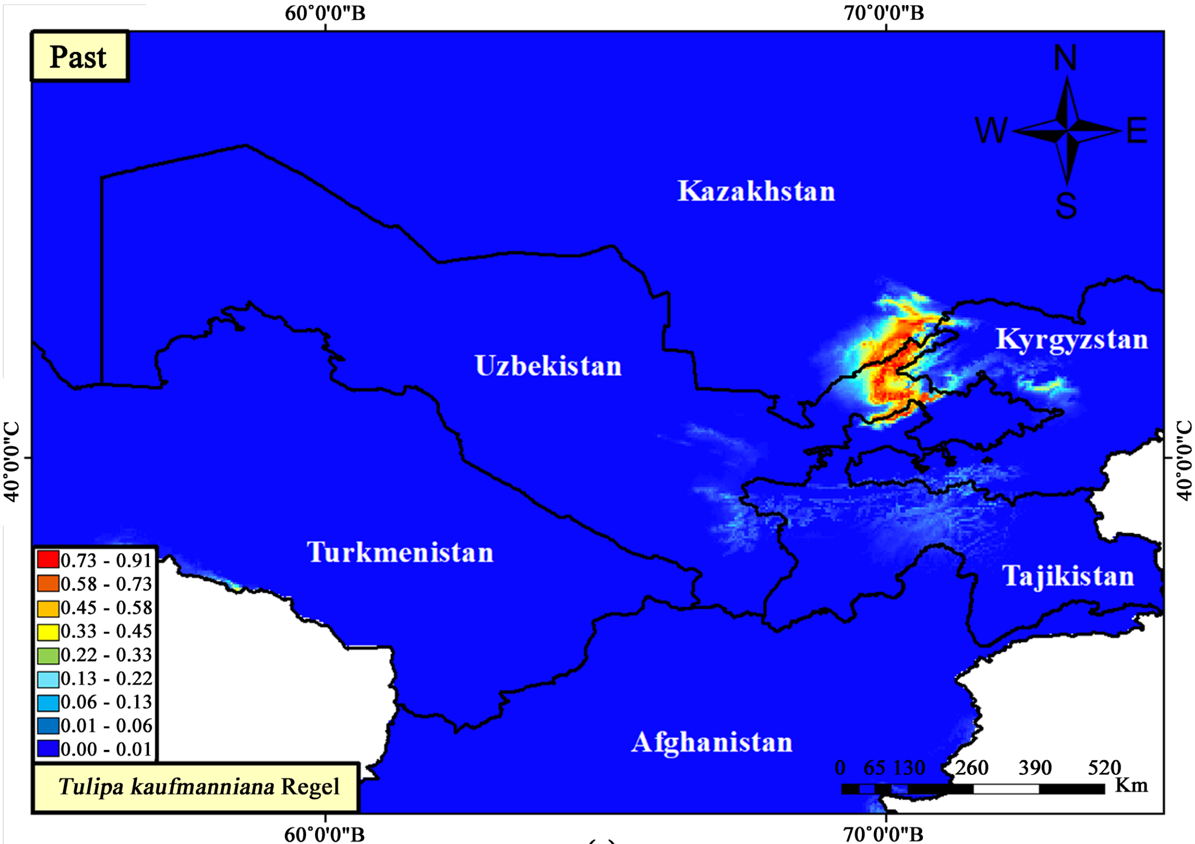


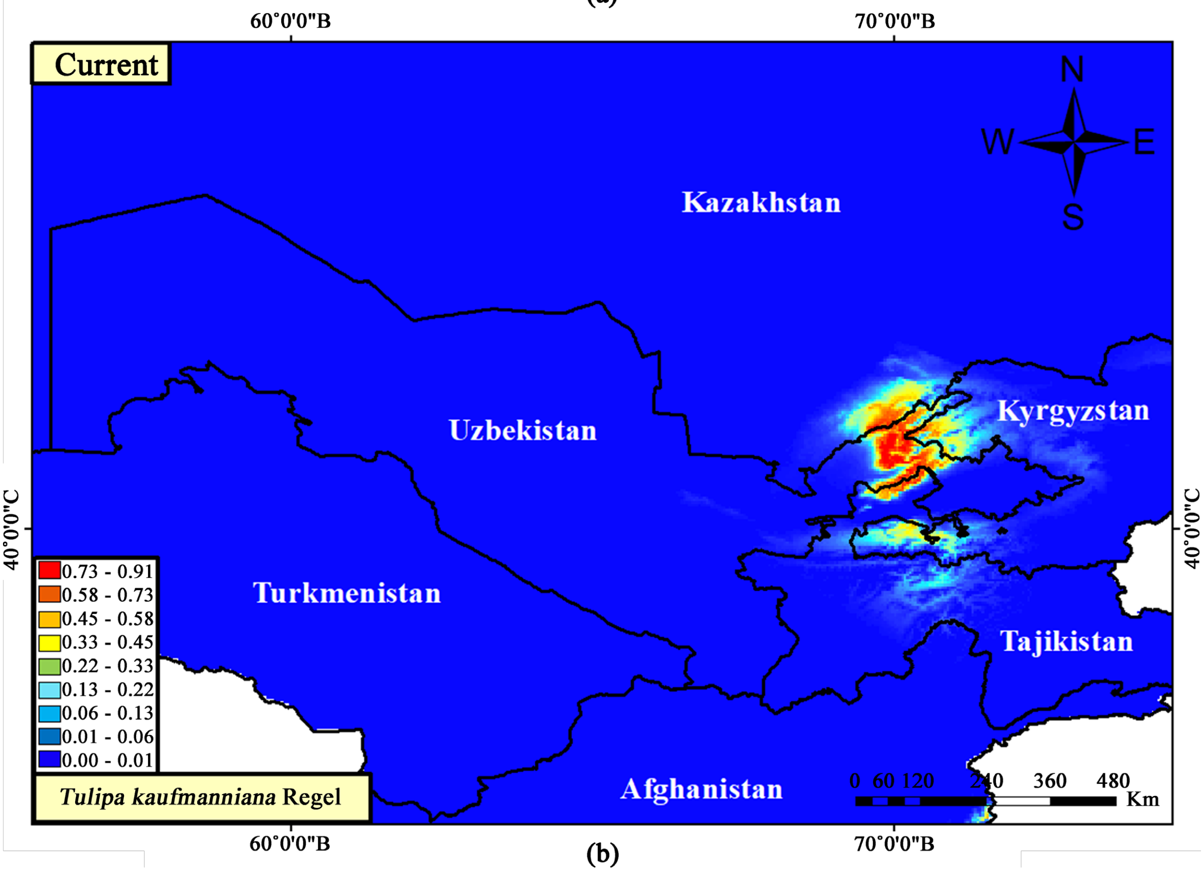
Figure 3. Species growth coefficient.

species for the Western Tien-Shan ridge, causing large differences between its real and potential range. The Tian-Shan Range averages 707.7 mm of annual precipitation in the areas where the coordinates are available and the Tien-Shan region has the most favorable annual rainfall for the growth of this tournament between the ridges, corresponding to the optimal rainfall range.

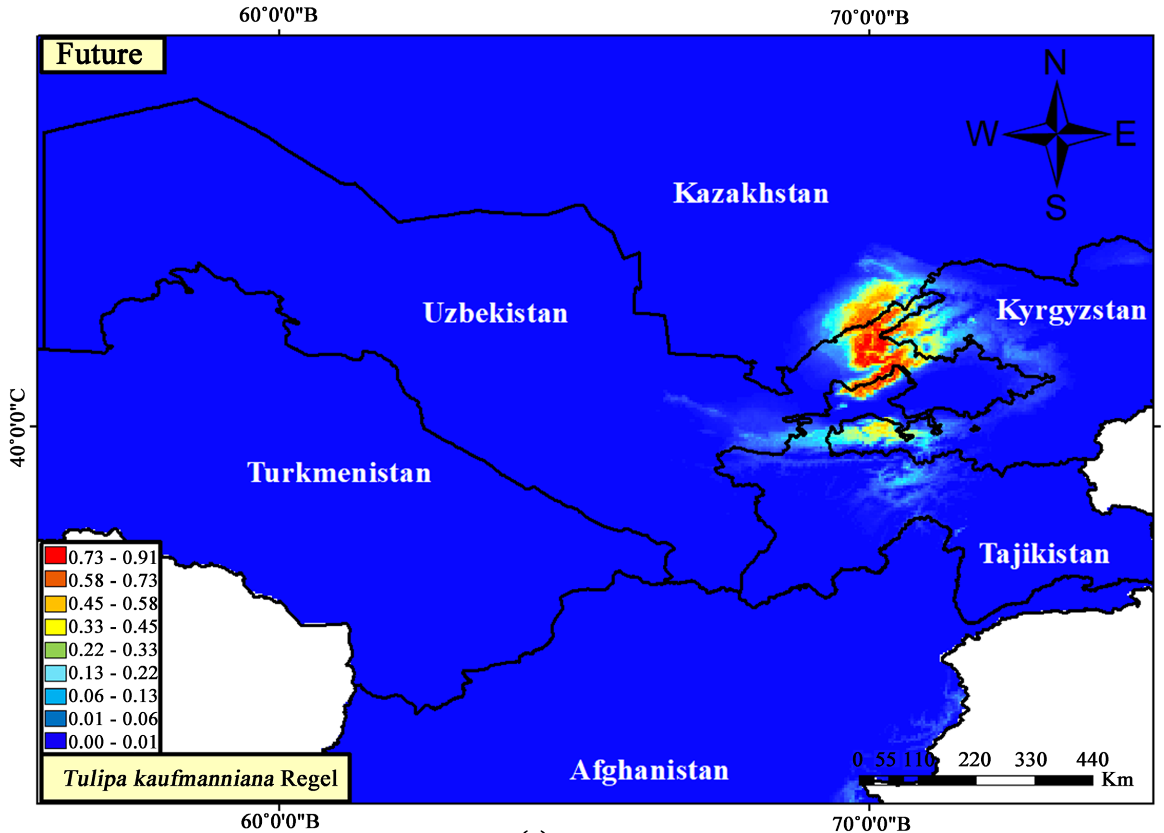
Modeling the *T. kaufmanniana* Regel based on climatic scenarios and identifying new populations in areas where it may occur requires constant monitoring and regular targeted field research. Analysis of the natural distribution range of the species shows that the areas where the species can grow are based on the Tien Shan area and adjacent areas (**Figure 4**). According to the modeling results,


60°0'0"B
70°0'0"B
Past
N
W
E
S
Kazakhstan
Uzbekistan
Kyrgyzstan
Turkmenistan
Tajikistan
Afghanistan
40°0'0"C
0.73 - 0.91
0.58 - 0.73
0.45 - 0.58
0.33 - 0.45
0.22 - 0.33
0.13 - 0.22
0.06 - 0.13
0.01 - 0.06
0.00 - 0.01
Tulipa kaufmanniana Regel
0 65 130 260 390 520
Km

(a)


60°0'0"B
70°0'0"B
Current
N
W
E
S
Kazakhstan
Uzbekistan
Kyrgyzstan
Turkmenistan
Tajikistan
Afghanistan
40°0'0"C
0.73 - 0.91
0.58 - 0.73
0.45 - 0.58
0.33 - 0.45
0.22 - 0.33
0.13 - 0.22
0.06 - 0.13
0.01 - 0.06
0.00 - 0.01
Tulipa kaufmanniana Regel
0 60 120 240 360 480
Km

(b)



(c)

Figure 4. Species distribution range ((a) past, (b) current, (c) future).

the relative contribution of environmental variables to the potential distribution area is shown in different tables. In the MaxEnt program, a number of indicators are used to assess the feasibility of a species prediction model. There are two different types of errors in modeling: **omission**—the presence of the quality of absence and prediction contribution, and **commission**—absence as a presence, prediction contribution. In this case, the graph exposes (diagram 1) that the red curve (fraction of background predicted) represents the contribution of "background" points in the lower variable cumulative boundary included in the modeled distribution region. The blue line—omission on training samples, describes the performance of the model and shows the contribution of the point of existence that extends beyond the boundary of the region, from the bottom to the top of the boundary value, limiting the prediction of the existing region. Blue line—omission on tasting samples. Black line—Predicted omission (**Figure 4**).

The Area Under the curve (AUC) diagram (**Figure 5**) formed in MaxEnt of the *T. kaufmanniana* Regel distribution zone consists of three lines. The red curve (Traning data) line delimits the AUC, and the closer this line is to the upper left corner, the larger the area under the curve, and the better the model predicts availability points. The blue curve (Test data) line indicates that the model being studied is well described by the model. The black line is straight (Random Prediction) delimiting the area, the discrimination below is not higher than chance.

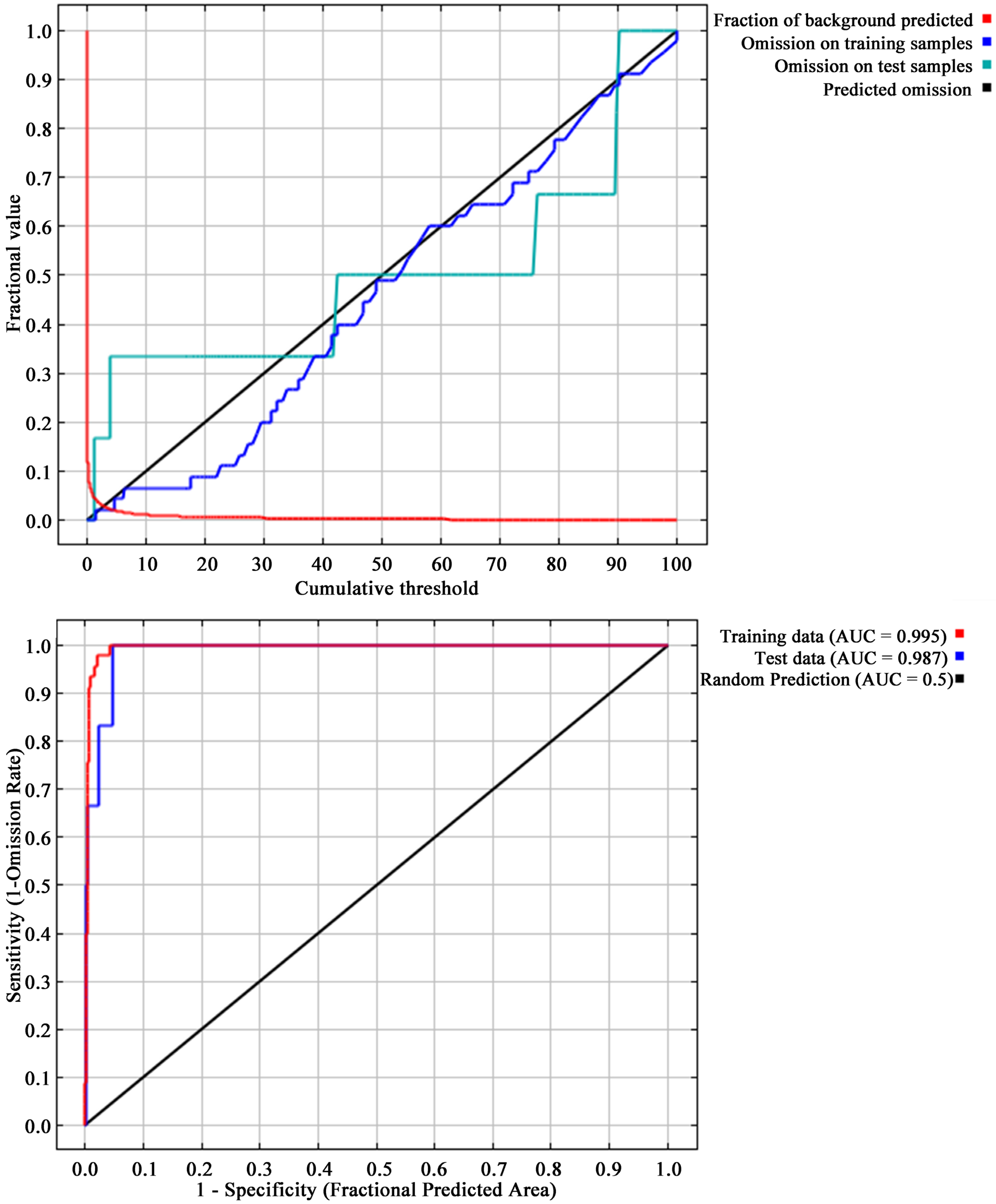


Figure 5. Feasibility of a species prediction model.

In this case, the model shows the climatic needs of the species, not the location of the species, which depends on many other conditions other than climate.

4. Conclusion

Data from the *T. Kaufmanniana* Regel show that the main distribution area of the species has been proven to be around the boundaries of the Tien-Shan mountain range. Climatic factors that are optimal for the species have been noted to be adequate temperatures and annual rainfall. The results of modeling are used to analyze rare and endangered species, to conduct long-term monitoring of them and to determine the ecological optimum of the species. Determining the ecological optimum of the species will allow for the successful introduction of these species in the future. In addition, data on rare and endangered species will be used in future editions of local Red Books.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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