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Modelling of the Climate Change Impact on the Spatial Distributions of *Crocus* Species in Iran

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Abstract

Global warming, droughts, widespread fires, and shifts in plant phenology contribute to a loss of biodiversity. Plant species are also facing a decrease in the desirability of their habitats due to climate change. These events result in significant genetic erosion within plant taxa. In the present study, to predict the current and future spatial distributions of *Crocus* species of Iran and possibility of expansion and reduction of their current habitats, the spatial distribution of this endangered genus, based on presence data of seven *Crocus* species, including *C. biflrous*, *C. cancellatus*, *C. caspius*, *C. haussknechtii*, *C. michelsonii*, *C. speciosus*, *C. sativus* was investigated under present and future climate change scenarios: RCP2.6 and RCP8.5 for the years 2050 and 2080 using a set of ecological variables (Sixteen environmental variables) and the MaxEnt model. The projected climate maps resulted in reductions and expansions, as well as positive and especially negative range change for the studied species in comparison to their current predicted distributions. Among all studied species, Saffron (*Crocus sativus*) showed the highest positive range change as well as the highest significant change under optimistic scenarios for 2050 and 2080, while *Crocus michelsonii* showed the highest range of negative changes under these scenarios. *C. biflorus*, *C. speciosus*, and *C. caspius* also revealed a negative range change, respectively. Finally, the results of this study revealed that the species whose current habitats are negatively affected by climate change (especially *C. michelsonii*) are the most endangered *Crocus* species in the face of climate change. Therefore, a conservation plan to protect these threatened species seems necessary.

Keywords: Climate change, *Crocus* species, Iran, MaxEnt, RCP2.6, RCP8.5, SDM

Introduction

The increase in global temperature, along with drought and wildfires, significantly contributes to

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the decline of biodiversity (Amedie, 2013). Based on the IPCC (Intergovernmental Panel on Climate Change), approximately 58% of plant taxa are expected to face a sharp decrease in habitat desirability due to climate change by 2080 (Warren et al., 2013). The mentioned catastrophic event resulted in significant genetic erosion in plant taxa (Jarvis et al., 2008). Considering the available evidence, climate change is known to be a negative event for the majority of species. The effect of climate change on a wide range of taxa will probably be negative (Muths et al., 2017; Yousefi et al., 2020).

Crop Wild Relatives (CWRs) are major natural genetic resources that play an important role in the improvement and promotion of crops (Maxted et al., 1997). CWRs include valuable genetic material, which may be useful for enhancing crops, such as increasing production and resistance against natural stresses. Consequently, assessing the impacts of climate change is a crucial step in establishing conservation priorities and executing management strategies (Guillera-Arroita et al., 2015).

Saffron (*Crocus sativus* L.) is a perennial bulb cultivated mainly in Iran, India, and the Mediterranean countries (Bathaie et al., 2010; Christodouloua et al., 2015). Saffron is known as the most expensive spice in the world, as well as the most valuable industrial and medicinal crop, primarily used for its aroma and flavor in food, and as a medicinal herb (Koocheki, 2004). Iran produces about 93% (301 tons) of the world's saffron production (Ghorbani and Koocheki, 2017). Furthermore, Central Asia, the Middle East, and the islands of South West Greece are considered the origin centers of saffron (Vavilov, 1951; Tammaro, 1989). The wild relatives of saffron can be utilized to enhance its quality and mitigate environmental stresses (Negbi, 1999). Iranian *Crocus* species exhibit highly variable flower coloration due to intensive gene exchange between genotypes. Therefore, it is suggested that the considerable genetic resources found in different *Crocus* species could be utilized to genetically improve *C. sativus*. Among the wild Iranian *Crocus* species, *Crocus pallasii* Goldb. is closely related to *C. sativus* (Sheidai et al., 2018). Unfortunately, several threatening factors, including climate change, land use change, overharvesting, and overgrazing, severely threaten these species. Therefore, they are classified in critically endangered (CR) and endangered (En) categories according to IUCN (International Union for Conservation of Nature) threatened categories (Mehrabian et al., 2020).

Ecological niche modeling (ENM) is an effective methodology for predicting distribution patterns in conservation management (Margules and Pressey, 2000; Groves et al., 2002; Peterson and Soberón, 2012; Flores-Tolentino et al., 2019; Mathur et al., 2023; Waheed et al., 2025). Up to now, a wide range of diffrent algorithms based on presence and/or absence data have been developed to predict distribution patterns of target taxa (Soberón and Peterson, 2005; Elith and Leathwick, 2007, 2009). Maximum entropy (MaxEnt) modeling is recognized as one of the best-performing methods for modeling diverse taxa based on presence data (Elith et al., 2006). So far, many studies have been conducted based on this methodology throughout the world (Rödder and Weinsheimer, 2009; Aragón et al., 2010; Rubidge et al., 2011; Khanum et al., 2013; Kujala et al., 2013; Legault et al., 2013; Adams-Hosking et al., 2015; Bleyhl et al., 2015; Luo et al., 2015; Sen et al., 2016; Ulrey et al., 2016).

Despite Iran's outstanding plant diversity, few modeling studies have been done in Iran. Saffron is an economically valuable species, and some of its wild Iranian relatives (as important breeding resources) are among the threatened taxa (Tabasi et al., 2021). To date, the distribution of these valuable taxa in Iran has not been modeled. Therefore, our study aims to predict the current and future spatial distributions of wild and cultivated *Crocus* species of Iran for the first time to forecast the possibility of expansion and reduction of their current habitats under scenarios projecting climate change, RCP2.6 (RCP, representative concentration pathway; optimistic scenario) and RCP8.5 (pessimistic scenario) for the years 2050 and 2080 using a set of ecological variables and the MaxEnt model. Finally, the results of this study can inform effective conservation decisions for these valuable species.

Material and methods

Study area

Iran is a segment of the Alpine-Himalayan geologic belt (Krinsley, 1970) that is considered one of the most seismically active regions in the world, with high natural uplands, as well as mountains that surround the irregular and lower interior (Fisher, 1968; Homke et al., 2004). The Zagros mountainous belt is a set of north-west to south-east trending parallel inhabits in the entire Western zones of Iran (Cucchi and Zini, 2003). In addition, the Alborz Mountain system is located in the Northern zone of Iran and stretches from the Southern parts of the Caspian Sea (Stöklin, 1974) from West (Azarbaijan) to East (Khorasan). This natural massif is located between the Caspian Sea and the Central plateau of Iran (Alavi, 1991). Other prominent mountainous systems, including the Kopet-Dagh, located in the Eastern margins of the Caspian Sea, extend into Northeastern Iran, Turkmenistan, and Northern Afghanistan (Afshar, 1979; Buryakovsky et al., 2001). Additionally, the Makran in the Southeast, as well as Jebal Barez in the Center, are other geomorphological formations of Iran (Fischer, 1968; McCall, 1997). Moreover, climatological units of Iran comprise of 35.5% hyper-arid, 29.2% arid, and 20.1% zone of the world. The precipitation shows an average of about 250 mm (about less than one-third of the average rainfall in the world, 860 mm) (Amiri and Eslamian 2010; Shakoor et al., 2010).

Species occurrence data collection

Distribution patterns originated from field assessments during 2017–2019 as well as some literature records available in several plant floras. Due to the lack of careful and reliable absence species distribution data, only presence data were used in this study. Distribution map including the presence of seven species (*Crocus biflorus* Mill., *Crocus cancellatus* Herb., *Crocus caspius* Ficher & Meyer., *Crocus michelsonii* B. Fedtsch., *Crocus speciosus* M. Bieb., *C. pallasii, C. sativus*) of the *Crocus* genus which enough data were available for their modelling (Fig.1). A geographic distribution database of these species was established using records that corresponded to 336 distribution points of them. These records were provided based on the review of Flora of Iran (Assadi et al., 1999), Flora Iranica (Rechinger, 1975), the illustrated flora of Golestan National Park (Akhani, 2005), plant samples from several Herbaria: HSBU, TUH, FUMH, the personal Herbarium of Dr. Akhani, the Herbarium of Hakim Sabzevari University, the Herbarium of Payame Noor University of Sari, and Virtual Herbaria of Wien (http://herbarium.univie.ac.at/database/search.php), several scientific literatures, as well as field excursions by authors. Additionally, ecological factors (e.g., latitude, longitude, and altitude) for some plant samples without geographic coordinates were provided by Google Earth ver.5.1.

Selection of environmental variables

In this study, first, based on a compilation of valid experiences of experts about the ecology of this group of taxa, a total set of 16 ecological variables (i.e. BIO2 = Mean Diurnal Range, BIO4 = Temperature Seasonality, BIO8 = Mean Temperature of Wettest Quarter, BIO11 = Mean Temperature of Coldest Quarter, BIO13 = Precipitation of Wettest Month, BIO15 = Precipitation Seasonality, BIO16 = Precipitation of Wettest Quarter, BIO19 = Precipitation of Coldest Quarter, Slope, Solar Radiation, Elevation, Sand Content, pH Index, Bulk Density, Coarse Fragments, Soil Organic Carbon Content) connected to the distribution pattern of *Crocus* species was used. Subsequently, collinearity among ecological variables was tested by Pearson's correlation coefficient (r), so if two variables were highly correlated (r > |0.70|), one of them was excluded according

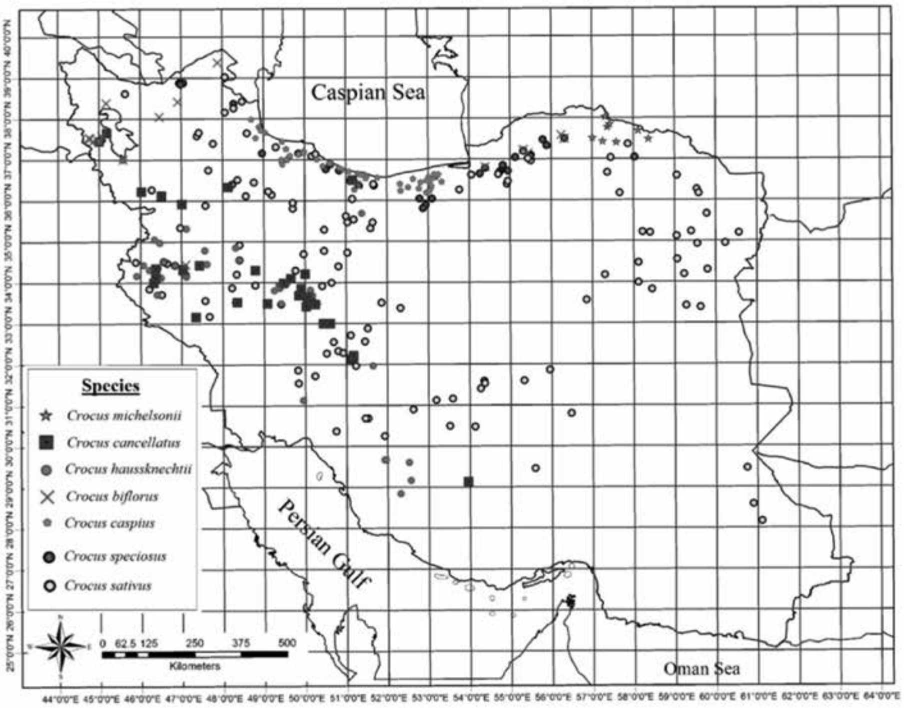

Fig. 1. Distribution map (based on presence data) of seven studied *Crocus* species: *C. biflrous*, *C. cancellatus*, *C. caspius*, *C. haussknechtii*, *C. michelsonii*, *C. speciosus*, and *C. sativus* in Iran

to our expert judgment in order to avoid collinearity (Elith et al., 2010). The source of selected variables after the correlation test is available in Table 1. To represent climate change influences, we used projected future climate variables for 2050 and 2080 (used the average of 16 General Circulation Models (GCMs) under optimistic (RCP 2.6) and pessimistic (RCP 8.5) with the 30 arc-second (ca. 1 × 1 km) resolution) with empirically downscaled bioclimatic data downloaded from the CCAFS website (Climate Change, Agriculture and Food Security; http://www.ccafs-climate.org).

Modelling process and evaluation

The MaxEnt model (Phillips et al., 2006) was applied for modelling species current and future habitat suitability. MaxEnt (jar file v3.4.1) was utilized through the dismo package v1.1-4 (Hijmans et al., 2017) in R v3.2.3 programming environment (R Core Team, 2018). The MaxEnt model is particularly used when the data points include presence-only with a limited number of records (e.g., Vasconcelos et al., 2012; Bosso et al., 2013; Fois et al., 2018). The models were evaluated using 10-fold cross-validation. In cross-validation, data is randomly divided

Table 1. Source of selected variables after correlation test, and estimates of their permutation importance

Source	Variable	Permutation importance (%)						
		C. biflorus	*C. cancellatus*	*C. caspius*	*C. haussknechtii*	*C. michelsonii*	*C. speciosus*	*C. sativus*
Bioclimatic variables (www.worldclim.org)	BIO2 = Mean Diurnal Range	18.7	3.6	27.3	0.9	-	1.9	2.4
	BIO4 = Temperature Seasonality	0.9	-	15.7	0.9	0.1	20.1	5.4
	BIO8 = Mean Temperature of Wettest Quarter	-	16.1	0.1	18.3	-	5.1	0.8
	BIO11 = Mean Temperature of Coldest Quarter	2.1	-	-	-	2.3	-	-
	BIO13 = Precipitation of Wettest Month	-	-	11.6	-	-	2.9	-
	BIO15 = Precipitation Seasonality	4.3	1	9.9	9	86.4	1	6.5
	BIO16 = Precipitation of Wettest Quarter	-	10.1	-	2	-	-	4.4
	BIO19 = Precipitation of Coldest Quarter	11.2	-	-	-	3.9	-	-
Topographic variables (www.worldgrids.org) (www.isric.org)	Slope	0.7	1.3	2	3.9	0.3	9.1	10.2
	Solar Radiation	43.4	7.1	5.3	2.6	-	29.7	19.8
	Elevation	5.9	3.5	9.8	3.2	-	8	8.1
Edaphic predictor (www.soilgrid.org) (www.isric.org)	Sand Content	0.3	45.4	8.7	34.2	0.3	0.6	30.3
	PH Index	-	-	3.1	-	-	-	-
	Bulk Density	-	-	6.7	-	-	-	-
	Coarse Fragments	-	4.9	-	0.6	0.1	4.9	9.1
	Soil Organic Carbon Content	12.6	7	-	24.5	6.7	16.8	3

into 10 parts, nine parts are used for model fitting, and the fitted model is evaluated on the holdout part (Valavi et al., 2018). We also considered permutation importance to define the main environmental variables that have influenced the potential distribution of the studied species (Abdelaal et al., 2019). To assess the accuracy of the modelling results, the Area Under the Curve (AUC) (Yi et al., 2016; Fois et al., 2018) of the Receiver Operating Characteristic Curve (ROC) was computed (Lobo et al., 2008). AUC shows the power of the model to discriminate the presence of a random background (Phillips et al., 2009).

Results

Modelling outputs for the potential habitat suitability of *C. biflorus*, *C. cancellatus*, *C. caspius*, *C. haussknechtii*, *C. michelsonii*, *C. speciosus*, and *C. sativus* with 16 environmental variables (correlation test) showed perfect predictive performance with AUC values (i.e., 0.944, 0.945, 0.990, 0.946, 0.980, and 0.898, respectively). Considering permutation importance, Precipitation Seasonality (BIO15), Sand Content, Solar Radiation, and Mean Diurnal Range (BIO2) were respectively the main environmental variables that have influenced the potential distribution of all species. In this regard, for *C. biflorus*, Solar Radiation and Mean Diurnal Range (BIO2); for *C. cancellatus*, sand content and Mean Temperature of Wettest Quarter (BIO8); for *C. caspius*, Mean Diurnal Range (BIO2) and Temperature Seasonality (BIO4); for *C. haussknechtii*, sand content and soil organic carbon content; for *C. michelsonii*, Precipitation Seasonality (BIO15); for *C. speciosus*, Solar Radiation and Temperature Seasonality (BIO4) and finally for *C. sativus*, sand content and Solar Radiation were respectively important (Fig. 2).

The projected climate maps under optimistic and pessimistic scenarios (RCP 2.6 and RCP8.5) of 2050 and 2080 (Fig. 3) resulted in reduction and expansion as well as positive and especially negative range change for the studied species in comparison to their current predicted distributions (Tables 2 and 3). Among the studied species, *C. michelsonii* showed the highest range of negative changes based on the loss and gain of suitable habitats under these scenarios. *C. biflorus*, *C. speciosus*, and *C. caspius* also revealed a negative range change (less than *C. michelsonii*) under the scenarios mentioned above, respectively. However, among the studied species, *C. sativus* showed the highest positive range changes as well as the highest increase (significant increase) under optimistic scenarios for 2050 and 2080. Some species, like *C. cancellatus* and *C. haussknechtii*, showed different range changes under these scenarios.

The current distribution patterns of these taxa in Iran are often concentrated in Alborz (North and North West), Kopet Dagh (North East), and Zagros (West). The main area of *Crocus* species distribution is confined to the Mediterranean phyto-chorion that extends into the Irano-Turanian region (Negbi, 1999).

Discussion and Conclusion

The present study demonstrated the potential geographical distributions of seven

Crocus species in Iran under both current and future climate scenarios. The results obtained in the present study showed that BIO2 (Mean Diurnal Range), BIO15 (Precipitation Seasonality), edaphic factors (Sand Content), and topographic variables (Solar Radiation) are generally key to the geographic distributions of the studied species.

Based on Benschop (1993), temperature is the most important environmental factor controlling the growth and flowering of *crocus* species by affecting enzyme activity in plant metabolism. It is determined that bulb and corm size is a major factor in determining the capacity of bulbous plants to flower as well as efficient reproduction (Le Nard and De Hertog, 1993). In *Crocus*, flower

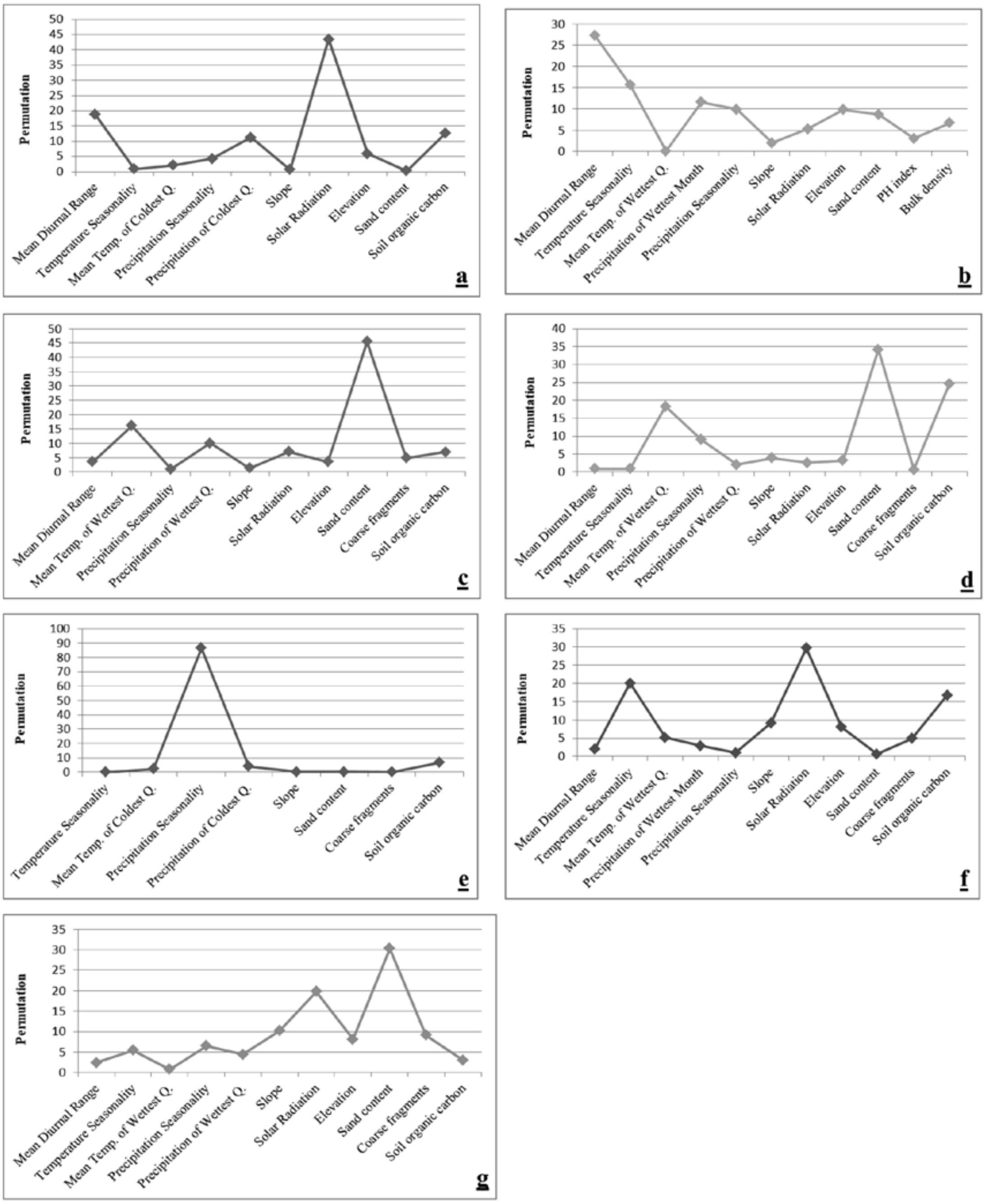

Fig. 2. permutation importance of *C. biflorus* (a), *C. caspius* (b), *C. cancellatus* (c), *C. haussknechtii* (d), *C. michelsonii* (e), *C. speciosus* (f), *C. sativus* (g)

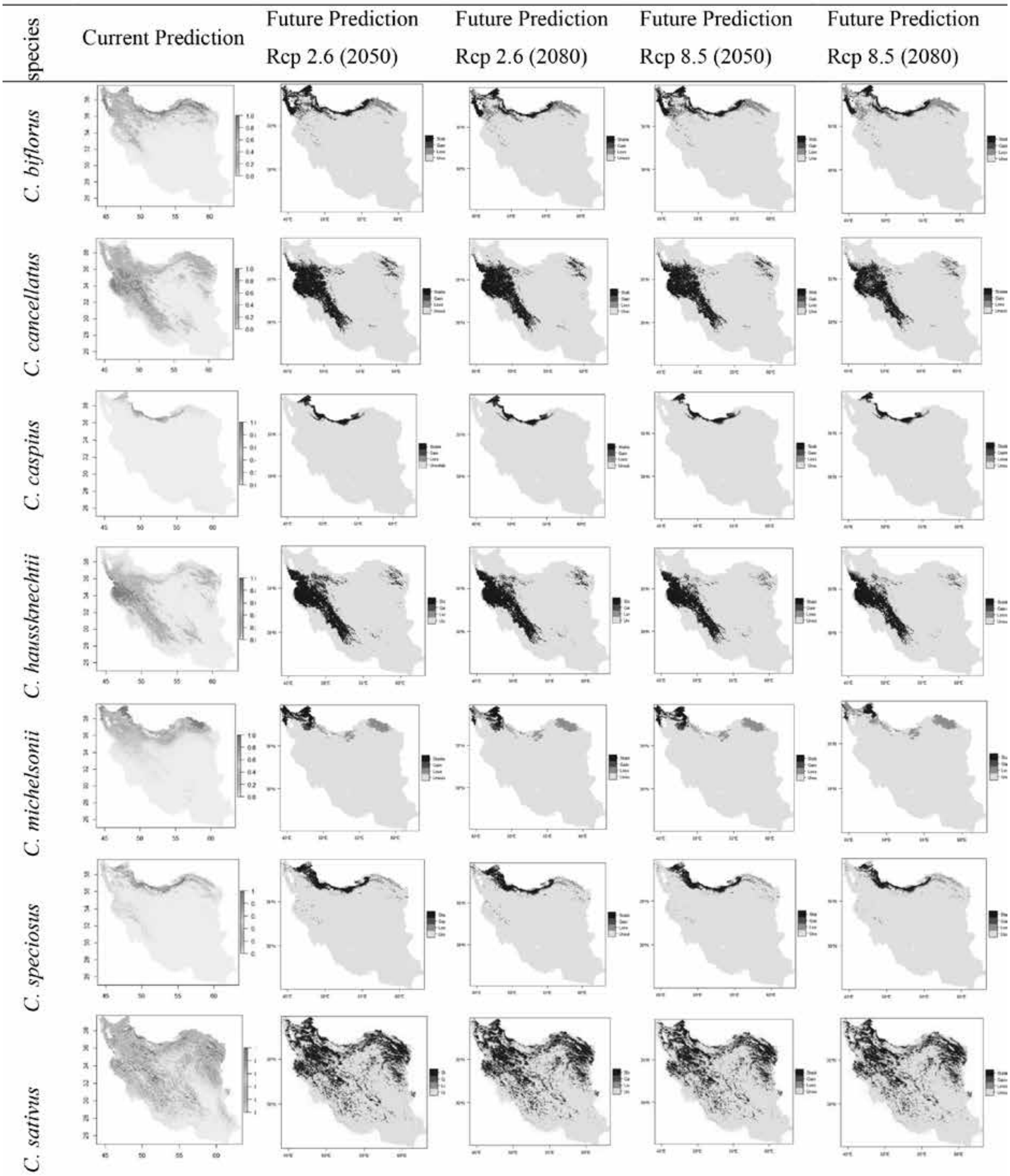

Fig. 3. Prediction of species distribution potential under climate change scenarios RCP2.6 and RCP8.5 2050 and 2080

formation is directly related to corm size (Negbi et al., 1989; De Mastro and Ruta, 1993). The previous studies showed that low growth temperatures have a positive effect on the final biomass of the corms (Badri et al., 2007; Lundmark et al., 2009) and seed germination rate (Bernareggi et al., 2016) in this genus. Therefore, an increase in temperature will damage the reproductive cycle of this taxon. Based on species distribution modeling conducted in Cyprus, *Crocus cyprius* is experiencing a significant decline in its populations as the temperature rises, particularly evident in the warmest month (Louca et al., 2015). Moreover, the results of Baikov and Doronkin's (2020) study showed that climatic variables that influence the amount of heat in the warmest period of a year (for example, maximum average diurnal temperature of surface air in the warmest period of a year) may be taken into account as factors, limiting the population size of rare species in Iridaceae.

Furthermore, precipitation plays an important role in species richness, distribution patterns, and the diversification of plant spe-

Table 2. Percentage of gain, loss, and range change of studied species (RCP2.6 of 2050 and 2080)

Species	Time – Scenarios (2050 – RCP2.6)			Time – Scenarios (2080 – RCP2.6)		
	Gain	Loss	Range change	Gain	Loss	Range change
C. biflous	15.40	50.68	-35.29	9.45	57.17	-47.72
C. caspius	23.06	28.41	-5.35	26.21	26.98	-0.78
C. canellatus	24.45	8.88	15.57	22.54	9.33	13.20
C. haussknechtii	18.22	5.68	12.53	13.13	6.52	6.61
C. michelsonii	17.13	53.74	-36.61	16.19	66.49	-50.29
C. speciosus	17.85	39.81	-21.96	20.27	39.35	-19.09
C. sativus	41.49	9.43	32.05	47.30	8.77	38.53

Table 3. Percentage of gain, loss, and range change of studied species (RCP8.5 of 2050 and 2080)

Species	Time – Scenario (2050 – RCP8.5)			Time – Scenario (2080 – RCP8.5)		
	Gain	Loss	Range change	Gain	Loss	Range change
C. biflous	13.63	51.38	-37.76	6.32	64.80	-58.48
C. caspius	17.32	32.11	-14.78	13.74	34.85	-21.11
C. canellatus	16.38	14.97	1.41	11.95	29.65	-17.69
C. haussknechtii	6.85	15.26	-8.41	3.79	22.28	-18.49
C. michelsonii	14.20	61.89	-47.68	0.42	82.93	-82.50
C. speciosus	10.91	47.41	-36.50	4.42	59.21	-54.79
C. sativus	30.64	14.57	16.08	28.64	16.80	11.84

cies (Pausas and Austin, 2001; Yan et al., 2015). The potential distribution models of certain plant taxa in Iran, including *Astragalus caragana* Fischer & C. A. Meyer (Ardestani et al., 2015), *Daphne mucronata* Royle (Abolmaali et al., 2018), and *Onosma* L. (Khajoei Nasab et al., 2020), confirmed the importance of this environmental factor. Distribution patterns of studied taxa showing a wide range of average annual rainfall of between 300 mm (Zagros, Kopet Dagh, Central mountains as well as Southern Slopes of Alborz) to 1200 mm (Northern Slopes of Alborz), so precipitation has a great impact on the growth of these taxa in vegetative state (Jafarbeyglou and Mobaraki, 2009).

The results of the present study about the key effects of precipitation and temperature in geographic distributions of the studied species agree with the conclusions of previous studies on the effects of these factors on growth and distribution patterns of *Crocus* species (Benschop, 1993; Jafarbeyglu and Mobaraky, 2008; Louca et al., 2015; Tabasi et al., 2015).

Moreover, the distributions of plant taxa also depend on edaphic factors such as sand content as well as variables derived from topography (e.g., elevation, slope, solar radiation) (Hanson and Churchill, 1962; Guisan and Thuiller, 2005). The results of our study show that sand content plays a crucial role in the geographic distributions of the studied *crocus* species especially concerning the two closely related species, *C. sativus* and *C. haussknchtii* (Sheidai et al., 2018) as well as, *C. cancellatus*. In addition, *Crocus* species grow in a wide spectrum of soil types, but thrive best in deep soils. Accordingly, shallow soils and rocky texture (e.g., high elevations) are unsuitable for *Crocus* (Negbi, 1999). However, as temperature rises, *Crocus* populations are likely to need to migrate to higher elevations; they will not be able to establish themselves due to the unfavorable soils (e.g., shallow soils and rocky texture) of these areas for their growth. Several studies have emphasized the role of edaphic factors in shaping the spatial patterns of plant taxa in Iran (Mehrabian, 2015; Sayadi and Mehrabian, 2016; Sayadi et al., 2017; Moradi et al., 2019; Khajoei Nasab et al., 2020). The physical and chemical properties of soils (soil pH, calcium carbonate, soil texture, nitrogen, phosphorus, potassium, and organic matter contents of the soils) in the growth place of some *Crocus* species are determined in previous studies (Satıl and Selvi, 2007; Kandemir, 2009; Şık and Candan, 2009; Khattak and Khattak, 2011; Kandemir et al., 2012). Based on these studies, the levels of nitrogen (N), phosphorus (P), potassium (K), and organic matter are elevated in the soils that support the growth of various *Crocus* species.. The role of edaphic factors in geographic distributions of the studied *Crocus* species in the present study, especially about *C. haussknechtii*, is highly influenced by sand content and Soil Organic Carbon, supporting the suggestions of Kandemir et al. (2009, 2012) and Satıl and Selvi (2007) studies about this subject that *Crocus* species (for example, *Crocus* pallasii, synonym *C. haussknechtii*) prefer to grow in soils with rich organic matter contents.

Solar radiation is another key factor that affects the distribution of the studied *Cro-*

cus species. Solar radiation affects vegetation pattern, plant distribution, and growth by influencing near-surface air temperature, soil temperature, and soil moisture within a region (Coblentz and Riitters, 2004; Bennie et al., 2008; Yilmaz et al., 2016). The special importance of solar radiation in the crop production process is determined in several previous studies (Monteith, 1973; Penning de Vries et al., 1989). It is also considered a significant factor in the growth and distribution of *C. sativus* as noted by Kumar et al. (2009). Based on this study, saffron plants show poor growth in shaded conditions, whereas they exhibit the highest under direct sunlight.

The findings of our study revealed that the response of the studied species to environmental changes varies somewhat. Habitat loss occurs when a region that is predicted to be suitable under current climate conditions turns unsuitable as a result of climate change (Randin et al., 2009). Numerous studies have revealed the possibility of decline or loss of currently suitable habitats of certain plant taxa, such as *Thuja korainsis* Nakai. (Wang et al., 2016), *Alsophila denticulate* Baker. (Wang et al., 2016), *Bruguiera gymnorrhiza* (L.) Lam. (Cao et al., 2020) and *Pedicularis longiflora* Rudolph. (Cao et al., 2020) in light of future climate change scenarios. The findings of the present study suggest that the habitats of *C. michelsonii* are experiencing the most significant negative changes due to climate change. The distribution of *C. michelsonii* is limited to the Kopet Dagh. This area is recognized as a top conservation priority in Iran (Mehrabian et al., 2020). Furthermore, given that the growth of this species is significantly influenced by precipitation levels (Table 1), the potential loss of the appropriate habitat of *C. michlsonii* in Iran due to decreasing rainfall is highly predictable. Other species such as *C. biflorus*, *C. speciosus*, and *C. caspius* are also experiencing negative impact on their current habitats by climate change. The distribution of *C. caspius* is limited to the Hyrcanian region of Iran (Assadi et al., 1999). The lowest belt of the Hyrcanian forests, which serves as a primary habitat for this species, is currently diminishing following an intensification of land use in the area, mainly cattle grazing and cultivation of rice, cotton, and tea (Frey and Probst, 1986). In addition to the Hyrcanian region, *C. biflorus* and *C. speciosus* are also distributed in the Irano-Turanian region (Assadi et al., 1999). Based on Tabasi et al. (2021), the threatened *Crocus* species in Iran are mainly distributed in the Irano-Turanian region. The mountainous ecosystems of Almeh and Western Alborz, which are among the distribution areas for these two species, are considered significant distribution centers of the threatened *Crocus* species in this region. Furthermore, the findings of the current study (Table 1) indicated that temperature factors (Mean Diurnal Range for *C. caspius* and *C. biflorus* and Temperature Seasonality for *C. speciosus*) are critical bioclimatic variables influencing the growth of these species. Consequently, it is anticipated that a reduction in suitable habitats for these species will occur as a result of climate change and global warming, given that lower temperatures positively affect the growth of *Crocus* species (Badri et al., 2007; Lundmark et al., 2009).

On the other hand, numerous studies have revealed the possibility of habitat expansion among certain plant taxa (for example, Capparis spinosa L. (Ashraf et al., 2018), *Ambrosia artemisiifolia* L. (Adhikari et al., 2019), *Ambrosia trifida* L. (Adhikari et al., 2019), *Solanum carolinense* L. (Adhikari et al., 2019), and *Onosma* L. (Khajoei Nasab et al., 2020)) in light of future climate change scenarios. The anticipated expansions of the distribution range of various taxonomic plant groups in Iran are projected under these scenarios (Kafash et al., 2016; Farashi and Erfani, 2018; Kafash et al., 2018; Khajoei Nasab et al., 2020). According to the findings of the present study, the suitable habitat for *C. cancellatus*, *C. Haussknechtii*, and *C. sativus* is expected to increase under the RCP 2.6 scenario. These three species, especially *C. sativus*, benefit from a change in climate under this scenario. However, *C. sativus* is the sole species that benefits from climate changes associated with the RCP 8.5 scenario. Two other mentioned species showed stability or even a slight decrease in distribution under this scenario. Therefore, among the species examined, *C. sativus* is the only species that exhibited a positive range change in both scenarios. *C. sativus* (saffron) is a plant that requires a minimum level of water and nutritional treatment. This species thrives in temperate and dry climates. Consequently, it appears that various areas in Iran, particularly in the North East of Iran, are well-suited for saffron cultivation, as it requires a minimum level of water, resistance to dryness, and at the same time can be of economic significance to the country (Monazzam EsmaeilPour and Kardavani, 2011). Due to this subject, the increase in cultivation points of this species in Iran is predictable.

Among the studied species, *C. michelsonii*, whose current habitat in Kopet Dagh is significantly affected by climate change, is the most endangered species in the face of these changes. Consequently, this study prioritizes the conservation of *C. michelsonii*. Additionally, *C. biflorus*, *C. speciosus*, and *C. caspius* which have also revealed a negative shift in their range, are identified as other conservation priorities, respectively. Moreover, *C. michelsonii* and *C. caspius*, both exhibiting a Species Specialization Index (SSI) of less than 0.5, were considered as species of high conservation value in our previous study (Tabasi et al., 2021).

In this study, we employed MaxEnt as a tool to identify conservation priorities for seven *Crocus* species in Iran. The application of this tool appears to predict the potential habitats of these taxa effectively. Based on the findings, *C. michelsonii*, *C. biflorus*, *C. speciosus*, and *C. caspius* are the most threatened species among those studied, as they face a loss or reduction of their currently suitable habitats in the future. Conservation planning to protect these species, especially *C. michelsonii*, which has the possibility of losing its entire habitat in the Northeastern area of Iran (Kopet Dagh) and, as a result, facing extinction in the future, is necessary.

To ensure the effective conservation of plants amidst climate change, it is recommended to regularly monitor them as indicators at various levels: environmental, community, population, and individual. This monitoring aims to detect how ecosystems are responding to change. Observation can be conducted by investigating the presence, absence, richness, and composition of plants at designed monitoring stations. Moreover, tracking these variations in species over time is crucial. Our previous study established the current distribution pattern of *Crocus* species and determined the primary distribution centers of these taxa in Iran. Additionally, this study predicts the future distribution status of *Crocus* species. This data can assist in planning in situ conservation and guide ex situ conservation methods such as gene banks, field gene banks, and in vitro conservation for protecting this valuable genus and addressing climate change in Iran.

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