

Bioclimatic Modeling Of *Phlomoides Sogdiana* (Pazij & Vved.) Salmaki

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Abstract: The article presents data obtained through bioclimatic modeling of *Phlomoides sogdiana*, a species distributed in the flora of Uzbekistan whose current range has been shrinking. The study revealed that the species is distributed in Jizzakh, Samarkand, Navoi, Kashkadarya, and Surkhandarya regions. For the first time, a bioclimatic model map of *Ph. sogdiana* was created. Under future climate scenarios SSP1-RCP 2.6 and SSP5-RCP 8.5, an increase of +1°C in the annual mean temperature is predicted to have a positive effect on the species' growth, leading to an expansion of its potential distribution range.

Keywords: Arel, Chatkal, Malguzar, Nurata, Ugam, Pskem, Kurama, MaxEnt, GIS, SDM.

INTRODUCTION:

Conservation management [4, 17, 21], the assessment of current and future species distribution, the processes occurring under the influence of environmental variables, and the identification of potential distribution areas are carried out using bioclimatic modeling methods [17]. Knowing the distribution of species is crucial for environmental management. However, it is difficult to determine exactly where each species is located at a given time. Therefore, species distribution models (SDMs) are applied to predict the ecological and geographical niches of species. Species distribution models are of great importance in spatial ecology, biogeography, and in developing effective strategies for biodiversity conservation [6, 16, 17, 18]. Among these models, the MaxEnt [5] software is considered one of the most widely used approaches.

Research in this field is also rapidly developing in Uzbekistan. For instance, scientists of the Institute of Botany of the Academy of Sciences of the Republic of Uzbekistan have used the MaxEnt software in most studies dedicated to natural flora, climate change, conservation planning, the development of effective strategies, invasive alien species, and ecological issues. Examples include the studies "Systematic

mapping of the flora of the Southwestern Hissar, Hissar-Darvaz, and Panj foreland districts (Surkhandarya region)" and "Assessment of the current state of vegetation cover and pasture resources of the Republic of Karakalpakstan" [1, 2, 14].

In addition, in studies dedicated to the genus *Phlomoides* Moench in the Fergana Valley (taxonomy, geography, ecology, and conservation measures) and the dendroflora of the Fergana Valley, rare and endemic species whose ranges are sharply shrinking and which have been recommended for the next edition of the Red Book were also subjected to bioclimatic modeling [5, 9].

Therefore, this study was aimed at creating a bioclimatic model of *Phlomoides sogdiana* (Pazij & Vved.) Salmaki, a species of Uzbekistan's flora whose distribution area is currently shrinking, and assessing the impact of global climate change processes on its geographical distribution.

METHODS

Data Collection and Sources

During the field studies conducted between 2020 and 2024 in Jizzakh, Samarkand, and Navoi regions, the

collected data, as well as herbarium specimens stored in the National Herbarium of Uzbekistan (TASH) and other major herbaria (MW, LE), were used. In addition, to carry out this research, online platforms such as the Global Biodiversity Information Facility (GBIF, www.gbif.org) [22], plantarium.ru [23], and iNaturalist [24] were also employed. The collected specimens were georeferenced using Google Earth Pro 7.1 software.

Methods

Environmental Variables

Current climate data were obtained from CHELSA-

BIOCLIM+ (<https://chelsa-climate.org>) [3], elevation data from WorldClim v2.1 (www.worldclim.org) (spatial resolution 0.30 arc minutes, 1×1 km) [8], and soil rasters from SoilGrids (<https://soilgrids.org>; 250 m resolution) [10]. All of these datasets were processed in QGIS v3.22.9 software using the WGS 1984 (World Geodetic System 1984) projection for the territory of Uzbekistan. Conversion of rasters from GeoTIFF to ASCII (American Standard Code for Information Interchange) format was performed using R v4.3.1 (raster package). The environmental variables used in the study are presented in Table 1.

Table 1.

Environmental variables

Code	Climatic Variables	Descriptions	Units
BIO1	Annual mean temperature		°S
BIO2	Mean diurnal range		°S
BIO3	Isothermality	BIO1 / BIO7 * 100	%
BIO4	Temperature seasonality	Coefficient of Variation	
BIO5	Maximum temperature of the warmest month		°S
BIO6	Minimum temperature of the coldest month		°S
BIO7	Annual temperature range	BIO5 – BIO6	°S
BIO8	Mean temperature of the warmest quarter		°S
BIO9	Mean temperature of the driest quarter		°S
BIO10	Mean temperature of the hottest quarter		°S
BIO11	Mean temperature of the coldest quarter		°S
BIO12	Annual precipitation		mm
BIO13	Precipitation of the warmest month		mm
BIO14	Precipitation of the driest month		Mm
BIO15	Precipitation seasonality	Coefficient of Variation	1
BIO16	Precipitation of the wettest quarter		mm
BIO17	Precipitation of the driest quarter		mm
BIO18	Precipitation of the hottest quarter		mm
BIO19	Precipitation of the coldest quarter		mm
Elevation	Absolute elevation above sea level		m
BDRICM	Depth to bedrock	(R horizon) 200 sm	sm
BDRLOG	Probability of R horizon occurrence		%
BDTICM	Absolute depth to bedrock		sm
BLDFIE	Bulk density		kg/m 3

CECSOL	Soil cation exchange capacity		cmolc/kg
CLYPPT	Clay particle weight fraction	(<0,0002 mm)	%
CRFVOL	Coarse fragment volume		
OCSTHA	Soil organic carbon stock		t/ga
ORCDRS	Soil organic carbon content		permille
PHIHOX	pH index measured in water solution		pH
PHIKCL	pH index measured in KCl solution		pH

Future Climate Scenarios

In the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC), updated Shared Socio-economic Pathways (SSPs) [13] from the World Climate Research Programme (WCRP) Coupled Model Intercomparison Project Phase 6 (CMIP6) [7] simulations were used. Two climate scenarios were applied: SSP1-RCP2.6 (moderate) and SSP5-RCP8.5 (high emissions). SSP1-RCP2.6 represents an optimistic forecast characterized by medium population growth and very low greenhouse

gas concentrations, whereas SSP5-RCP8.5 reflects a pessimistic projection with high population growth and high greenhouse gas concentrations [19].

For predicting the potential future distribution of species, climate simulations corresponding to medium-term global climate change (2041–2060) were selected. The increase in global mean air temperature and changes in annual atmospheric precipitation for the period 2041–2060, relative to 1995–2014, are presented in Table 2 [12].

Table 2.

Increase in global mean air temperature and annual atmospheric precipitation in 2041–2060

Increase in average global temperature and annual atmospheric precipitation	Scenarios	Air temperature (° C)		Atmospheric precipitation (%)	
		mean	range	mean	range
	SSP1-1.9	0.9 °C	0.4°C–1.4°C	2.9%	0.9–5%
	SSP1-2.6	1.0 °C	0.5°C–1.5°C	2.7%	0.5–5%
	SSP2-4.5	1.3 °C	0.7°C–1.8°C	2.8%	0.7–4.8%
	SSP3-7.0	1.4 °C	0.8°C–2.0°C	2.4%	-0.3–5.1%
	SSP5-8.5	1.7 °C	1.0°C–2.4°C	3.8%	0.7–6.8 %

Species Distribution Modeling

The potential distribution of the species was modeled using version 3.4.1 of the MaxEnt modeling algorithm [15]. In the model, 75% of the species occurrence data were used as training data and 25% as test data [11]. On the maps, the study area was classified into five categories according to the degree of habitat suitability for the species. These included unsuitable (0.0–20), low suitability (21–40), moderate suitability (41–60), high suitability (61–80), and very high suitability (81–100) areas [20].

RESULTS AND DISCUSSION

Predictive Accuracy of the Model

The predictive accuracy of all SDM algorithms was generally evaluated using the AUC (Area Under the Curve) value. In assessing the discrimination capacity of SDMs, an AUC value of 1.0 indicates perfect prediction, while 0.5 and lower indicates unreliable prediction. Based on the AUC values of *Ph. sogdiana* in the model, the average accuracy in all periods exceeded 0.9 (Table 3, Figure 1). This demonstrates that the model has a high level of accuracy.

Table 3.

Model performance accuracy

Periods	AUC (training)	AUC (test)	RP (random)
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			prediction)
Current	0.978	0.987	0.5
SSP1-RCP2.6	0.957	0.893	0.5
SSP5-RCP8.5	0.981	0.985	0.5
Average	0.972	0.955	0.5

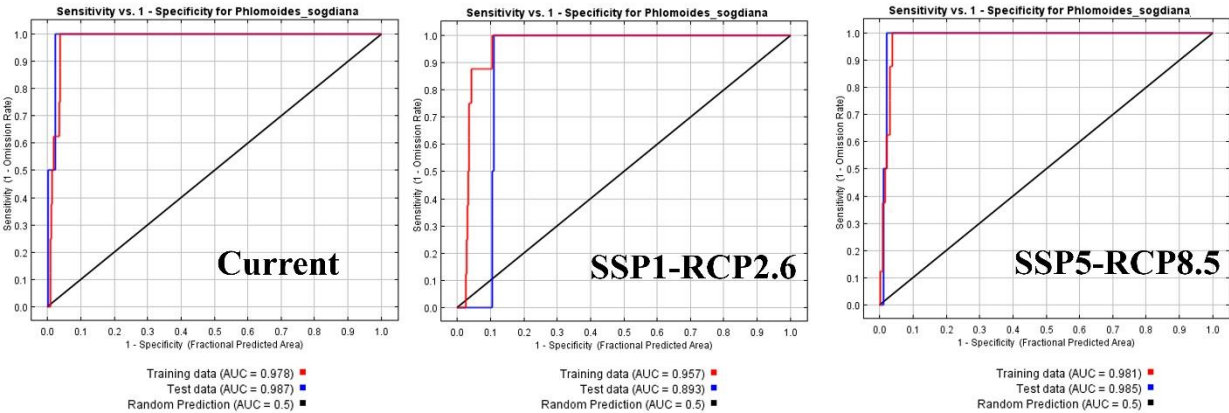


Figure 1. AUC value of the model for *Ph. Sogdiana*

Variables Contributing Most to the Model

The model was developed using 19 climatic variables, 11 soil variables, and elevation rasters. A total of 18 variables (55%) contributed to the model construction. The contribution of climatic variables to the model was 44.3%, elevation 2.4%, and soil parameters 53.3%. Among them, BDTICM (Depth to

Bedrock) contributed the most with 36.2%, followed by BIO9 (Mean temperature of the driest quarter) with 23.9%. The variable with the highest permutation importance was BDTICM (Depth to Bedrock), accounting for 39%. The indicators of the twelve variables with the highest contribution to the model are presented in Figure 2.

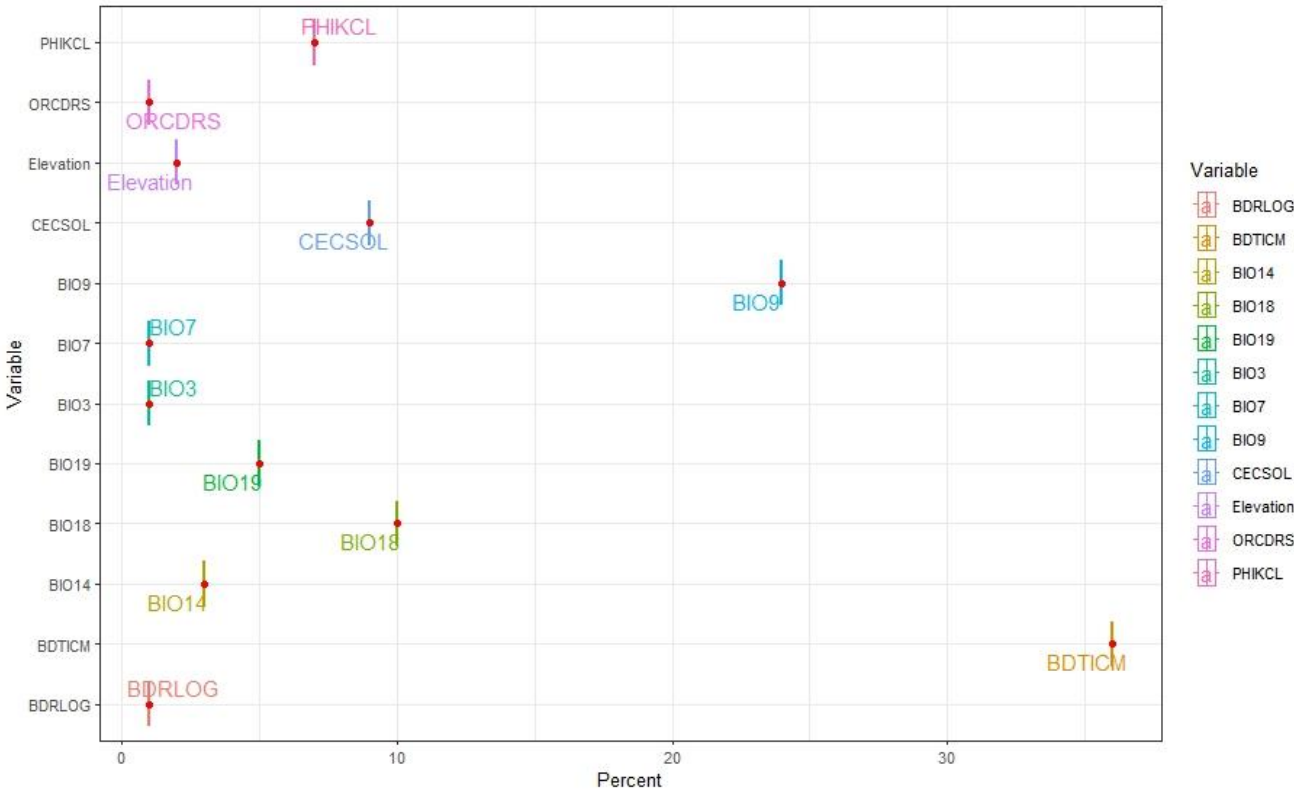


Figure 2. Variables contributing most to the potential distribution model of *Ph. sogdiana*

According to data from various sources, *Ph. sogdiana* is distributed in the Surkhan-Sherabad Valley and the Pamir-Alay mountain ranges (Malguzar, Nurata, Oqtov, Bakhiltov, Foziltov, Khobduntov, Koraqchatov, Turkiston, Zarafshan, Hissar, Kugitang). For the

current period, the areas predicted by the model as optimal for the species' growth correspond to the real-world areas where populations of the species occur (Figure 3). The areas suitable for the growth of the species under the current period and climate scenarios are presented in Table 4.

Table 4.

Suitability of Uzbekistan's territory for the growth of *Ph. sogdiana*

Periods	Current	SSP1-RCP2.6	SSP5-RCP8.5
Suitability level	Area km kv		
unsuitable	319332	210127	338489
low	49584	106814	79218
medium	45185	73017	15489
High	31694	53782	12331
Very high	3105	5160	3373
Total	448900	448900	448900

The potential distribution area of *Ph. sogdiana* in the current period is 3,105 km². Compared to this period, under the future climate scenario SSP1-RCP2.6, which is characterized as an optimistic forecast, the predicted areas increase and amount to 5,160 km². Within this scenario, not only does the area with favorable conditions for the species expand, but new habitats with suitable environments also emerge.

Among them are the dried part of the Aral Sea and the Qurama mountain range (Figure 4). Under the SSP5-RCP8.5 climate simulation, the potential distribution range of the species expands compared to the current period, but decreases relative to SSP1-RCP2.6, amounting to 3,373 km² (Figure 5). According to the model developed under the influence of this scenario, the current range of the species will change.

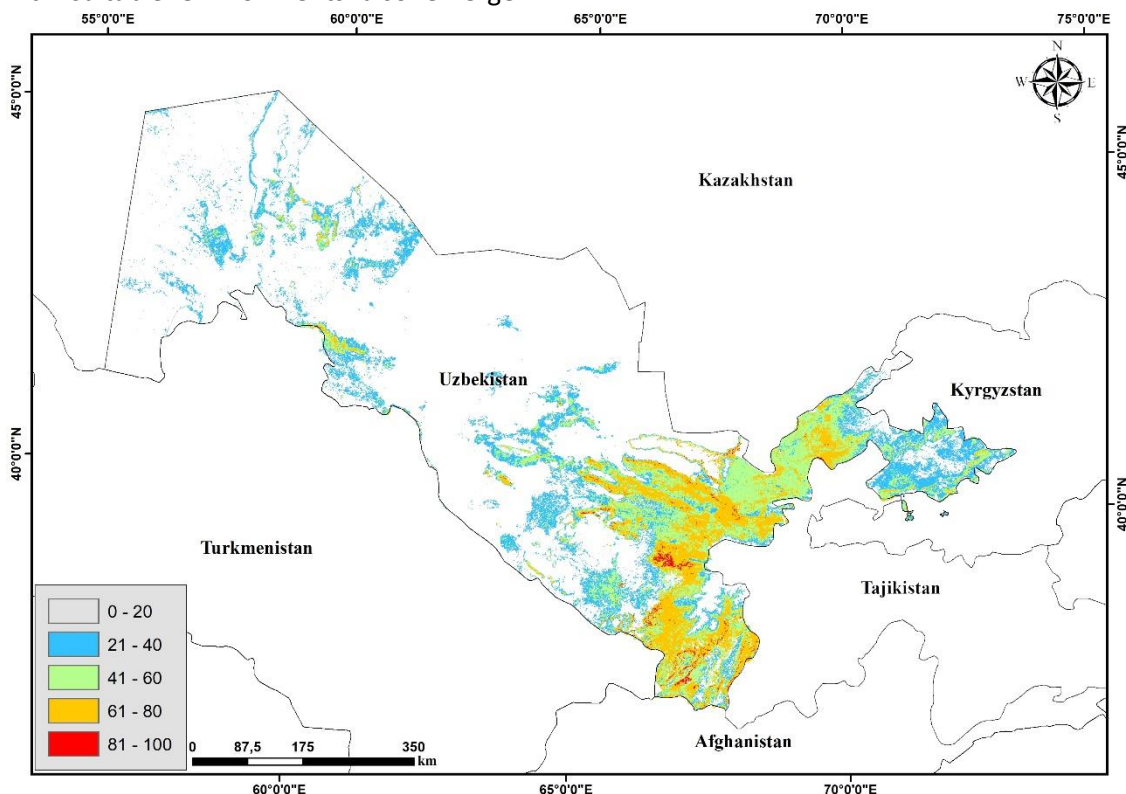


Figure 3. Potential distribution map of *Ph. sogdiana* in the current period

The present distribution range of *Ph. sogdiana*, which includes the Pamir-Alay, Nurata, and residual

mountains of the Kyzylkum, will completely disappear, and the species' new growth habitat will

be formed only in the Western Tien Shan ranges (Ugam, Pskem, Chatkal). This result confirms Fadrique's theory that, as a consequence of climate

change, the potential distribution range of some species shifts toward the poles, while others migrate to higher mountain areas.

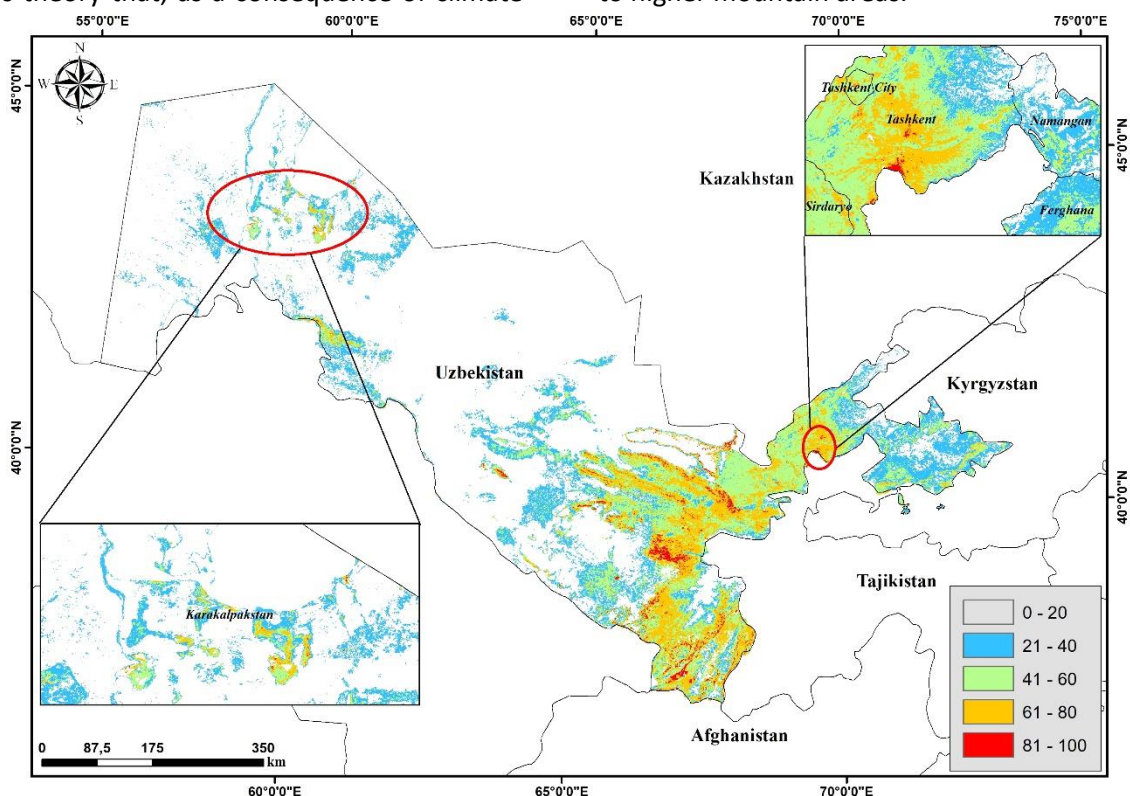


Figure 4. Potential distribution map of *Ph. sogdiana* under SSP1-RCP2.6

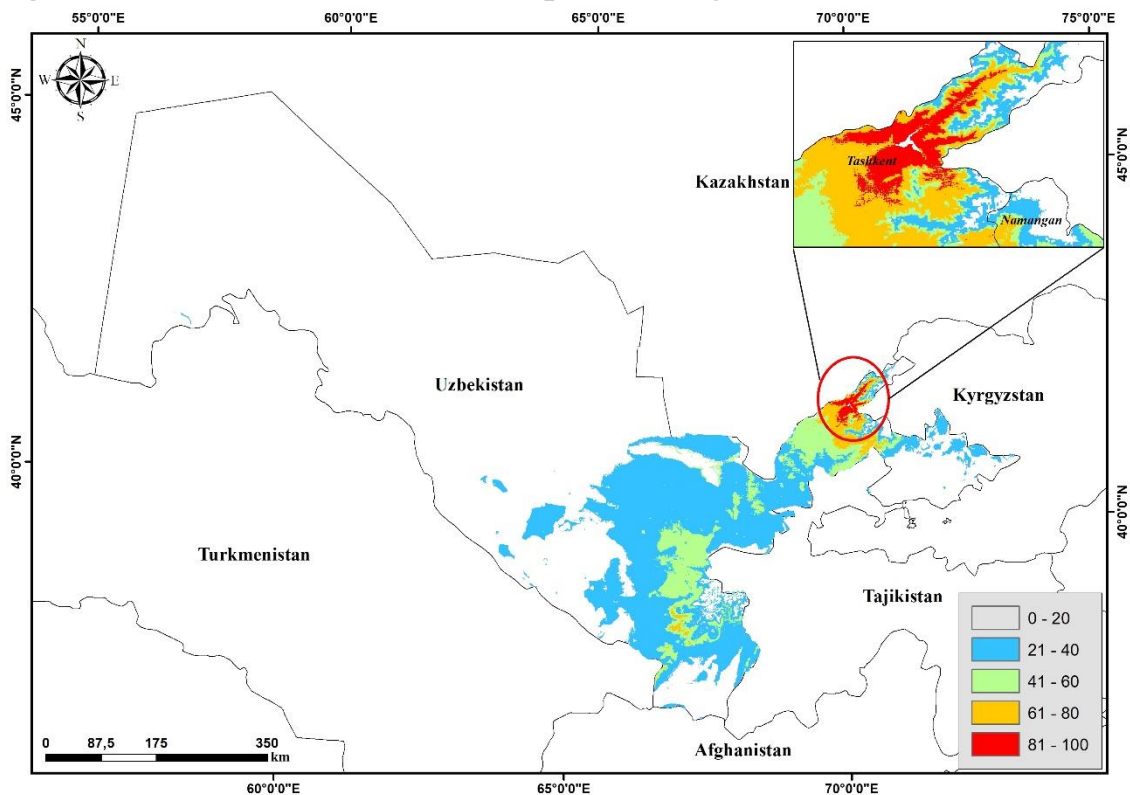


Figure 5. Potential distribution map of *Ph. sogdiana* under SSP5-RCP8.5

CONCLUSION

Within the framework of climate change scenarios,

the increase in annual average temperature was manifested in two different ways in the model. In both scenarios, the potential distribution range of *Ph.*

sogdiana expands compared to the current period. Under the optimistic climate simulation SSP1-RCP2.6, new areas with optimal conditions for the species' distribution are formed in the west, particularly in the dried basin of the Aral Sea. Under the SSP5-RCP8.5 climate scenario, the current distribution range of the species disappears, and new habitats emerge in the north, specifically in the Western Tien Shan ranges of Ugam, Pskem, and Chatkal. An increase of +1°C in annual average temperature has a positive effect on the growth of the species, while a rise of +1.7°C leads to changes in its range. According to the SSP5-RCP8.5 model forecast, it is recommended to organize targeted field research in the newly formed habitats in order to detect populations of *Ph. sogdiana*.

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