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Modelling of Potential Distribution of *Helichrysum nuratavicum* Krasch (Asteraceae) in Uzbekistan

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Abstract
The strong impact of climate change on the distribution of plant species on Earth is currently of great interest in the field of biogeography. In this research work, the endemic *Helichrysum nuratavicum* plant from the flora of Uzbekistan was selected to be studied. For current and future climatic scenarios for *H. nuratavicum*, the real and potential areal was assessed based on high-precision environmental data, geographical distribution, ecology, data of the National Herbarium of Uzbekistan (TASH) and the results of scientific field research, annual precipitation and average temperature ratios using Diva-GIS, Maxent program. In this case, the distribution was assessed on the basis of environmental factors, and the areas with the most optimal conditions were predicted according to climate change scenarios, the distribution of the species rcp 8.5. Based on the climatic scenario, and also the maps representing the distribution of the species were created. The results of our research have shown that areas with an optimal climatic index of the geographical area of the species will expand to the south in all future scenarios.

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INTRODUCTION

Understanding the principles of species distribution and predicting possible changes in ecosystems is one of the main tasks of modern botanical research (Sandanov & Pisarenko, 2018). MaxEnt (Maximum Entropy Species Distribution Modeling) is widely used in current research to model the geographical distribution of plant species and predict their future localization (Phillips and Dudík, 2008). To model the distribution of species according to future climate change scenarios the latest generation of climate scenarios - AR5 [RCP Representative Concentration Pathway] that has four scenarios (RCP 2.6, RCP 4.5, RCP 6.0, RCP 8.0) are widely used (Stocker et al., 2013). In Uzbekistan, the research in this area is at an early stage of development, the identification of areas with optimal conditions for spreading of plant species and predicting the changes that may occur in the future is developing (Akbarov et al., 2020).

Climate change may cause extinction of plant species that could not adapt to climatic conditions and have a limited geographical distribution due to changes in the growing conditions (Fois et al., 2018).

The article aims to identify and assess the real and potential areal of some rare and endemic species of Uzbekistan, and to predict their future condition that might arise due to climate change.

MATERIALS AND METHODS

The object of scientific research is *Helichrysum nuratavicum* Krasch., an endemic species of Uzbekistan that belongs to the genus *Helichrysum* Mill. *Helichrysum* Mill. Belongs to the family Asteraceae, 8 species are distributed in Central Asia (Keys to plants …., 1993), 4 species in Uzbekistan (Flora of Uzbekistan, 1962; Flora of the USSSR, 1959).

H. nuratavicum is endemic to the flora of Uzbekistan and to Nurata mountain system. This plant is also included in the red data book of Uzbekistan (2019) as a 2nd category species. It is found in the central part of the Nurata mountain system, in the Nurata State reserve (Majrumsay, Andigensoy, Hayotsay, Tikchasay, Bolasay, Dushah) at an altitude of 1200-2000 meters on rocky and semi-rocky slopes, where they grow as a sparse and isolated, and sometimes as small groups (Red book of….2017; Khujanov, 2020; Mustafaev and Khujanov, 2020).

Bioclimatic modeling: 14 geographical coordinates that show the natural growing environment of H. *nuratavicum* were identified in the territory of the Nurata mountain system. The main sources of data are the National Herbarium of Uzbekistan (TASH) and targeted field surveys that were carried out in 2018-2020. The modeling of potential spreading areas of *H. nuratavicum,* and prediction of climatic scenarios were performed using MaxEnt program (Phillips and Dudík, 2008; Phillips et al., 2006). Climate data were downloaded from the WorldClim 2.1 (2.5-minute phase pixels) database (www.worlclim.org) and analyzed using ArcGis 10.6.1 software. 19 bioclimatic variability indicators were used in the modeling (Table 1) (Fick & Hijmans, 2017), (www.worlclim.org).

Table 1: Indicators of bioclimatic variability

Code	Indicators of bioclimatic variability	Remarks	Unit
BIO1	Annual mean temperature		^0C
BIO2	Mean diurnal range		^0C
BIO3	Isothermality	BIO1 / BIO7 * 100	%
BIO4	Temperature seasonality	Variability coefficient	^0C
BIO5	Max temperature of warmest month		^0C
BIO6	Min temperature of coldest month		^0C
BIO7	Temperature annual range	BIO5 – BIO6	^0C
BIO8	Mean temperature of wettest quarter		^0C
BIO9	Mean temperature of driest quarter		^0C
BIO10	Mean temperature of warmest quarter		^0C
BIO11	Mean temperature of coldest quarter		^0C
BIO12	Annual precipitation		mm
BIO13	Precipitation of wettest month		mm
BIO14	Precipitation of driest month		mm
BIO15	Precipitation seasonality	Variability coefficient	%
BIO16	Precipitation of wettest quarter		mm
BIO17	Precipitation of driest quarter		mm
BIO18	Precipitation of warmest quarter		mm
BIO19	Precipitation of coldest quarter		mm

Based on current and future climatic scenarios for *H. nuratavicum*, the following formulas were used to determine the future distribution of this species in Uzbekistan, as a percentage from the total area (table 2).

Table 2: Formulas used to determine the future distribution of the species

$\sum s$ – 448.9 km^2 (Total area of Uzbekistan)		
f_1 - 95000 km^2 (1970-2000)	$f_1 \cdot k / \sum s = x_1$	$P_1 = x_1 = 21\%$
f_2 - 92500 km^2 (CURRENT)	$f_2 \cdot k / \sum s = x_2$	$P_2 = x_2 = 20\%$
f_3 - 72500 km^2 (RCP2.6 – 2050)	$f_3 \cdot k / \sum s = x_3$	$P_3 = x_3 = 16\%$
f_4 - 90000 km^2 (RCP8.5 – 2050)	$f_4 \cdot k / \sum s = x_4$	$P_4 = x_4 = 20\%$
f_5 - 75000 km^2 (RCP2.6 – 2070)	$f_5 \cdot k / \sum s = x_5$	$P_5 = x_5 = 18\%$
f_6 - 75000 km^2 (RCP8.5 – 2070)	$f_6 \cdot k / \sum s = x_6$	$P_6 = x_6 = 16\%$
k – 100%		

RESULTS AND DISCUSSION

According to the results of the modeling, the AUC indicators are followings: PAST (1970-2000) (training (accuracy level)), 0.95±05; (test), 0.96±0.04; CURRENT, (accuracy level), 0.96±0.04; (test) 0.97±0.03; RCP 2.6, 0.94 ±0.06 by 2070; (test), 0.95±0.05, RCP 8.5 0.97±0.03 by 2050; (test) 0.98±0.02, RCP 8.5 0.98±0.02 by 2070; (test) 0.98±0.02. The highest accuracy was observed in the RCP 8.5 scenario.

According to the results of the modeling, the relative contribution of environmental variables to the potential distribution area of *H. nuratavicum* was different in size (Figure 1).

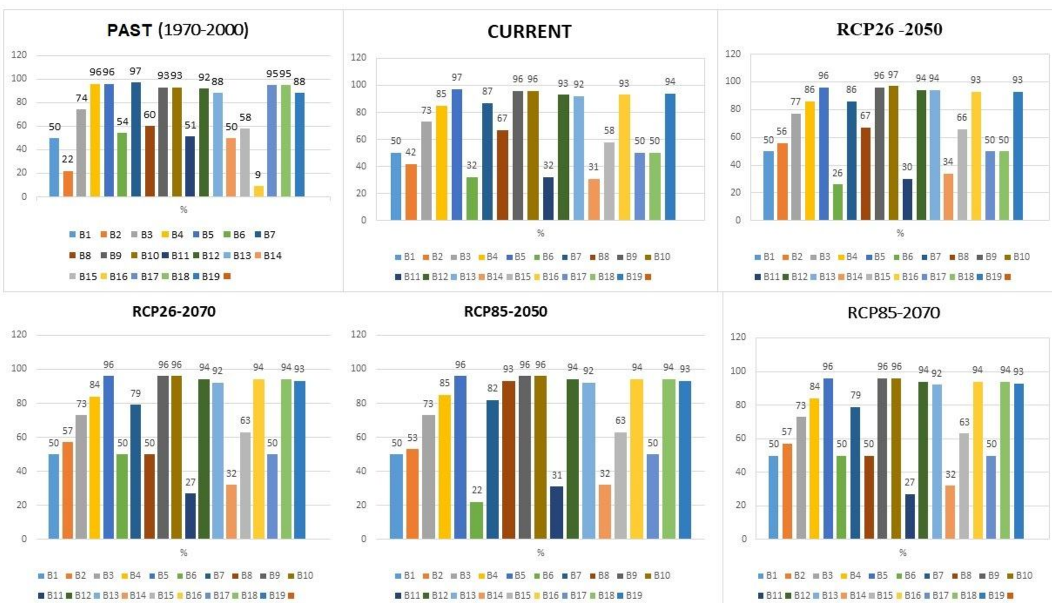

Figure 1: The relative contribution of environmental variables that were quantified according to the predictions of MaxEnt models using PAST (1970-2000), CURRENT and FUTURE bioclimatic scenarios.

According to the forecast, the changes in the following bioclimatic indicators will have a negative impact on distribution of *H. nuratavicum:* increase of mean temperature of wettest quarter (BIO 08, from 67% to 93% in the RCP 85-2050) and precipitation of wettest quarter (BIO16, from 9% to 94%), a decrease in precipitation of driest quarter (BIO17, from 95% to 50%) and precipitation of warmest quarter (BIO18, from 95% to 50%) (Table 3).

Table 3: Bioclimatic indicators impact on distribution of *H. nuratavicum*

Code	Past 1970–2000	Current	RCP26-2050	RCP26-2070	RCP85-2050	RCP85-2070
BIO04	96%	85%	86%	84%	85%	84%
BIO05	97%	97%	96%	96%	96%	96%
BIO07	97%	85%	86%	79%	82%	79%
BIO08	60%	67%	67%	50%	93%	50%
BIO09	93%	96%	96%	96%	96%	96%
BIO10	93%	96%	94%	96%	96%	96%
BIO12	92%	93%	94%	94%	94%	94%
BIO13	88%	92%	94%	92%	92%	92%
BIO16	9%	93%	93%	94%	94%	94%
BIO17	95%	50%	50%	50%	50%	50%
BIO18	95%	50%	50%	94%	94%	93%
BIO19	88%	94%	93%	93%	93%	94%

The following bioclimatic indicators have highest contribution in finding the most favorable climatic conditions for this species: **PAST** (BIO19: 53%), (BIO04: 36%), (BIO03: 11%), (BIO15: 0.5%), (BIO13: 0.1%); **CURRENT** (BIO07: 84%), (BIO19: 5.3%), (BIO14: 5.2%), (BIO15: 5.1%); **FUTURE** RCP26-2050 (BIO04: 58.4%), (BIO19: 24%), (BIO14: 12%), (BIO08: 3.5%), (BIO15: 1.3%), (BIO02: 1.2%); RCP26-2070 (BIO04: 45%), (BIO19: 43%), (BIO14: 12%), (BIO15: 0.2%); RCP85-2050 (BIO04: 48%), (BIO19: 39%), (BIO14: 14%) and RCP85-2070 (BIO04: 27%), (BIO19: 51%), (BIO14: 15%). While BIO19 returned to high values in all modeling and climate scenarios, BIO04, BIO14 and BIO15 had high values in all periods but one.

The maps show areas with high probability of favorable conditions for the distribution of species as RED color, areas with low probability of adaptation as BLUE, moderately and above average compatible areas as light and dark YELLOW, respectively. In the past (1970-2000) the areas with favorable climatic conditions for the optimal growth of *H. nuratavicum*, belonged only to the Pamir Alay's Nurata mountain system, however during the current period it expanded to Nurata, North Turkestan, Molguizar, Zarafshon, Hissar systems as well. According to future climate change scenarios the *H. nuratavicum* will be present in RCP2.6 (2050) Nurata, North Turkestan, Molguzar, Zarafshon, Hissar, Bobotog and Kuhitang; RCP 2.6 (2070) Nurata, North Turkestan, Molguzar, Hissar, Bobotog; RCP8.5 (2070) Nurata, North-Turkestan, Molguzar, Hissar, Bobotog. The results show that the areas with favorable climatic conditions for the spread of *H. nuratavicum* accounted for 13% of the total area of Uzbekistan in the PAST (1970-2000) and 15% during the CURRENT conditions. It is expected to expand in the future as the following climatic scenarios suggest: RCP2.6-2050 16%, RCP2.6-2070 18%, RCP8.5-2050 20% and RCP8.5-2070 17% (Figure 2).

The fact that *H. nuratavicum* is an endemic species to the Nurata mountain system results in a large difference between its real and potential areal. Therefore, modeling based on climatic scenarios requires regular monitoring and regular targeted field research to identify new populations of *H. nuratavicum* in new areas where this species is likely to occur in the future.

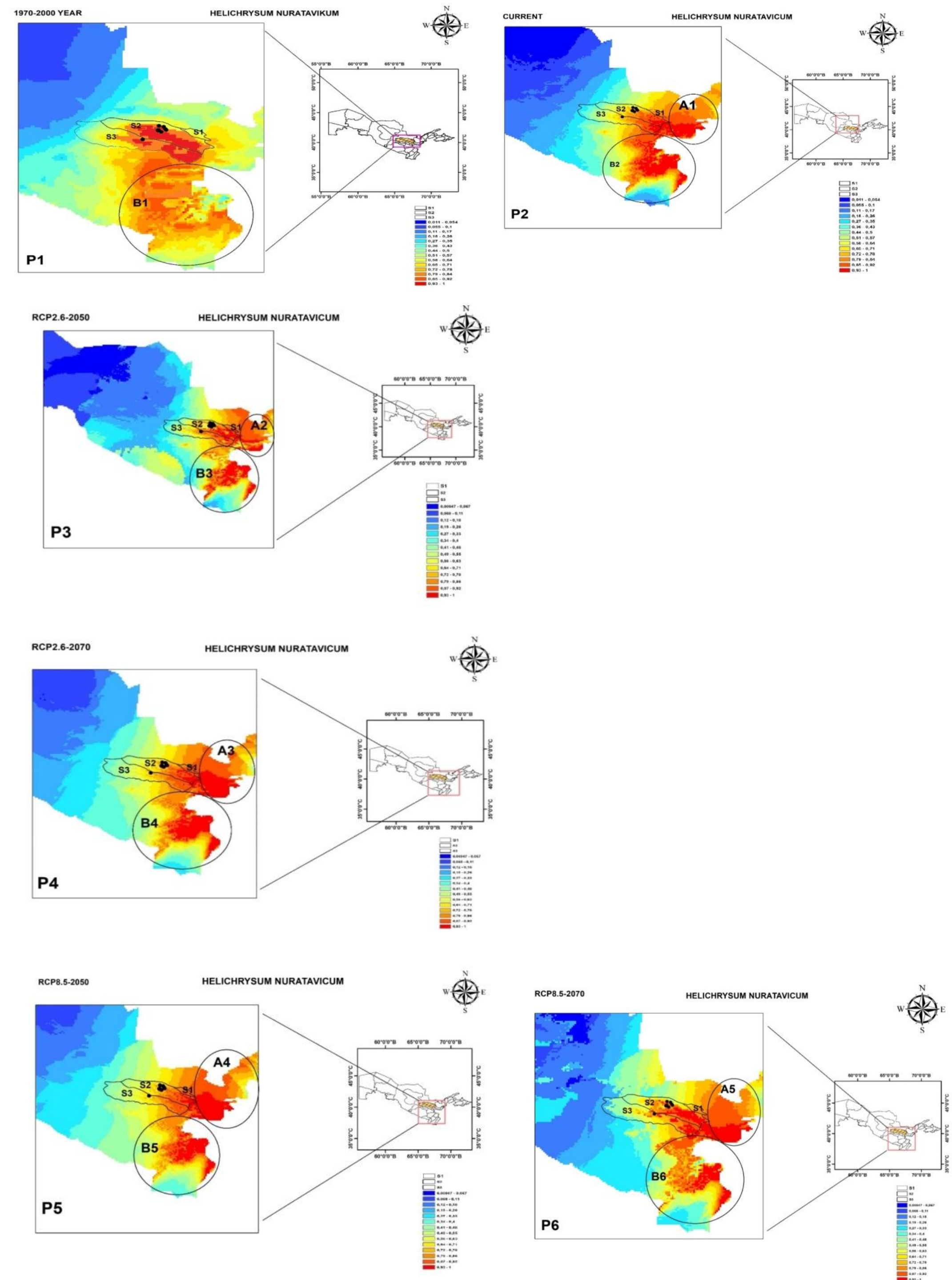

Figure 2: Suitable conditions for the spread of *Helichrysum nuratavicum*.

CONCLUSION

Areas with favorable climatic conditions for optimal growth of *Helichrysum nuratavicum*, in the recent past (1970-2000) period only the located in the Nurata ridge of Pamir Alay, while during the CURRENT period, expanded to the Nurata, North Turkestan, Molguzar, Zarafshan, Gissar, Babatag ridges. The fact that *H. nuratavicum* is an endemic species for the Nurota ridge makes great differences between its real and potential range. For *H. nuratavicum*, modeling based on climate scenarios requires identification of new populations in areas where the predicted species may be found, areas with optimal climatic conditions expanding south in all future scenarios, and constant monitoring and regular targeted field research.

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