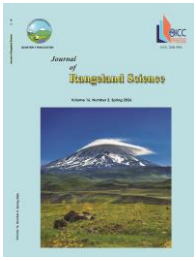

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Research Article

Predicting the Effects of Climate Change on the Current and Future Distribution of *Ferula Ovina Boiss* Species in Central Zagros, Iran

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Abstract

Climate change has become a serious challenge over the last century, and studying its effects on the distribution of plant species is necessary to sustainably manage and protect rangelands. This study investigates the current and future distribution range of *Ferula ovina Boiss* species in the central Zagros region in Chaharmahal and Bakhtiari province for the year 2050 under two main climate change scenarios, RCP4.5 and RCP8.5. To achieve this, 19 bioclimatic variables were calculated using long-term data series from 10 meteorological stations in the central Zagros area. Additionally, physiographic variables including: slope, aspect, and hypsometry were derived from a digital elevation model with a 30 m resolution. The points of species presence and absence were determined using logistic regression. The vegetative behaviors of the species and their equations were calculated under current conditions, and their map was modeled. In the next step, bioclimatic data for the next three decades were extracted from the WorldClim.org website, and the extracted data were substituted into the equations for current conditions. Finally, the future distribution of F. *ovina* species for the next three decades was determined under two RCP scenarios, 4.5 and 8.5. Among the bioclimatic variables, BIO1 (annual temperature), BIO10 (average temperature of the warmest month), and BIO11 (average temperature of the coldest month) are the most important for the habitat suitability of F. *ovina* species. The mentioned variables increase in value as climatic conditions become more challenging. The elevation of its suitable habitat will increase by 200-500 m, and as a result, the area of suitable habitat decreases in response to climate change. Under the pessimistic climate scenario, 65% of suitable habitats will be lost by 2050, and the current unsuitable habitats will increase by about 8%. Overall, climate change and rising temperatures will cause the vertical displacement and movement of F. *ovina* species towards higher geographical latitudes, indicating a drastic reduction in its presence in the central Zagros habitats over the next three decades.

Keywords: Habitat modeling, Climate change scenario, Logistic regression, Bioclimatic variables

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1. Introduction

Climate change and its effects, such as global warming and changes in natural ecosystems, have become a serious global challenge for human societies in recent years (Benito-Garzon et al., 2008). One of the most significant impacts of climate change on plant ecosystems is the shifting geographic distribution (Lawler et al., 2006; Valjarević et al., 2022). Climate change impacts species' tolerance limits and the environmental factors that influence species distribution (Sanjuán et al., 2016). Predicting the effects of climate change on the distribution of valuable plant species is crucial for conservation, assessing threat levels, and management (Lawler et al., 2006; Soilhi et al., 2022; Xia et al., 2022). Therefore, it is essential to understand the potential impacts of climate change on species distribution to make informed management decisions and reduce the detrimental effects of climate change on biodiversity (Pressey et al., 2007). To control and reduce the negative impacts of climate change, it is essential to model the effects of climate change on the future distribution of species (Guisan & Zimmermann, 2000; Narouei et al., 2023). Predicting the future geographic distribution of species requires collecting information on species presence, environmental variables, and combining this information with new environmental conditions (Porfirio et al., 2014). This information addresses two critical questions: a) under what conditions is the species currently found? And b) under which circumstances would it be found in the future? (Hijmans & Graham, 2006; Li et al., 2018).

Various modeling methods have been used to study the distribution of plants and animals. In some studies, models such as the Maxent model and the Generalized Boosted Model have been applied to determine the distribution of plant species (Guisan & Zimmermann, 2000; Hijmans & Graham, 2006; Abolmaali et al., 2018; Farzadmehr & Sangooni, 2019). These methods have been used to predict species' responses to climate change. The purpose of many modeling methods is to predict suitable habitats for valuable plant species, particularly for endangered species (Mahmoodi et al., 2022; Mousazade et al., 2019). One common statistical method for predicting plant species habitats is the logistic regression model. The logistic regression model is a group discriminative model that depends on species presence and absence data to provide a model based on correlation and relationship with environmental variables such as soil, climate, and topography factors (Abolmaali et al., 2018; Molaei Sham Asbi et al., 2017; Zhou et al., 2019). A study of the spatial distribution of grassland species habitat showed that logistic regression is a suitable model for generating predictive maps of grassland species habitats in the South of Golestan province, Iran (Esfanjani et al., 2015). Another study showed that using the generalized line model to assess the habitat suitability of Ferula gummosa species in Firouzkoh, Tehran, provides acceptable results (Mohammady et al., 2021). Modeling the potential range of Gymnocarpus decander Forssk using multivariate statistical methods and logistic regression showed that the percentage of the potential habitat range of the target species is 52.3%, while this species is distributed in 48.2% of the studied area at present (Narouei et al., 2023).

The central Zagros area in Iran is so significant for biodiversity due to its climatic conditions and unique natural features, as well as its great diversity of plants and animal species (Sangooni et al., 2019). The mountainous area of Zagros is one of the areas at risk from global warming and climate change (Naghipour Borj et al., 2019). Studies indicate a trend of increasing temperatures in most meteorological stations of central Zagros. Over the last 15 years, the average annual temperature in the central Zagros has increased, while the annual rainfall in the region has decreased during this period (Haidarian Aghakhani et al., 2017). This process of climate change is a major concern for biodiversity management and conservation in the region, as it affects various biological aspects of species.

Several researchers have studied the effects of climate change on habitats of valuable plant species in central Zagros (Guisan & Zimmermann, 2000; Haidarian Aghakhani et al., 2017; Shaban et al., 2023). Predicted the effects of climate change on the potential distribution of Amygdalus scoparia Spach species using consensus modeling in central Zagros. The changes in the geographic distribution of the species in 2050 under the RCP 4.5 and RCP 8.5 climate scenarios showed that the extent of the species' habitat will decrease, and some areas will see the emergence of areas vulnerable to the occurrence of the species (Haidarian Aghakhani et al., 2017).

Farzadmehr & Sangooni (2019) determined the climatic characteristics of the habitat and the geographic distribution of two grazing species using the random forest modeling method in the central Zagros region, Iran. The results indicated that the variables of total annual precipitation (BIO12), average temperature of the most fertile season (BIO8), and average daily temperature range (BIO2) and the all these three variables explained more than 68% of the changes in the species Bromus tomentellus Boiss and 64% of the variation in the species Agropyron trichophorum Richt.

Naghipour Borj et al. (2019) studied the effects of climate change on the geographic distribution of Pistacia atlantica Desf in central Zagros. According to the results of entropy modeling, the area of suitable habitat for wild pistachio species in Chaharmahal and Bakhtiari province

10.57647/jrs.2026.1602.14

is about 14.7% (2413 km^2). The results also showed that the extent of wild pistachio habitat in 2050 would decrease by about 81% under the RCP4.5 scenarios and about 11% under RCP8.5 scenario compared to today. In another study, the use of the consensus modeling method to predict the impact of climate change on the distribution of the invasive Fritillaria imperialis L. in Chaharmahal and Bakhtiari provinces. The results showed that seasonal temperature variation and total annual precipitation were the most important factors in determining the habitat requirements of the species Fritillaria imperialis. Moreover, the habitat of this species in the future under the RCP4.5 and RCP8.5 scenarios will be 19.7% and 61% smaller than the current area, respectively (Naghipour Borj et al., 2019). In this context, a study on the impact of climate change on Astragalus adscendence species in central Zagros revealed that about 33.6% of the area (548,678 km^2) is a suitable habitat for A. adscendence species. Annual rainfall, is o-temperature, annual temperature range, and slope are the most important bioclimatic variables for habitat suitability (Haidarian Aghakhani et al., 2017).

Considering the research results and emphasizing the negative impacts of climate change on the geographic distribution of plant species, it is necessary to predict the habitats of other valuable species in the central Zagros region for future conservation. *Ferula ovina Boiss*. species is one of the key species and one of the main components of central Zagros pastures and it is distributed in about 25% of the habitats of Chaharmahal and Bakhtiari provinces. F. *ovina* is a plant of the umbellifer family (Apiaceae) that grows to the height of 1-1.5 m. Its leaves have a sheathed petiole, and its leaf blade is large and relatively deeply lobed. The leaves are dark green, and the flowers are yellow. This plant is found in most pastures of the central Zagros and can be used as fodder if it has a suitable canopy (Mozaffarian & Sanborn, 2016). Unfortunately, the habitat of this species is being destroyed owing to excessive grazing and overexploitation of natural areas. To prevent the extinction of this species while preserving it, efforts should be made to restore the destroyed areas. This species has high medicinal value, and its composition has been researched. Compounds such as sesquiterpenes, coumarins, and disulfides have been identified. Moreover, the compounds obtained from the plants of this genus contain antiviral and antioxidant biological substances (Iranshahi et al., 2009). Considering the significant distribution of this species in the studied area (about 25%), as well as its the importance of this species for forage production, water and soil conservation, and many medicinal values, research is needed to determine the potential habitat of the species for planting or revitalizing rangelands. Some studies have been done in relation to the habitat conditions of F. ovina (Azhir and Shahmoradi, 2007; Govili Kilaneh & Vahabi., 2012). Additionally, the investigation of the potential habitat of this plant using different models has been done by researchers in Feridonshahr, Isfahan province (Safaei & Tarkesh Esfahani, 2013; Rahmati et al., 2015; Ghazimoradi & Ebrahimi., 2020). In another study, Motamedi et al. (2022) predicted the current and future range of F. ovina in southern Alborz habitats. The results of their research showed that in the next three decades, the presence of F. ovina species would decrease in the habitats of Southern Alborz. The current study aimed to predict the current and future range of F. ovina in Chaharmahal and Bakhtiari provinces in central Zagros using a logistic regression model and two climate-warning models (two RCP4.5 and RCP8.5 scenarios).

2. Materials and methods

2.1. Study area

The present study was conducted in Central Zagros, Chaharmahal and Bakhtiari province, Iran, covering an area of 1,632,835 ha (figure 1). This province is predominantly mountainous, with altitudes ranging from 778 to 4230 m. The average annual rainfall varies from 1600 mm in the highest areas, such as Zard Kouh Mountain, to 298 mm in the lowest rainfall areas. The average annual temperature of the province is 12.4°C (Naghipour Borj et al., 2019). The province has a varied climatic classification, ranging from cold humid to warm semi-humid, which makes it ecologically valuable and significant for biodiversity (Molaei Sham Asbi et al., 2017). F. *ovina* is distributed in approximately 25% of the pasture habitats in the province, mainly in the northwestern, western, and southern regions of Chaharmahal and Bakhtiari provinces (figure 2).

A: Occurrence points (presence and non-presence map F. *ovina* species)

In the present study, to prepare the initial vegetation map of the species, the up-to-date ecological regions map of the country was obtained from the Research Institute of Forests and Rangelands, Tehran, Iran. Then, the minimum and maximum elevation (2000-2600 m) of the distribution was determined by visiting different habitat areas of the species. In addition, a land use map was provided from the Water and Soil Research Institute, Tehran, Iran, the rangeland areas were identified and other land uses were removed from the map, and maps were then modified by revisiting the field in the ArcGIS environment and the current presence map of the species was finalized (Pejhan, 2013). A total of 174 points indicating species presence

were collected through field visits and observations conducted by the implementers of the ecological zones recognition project using GPS.

B: Environmental information in the place of occurrence of F. *ovina* species

Data from 10 synoptic stations in Chaharmahal and Bakhtiari provinces and nearby areas were used to generate the environmental information layer for 19 bioclimatic variables (Table 1). Additionally, to calculate 19 bioclimatic variables for the coming years 2050, the World Clim.org website was used with a 30-second resolution, which is one of the data sources for the Fifth Assessment report (Pejhan, 2013). Furthermore, slope, aspect, and elevation maps were created as environmental data inputs using a digital elevation model with a 30-second resolution in ArcGIS 10.8.

C: Spatial distribution of F. *ovina* species prediction

Logistic regression was employed to predict the geographic distribution of F. *ovina* (Eq. 1 and Eq. 2). Each of the climatic and physiographic variables was included in the logistic regression model as an independent variable, while the presence or absence of F. *ovina* was considered as the dependent variable, and the corresponding equation was obtained. After verifying the efficiency of the model, it was utilized to predict the geographic distribution of the species in 2050, under the RCP4.5 and RCP8.5 scenarios, using the MRI-ESM2-0 general circulation model. The results were then transformed into maps with the aid of ArcGIS 10.8. The prediction maps of the model contain the values of the probability of species presence between zero and one for the suitable habitat, which were assessed using the Cohen kappa coefficient to determine the accuracy of the output map.

$$p = \frac{1}{1+e^{-z}} \quad (1)$$

$$z = B_0 + B_1x_1 + B_2x_2 + \cdots + B_nx_n \quad (2)$$

Where:

z is the linear multivariate equation resulting from the logic function, which is the dependent or response variable.

Bi represents the coefficients of the regression model, and Xi represents the independent environmental variables.

In this model, after the dependent variable is transformed into a logit variable, the probability history estimate is used to predict the probability of occurrence of the species (Safaei et al., 2013). In the present study, equation 3 was used to calculate the kappa coefficient (Moghadam, 2010).

$$K = \frac{\left(\frac{a+d}{n}\right) - \frac{(a+b)(a+c)+(c+d)(d+b)}{n^2}}{1-\frac{(a+b)(a+c)+(c+d)(d+b)}{n^2}} \quad (3)$$

where a stands for true positives, i.e., predictions that are present in the model and seen in the real world, and that the model registers as being present; b stands for false positives, i.e., c represents false negatives, i.e., predictions that are not present in the model but exist in the real world and are registered as model errors; d represents true negatives, i.e., predictions that are neither present in the model nor seen in the real world, and the model registers them as absent (Hijmans & Graham, 2006).

3. Result

3.1. Environmental variables affecting the range of F. *ovina* species

According to the regression relationship between the occurrence of the species and the environmental factors, the values of each variable affecting the current and future range of *Ferula ovina* species are presented in Table 2. The values of bioclimatic variables BIO1 (annual temperature), BIO10 (average temperature of the hottest month) and BIO11 (average temperature of the coldest month), which are related to climatic condition, change as the the suitability of the habitat for the presence of *Ferula ovina* species will decrease in the future.

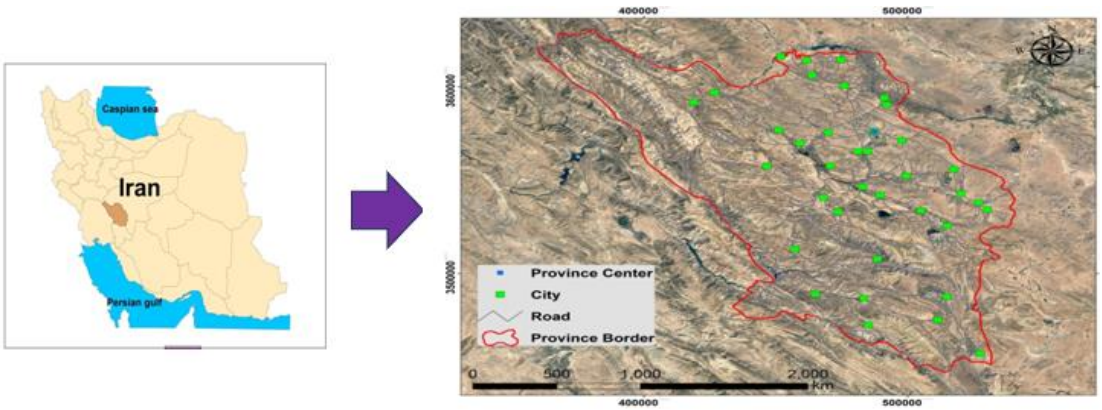

Figure 1. Geographical location of the study area

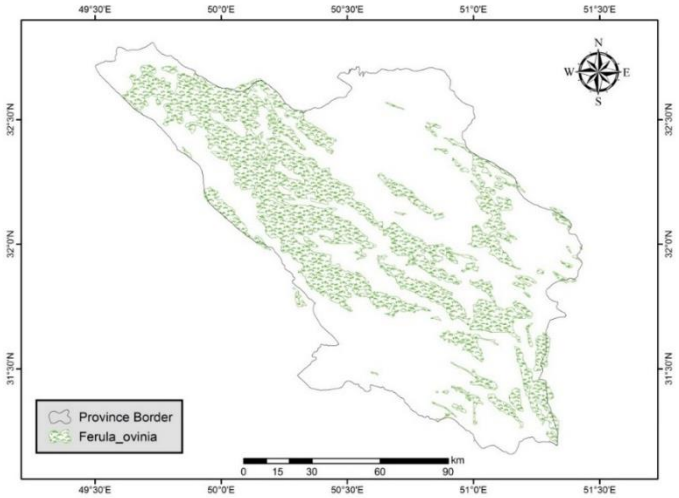

Figure 2. Spatial distribution of *F. ovina* in Chaharmahal and Bakhtiari province, Iran

Table 1. Environmental Bioclimatic variables (BIO) used for the spatial distribution of *F. ovina* species modeling process

Bioclimatic variables (BIO)	Definition	The unit
BIO1	Average annual temperature	C°
BIO2	Monthly minimum and maximum temperatures	C°
BIO3	100× isothermal (BIO2/BIO7)	C°
BIO4	Seasonal temperature (standard deviation × 100)	C°
BIO5	The maximum temperature of the hottest month	C°
BIO6	Minimum temperature of the coldest month	C°
BIO7	Annual temperature range (BIO5-BIO6)	C°
BIO8	Average temperature of the wettest season	C°
BIO9	Average temperature of the driest season	C°
BIO10	Average temperature of the hottest season	C°
BIO11	Average temperature of the coldest season	C°
BIO12	Monthly rainfall	mm
BIO13	Precipitation of the wettest month	mm
BIO14	Rainfall of the driest month	mm
BIO15	Seasonal rainfall (coefficient of variation)	mm
BIO16	Rainfall of the wettest season	mm
BIO17	Rainfall of the driest season	mm
BIO18	Rainfall of the hottest season	mm
BIO19	Rainfall is the coldest season	mm
Slope	-	%
Aspect	-	-
Elevation	-	m

Table 2. Environmental variables affecting the range of *F. ovina* species in rangelands of Chaharmahal and Bakhtiari provinces, Iran

Habitat suitability	Current dispersion			Potential future dispersion ($RCP_{4.5}$)			Potential future dispersion ($RCP_{8.5}$)		
	$BIO_1(C^o)$	$BIO_{10}(C^o)$	$BIO_{11}(C^o)$	$BIO_1(C^o)$	$BIO_{10}(C^o)$	$BIO_{11}(C^o)$	$BIO_1(C^o)$	$BIO_{10}(C^o)$	$BIO_{11}(C^o)$
Great fit	11.11	20.32	-0.93	12.1	21.3	1.1	12.8	22.78	1.3
Average fit	13.7	24.8	2.87	14.7	25.9	29	14.87	26.71	3.1
Poor fit	14.7	26.6	3.4	15.9	27.2	4.1	16.2	28.8	4.9
Unsuitable	17.6	33.1	5.5	31.8	26.1	6.6	32.2	29.71	7.6

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3.2. Prediction map of the current and potential future distribution of F. *ovina* species

figure 3 depict the map of the projected distribution of F. *ovina*, at the current time and figures of 4 and 5 its potential distribution over the next three decades (year 2050) under two different climate scenarios - milder (RCP4.5) and more severe (RCP8.5). Table 3 shows the probability classes for the occurrence of F. *ovina* at present and in 2050 under the two climate scenarios. Based on the current prediction map, the habitat area of F. *ovina* with a high probability of presence (over 75%) is approximately 1,323051 ha. This species is distributed in about 81% of the area of Chaharmahal and Bakhtiari province. However, according to the prediction maps for 2050, the habitat area with a probability of presence of this species under the two climate scenarios RCP4.5 and RCP8.5 is 1,296751 ha (79%) and 258,937 ha (16%), respectively. In this way, under the pessimistic climate scenario, 65% of suitable habitats will be lost in 2050, and the current unsuitable habitats will increase by about 8%. The elevation of its suitable habitat will increase by 200-500 m, and as a result, the suitable habitat level of F. *ovina* species will decrease drastically in response to climate change in the next three decades.

By comparing the Digital Elevation Model (DEM) map information with the species presence map in the current conditions and also under RCP4.5 and RCP8.5 scenarios in 2050, the change in altitude of the species was investigated. F. *ovina* species is currently located at an altitude of 2000-3200 m, while under the RCP4.5 scenario, it is likely to occur at an altitude of 2200-3300 m and under the RCP8.5 scenario at an altitude of 2500-3500 m.

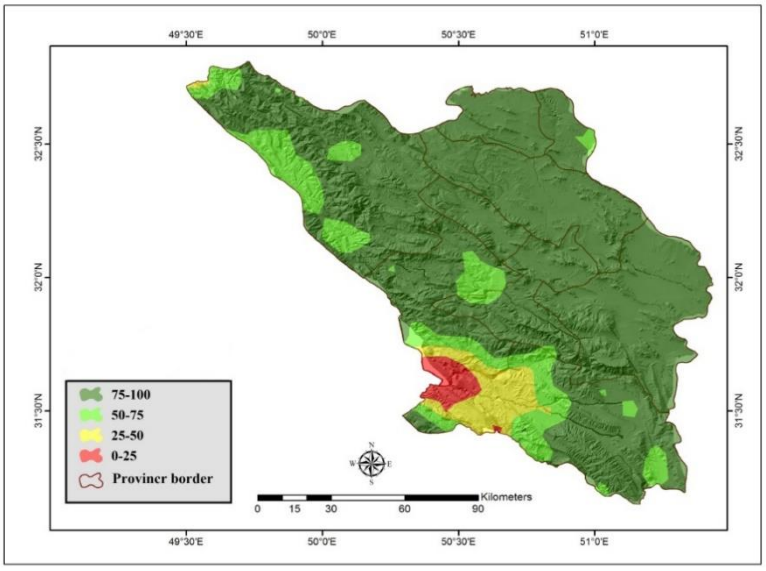

Figure 3. The Current distribution and prediction map of *F. ovina* species in Chaharmahal and Bakhtiari province, Iran

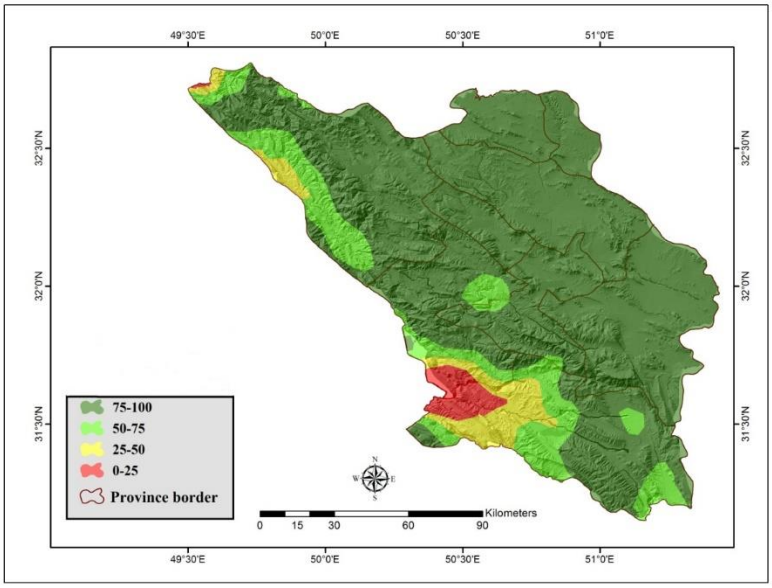

Figure 4. Predicted future potential map under $RCP_{4.5}$ scenarios of *F. ovina* species in Chaharmahal and Bakhtiari province, Iran

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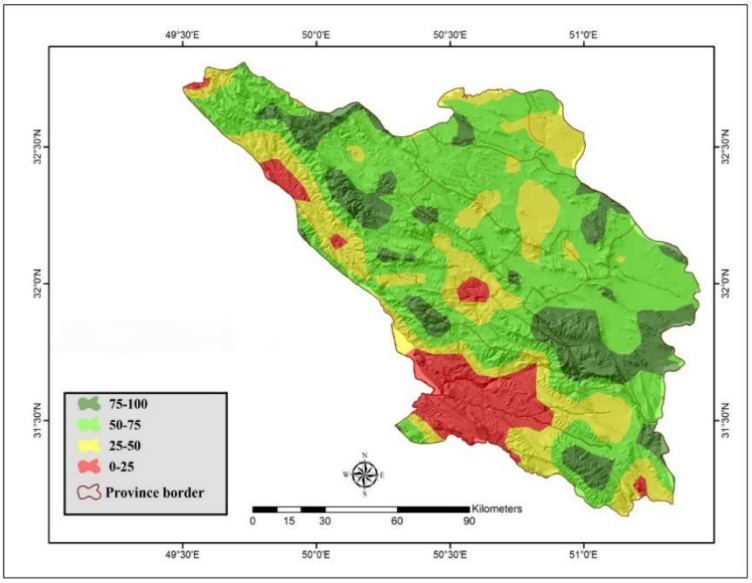

Figure 5. Predicted future potential map under $RCP_{8.5}$ scenarios of *F. ovina* species in Chaharmahal and Bakhtiari province, Iran

Table 3. The habitat suitability classes of *F. ovina* in the current and future

The probability of the occurrence of Species in habitat	Habitat suitability	Current dispersion		Potential future distribution In 2050, under scenario (RCP4.5)		Potential future distribution In 2050, under scenario (RCP8.5)	
		ha	%	ha	%	ha	%
75-100 %	Great fit	1323051.1	80.98	1296751.1	79.37	258937.8	15.84
50-75 %	Average fit	206587.3	12.64	215130.9	13.16	854526.8	52.30
25-50 %	Poor fit	74614.7	4.56	83053.2	5.08	362145.7	23.16
0-25 %	Unsuitable	29424.3	1.80	38742.2	2.37	158057.7	9.67

3.3. Model validation

The evaluation of the model's performance was based on data regarding the presence and absence of F. *ovina*, using the Kappa coefficient. The value of this index for F. *ovina* was found to be 0.82, which, according to the classification of Kappa coefficients presented by Arabameri et al. (2019), indicates that the model has good and acceptable accuracy.

The Kappa coefficient is a statistical measure that assesses the agreement between predicted and observed values. In this case, a value of 0.82 indicates a strong agreement between the predicted and observed presence and absence of F. *ovina*. As such, the model is considered to be reliable for predicting the species' distribution under future climate scenarios. However, it is important to note that the Kappa coefficient is only one measure of model accuracy, and it may not capture all aspects of model performance. Therefore, it is recommended to use additional measures of model performance, such as sensitivity and specificity, to provide a more comprehensive assessment of the model's accuracy. Overall, the Kappa coefficient provides evidence that the model used in this study is an effective tool for predicting the distribution of F. *ovina* under future climate scenarios.

4. Discussion

Species distribution prediction models are useful for identifying potentially suitable areas for a species' distribution and play an important role in determining areas suitable for rangeland restoration (Narouei et al., 2023). In this study, we modeled the current favorable habitats of F. *ovina* in Chaharmahal and Bakhtiari provinces in the central Zagros Mountains in Iran. Additionally, we estimated the potential consequences of climate change for the year 2050 on the distribution of this species. Our modeling results for the species F. *ovina* in the province indicate that the spatial situation of the target species in 2050, with the RCP4.5 scenario (balanced), is almost similar to the present situation, while with the RCP8.5 (pessimistic) scenario, the optimal habitat extent of the selected plant in the province would decrease by 100-75%. However, some high-altitude areas, we may observe the emergence of habitats in some high-altitude areas that are susceptible to the occurrence of species, which will be suitable in terms of climatic conditions.

According to the findings of this study, under the current conditions, the elevation above sea level for the studied species is between 2000-3200 m. If the modeling results in 2050 in the areas that will be suitable due to climate

change, the minimum and maximum elevation will show 2200-3300 m in scenario 4.5 and 2500-3500 m in scenario 8.5, respectively. Other researchers have emphasized the effect of altitude on the distribution of F. *ovina* species (Safaei & Tarkesh Esfahani., 2013; Rahmati et al., 2015; Motamedi et al., 2022). Also, the results indicated that the bioclimatic variables affecting the distribution of F. *ovina* species are mainly related to the temperature indices, which increase with the harshness of the climatic conditions. As the temperature increases due to climate change, the habitat size of this species will decrease and it will move to areas that are higher and therefore have a lower temperature. With global warming, species migrate to high latitudes or altitudes. According to the results of this research (Motamedi et al., 2022), in a study in southern Alborz habitats found that climate change and temperature increase will cause the reduction of southern Alborz habitats. Researchers mentioned the expansion of plants towards the elevations during the recent periods as an example of the displacement of species under the influence of climate change (Bork et al., 2002)

According to the findings of this research, this species will lose about 2% of its vegetation areas in the RCP4.5 scenario and more than 65% in the 8.5 scenario. Although the decrease in the presence of rangeland species due to climate change and temperature increase in central Zagros habitats has been reported by other researchers (Haidarian Aghakhani et al., 2017; Naghipour Borj et al., 2019; Shaban et al., 2023), contrary to the results of this research, Ghazimoradi & Ebrahimi (2020) found that with increasing temperature in the future, the extent of habitat of F. *ovina* is expected to increase in Freudenshahr, Isfahan province, Iran.

Thuiller (2007) noted that one of the most important effects of climate change is the shift in the geographic range of plant species. He also suggested that changes in different ecosystems are not identical, and each ecosystem requires appropriate methods of study. As species move toward the poles or to higher elevations, they may disappear or become confined to a refuge, while other species may expand their range. Biologists have expressed concern about the destruction of species whose access to suitable habitat is limited.

5. Conclusion

The results of our study and similar studies are valuable for vegetation conservation and recovery programs. F. *ovina* is a perennial pasture and medicinal plant that is very important for forage production and soil conservation, and modeling its spatial distribution due to climate change may be a positive step for the conservation and recovery of this species. The results suggest that the area of suitable habitat for F. *ovina* is likely to decrease in 2050 when compared to the current time. This decrease in area is attributed to the impact of climate change, which is expected to alter the climatic and physiographic variables that influence the occurrence of the species.

In summary, the maps and probability classes presented in this study provide valuable information for conservationists and policymakers, aiding them in prioritizing conservation and management efforts to protect endangered plant species like F. *ovina*. However, it is notable that the predictions are subject to uncertainty and further research is needed to improve our understanding of the impacts of climate change on plant species.

Generally, the prediction of the potential distribution of the species provides valuable information for identifying the suitable cultivation places and also for the management of the target species in the future. Furthermore, due to the inherent interrelationship between different ecosystems, it is vital to protect species diversity to maintain services to humans in a sustainable manner. A better understanding of species distribution models in light of climate change and changes in the spatial database can lead to the development of conservation strategies that benefit the ecosystem and species (Naghipour Borj et al., 2019). We expect that the predictive model used in this study will be effective for future conservation strategies. At the global level, it is important to conserve biodiversity in the central Zagros because it is ecologically and biologically significant (Sangooni et al., 2019). As a result, since the studied area is an important part of the central Zagros, double efforts are necessary to protect the species from climate change. Conservation efforts for these species should include their cultivation in suitable climatic areas (as identified by the model) and the conservation of areas that have been identified and currently exist as suitable, sustainable areas

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Authors Contribution

All the authors have participated sufficiently in the intellectual content, conception and design of this work or the analysis and interpretation of the data (when applicable), as well as the writing of the manuscript.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Conflict of interests

The author states that there is no conflict of interest.

References

Abolmaali, S.M.R., Tarkesh, M. and Bashari, H., 2018. MaxEnt modeling for predicting suitable habitats and identifying the effects of climate change on a threatened species, Daphne mucronata, in central Iran. Ecological Informatics, 43(2), 116–123. doi.org/10.1016/j.ecoinf.2017.10.002

Arabameri, A., Pradhan, B. and Rezaei, K., 2019. Spatial prediction of gully erosion using ALOS PALSAR data and ensemble bivariate and data mining models. Geosciences Journal, 23(4): 669–686. doi.org/10.1007/s12303-018-0067-3

Azhir, F. and Shahmoradi, A.A., 2007. Autecology of *Ferula ovina Boiss*. in Tehran Province, Iranian Journal of Range and Desert Research,14(3),359-367. (In Persian).

Benito-Garzon, M. Sanchez de Dios, R. and Sainz Ollero, H. 2008. Effects of climate change on the distribution of Iberian tree species. Applied Vegetation Science, 11(2), 169-178. doi.org/10.3170/2008-7-18348

Bork, E.W., Adams, B.W., Willms, W.D., 2002. Resilience of Foothills Rough Fescue, Festuca campestris, rangeland to wildfire. Can. Field-Naturalist, 116(1), 51–59. doi.org/10.7939/R3FB4X08W

Esfanjani, J., Zare, C.M.A., Esmaeili, M.M. and Behmanesh, B., 2015. Habitat distribution modeling species ranges southern of Golestan province with Logistic regression watershed Management Research 108(1),53-61(In Persian).

Farzadmehr, J. and Sangooni, H., 2019. Determination of the potential habitat of medicinal species of wild borage (Anchusa italica Retzius) in Khorasan Razavi province using generalized boosted model (GBM). Rangeland 13(4), 621–631.

Ghazimoradi, M. and Ebrahimi, A. 2020. Modeling of potential habitats of species Ferula *ovina* for current and next year's using generalized additive model (GAM), Fereidunshahr regional, in Isfahan province, Iranian Journal of Range and Desert Research, 27(2), 321-333. (In Persian). doi.org/10.22092/ijrdr.2020.110429.1597

Govili Kilaneh, E. G. and Vahabi, M. R. 2012. The Effect of Some Soil Characteristics on Range Vegetation Distribution in Central Zagros, Iran, Journal of Water and Soil Sciences, 16(59), 245-258.

Guisan, A .and Zimmermann, N.E., 2000. Predictive habitat distribution models in ecology. Ecological modelling, 135(2-3), 147–186. doi.org/10.1016/S0304-3800 (00)00354-9

Haidarian Aghakhani, M., Tamartash, R., Jafarian, Z., Tarkesh Esfahani, M. and Tatian, M.R., 2017. Forecasts of climate change effects on Amygdalus scoparia potential distribution by using ensemble modeling in Central Zagros. Journal of RS and GIS for Natural Resources. 8(3), 1-14.

Hijmans, R.J. and Graham, C.H., 2006. The ability of climate envelope models to predict the effect of climate change on species distributions. Global change biology, 12(12), 2272-2281. doi.org/10.1111/j.1365-2486.2006.01256.x

Iranshahi, M., Famili, A., Basarlv, C. and Pyasnth, S., 2009. Purification and determination of compounds in *Ferula ovina Boiss*. roots. Journal of Medicinal Plants 36(1), 26-39. (In Persian).

Lawler, J.J., White, D., Neilson, R.P. and Blaustein, A.R., 2006. Predicting climate-induced range shifts: Model differences and model reliability. Global change biology, 12(8), 1568-1584. doi.org/10.1111/j.1365-2486.2006.01191.x

Li, H., Zhang, X., Zhang, Y., Yang, X. and Zhang, K., 2018. Risk assessment of forest landscape degradation using Bayesian network modeling in the Miyun Reservoir catchment (China) with emphasis on the Beijing–Tianjin sandstorm source control program. Land Degradation & Development, 29(11), 3876-3885. doi.org/10.1002/ldr.3133

Mahmoodi, S., Heydari, M., Ahmadi, K., Khwarahm, N.R., Karami, O., Almasieh, K., Naderi, B., Bernard, P. and Mosavi, A. 2022. The current and future potential geographical distribution of Nepeta crispa Willd., an endemic, rare and threatened aromatic plant of Iran: Implications for ecological conservation and restoration. Ecological Indicators, 137, 108752. doi.org/10.1016/j.ecolind.2022.108752

Mohammady, M., Pourghasemi, H.R., Yousefi, S., Dastres, E., Edalat, M., Pouyan, S. and Eskandari, S., 2021. Modeling and Prediction of Habitat Suitability for Ferula gummosa Medicinal Plant in a Mountainous Area. Nat. Resour. Res. 30, 4861–4884. doi.org/10.1007/s11053-021-09940-3

Moghadam, M. 2010. Rangeland and Rangeland Management, University of Tehran Press, 470 pages, (In Persian).

Molaei Sham Asbi, M., Ghorbani, A., Sefidi, K., Bahrami, B. and Hashemi Majd, K., 2017. Effects of ecological factors on distribution of Artemisia aucheri Boiss. in southeast faced slopes of Sabalan. Rangeland 11, 139–151.

Motamedi, J., Khodagholi, M. and Khalifazadeh, R. 2022. Forecasting the current and future range of Ferula *ovina* species under two climate-warning models (Rcp4.5 and Rcp8.5) in southern Alborz pasture habitats, Qazvin province, Iranian Journal of Rangelands, 16(3), 574-585 (In Persian).

Mousazade, M., Ghanbarian, G., Pourghasemi, H.R., Safaeian, R. and Cerdà, A., 2019. Maxent data mining technique and its comparison with a bivariate statistical model for predicting the potential distribution of Astragalus fasciculifolius Boiss. in Fars, Iran. Sustainability, 11(12), 3452. doi.org/10.3390/su10023452

Mozaffarian, F. and Sanborn, A.F., 2016. Two Species of the Genus Tibicen Latreille, 1825 (Hemiptera: Cicadidae) in Iran, with an Identification Key to the Genera of the Family Cicadidae (Hemiptera) in the Country. Acta Zoologica Bulgarica, 68(4), 469-476.

Naghipour Borj, A.A., Haidarian Aghakhani, M. and Sangoony, H., 2019. Application of ensemble modelling method in predicting the effects of climate change on the distribution of Fritillaria imperialis L. Journal of Plant Research (Iranian Journal of Biology), 32(3), 747-758. (In Persian).

Narouei, M., Javadi, S.A., Khodagholi, M., Jafari, M. and Azizinezhad, R., 2023. Modeling potential habitats for Gymnocarpus decander using multivariate statistical methods and logistic regression (Case study: Sistan and Baluchestan Province). Journal of Rangeland Science, 13(3), 1-11. doi.org/10.57647/j.jrs.2023.1303.1577

Pejhan, A. 2013. Effects of climate change on spatial distribution of Artemisia Dashti species in Alborz Province using species distribution prediction models (Case Study: Alborz Province), master thesis, Alborz University of Technology, 119 p (In Persian).

Porfirio, L. L., Harris, R. M. B., Lefroy, E.C., Hugh, S., Gould, S.F., Lee, G., Bindoff, N.L. and Mackey, B., 2014. Improving the use of species distribution models in conservation planning and management under climate change. PLoS One, 9(11), e113749. doi.org/10.1371/journal.pone.0113749

Pressey, R.L., Cabeza, M., Watts, M.E., Cowling, R.M. and Wilson, K.A., 2007. Conservation planning in a changing world. Trends in ecology & evolution, 22(11), 583-592. doi.org/10.1016/j.tree.2007.10.001

Rahmati Z., Tarkesh Esfahani M., Pourmanafi S. and Vahabi M R. 2015. Potential Habitat Modelling of Ferula *ovina* Using Artificial Neural Network in Fereydunshahr Region, Isfahan Province. Iranian Journal of Applied Ecology, 4(11), 41-53. (In Persian). doi.org/ 10.18869/acadpub.ijae.4.11.41

Safaei M. and Tarkesh Esfahani M., 2013. Habitat protection of *Ferula Ovina Boiss*. as a medicine plant using habitat potential modeling (suggested model: ecological niche factor analysis), Journal of Plant Ecosystem Conservation, 1 (1),105-122.

Safaei, M., Tarkesh Esfahani, M., Basiri, M. and Bashari, H., 2013. Potential habitat modeling of Astragalus verus Olivier using Ecological-Niche Factor Analysis. Journal of Rangeland, 7(1), 40-51.

Sangooni, H. M.R. Wahhabi, M. Tarkesh. H. Eshghizadeh, R, and Soltani, S.2019. Determining the climatic characteristics of the ecosystem and the geographical distribution of two rangeland species using stochastic forest modeling in the Central Zagros region, Journal of Plant Ecology, 10 (1), 1-18. (In Persian).

Sanjuán, Y., Gómez-Villar, A., Nadal-Romero, E., Álvarez-Martínez, J., Arnáez, J., Serrano-Muela, M.P., Rubiales, J.M., González-Sampériz, P. and García-Ruiz, J.M., 2016. Linking Land Cover Changes in the Sub-Alpine and Montane Belts to Changes in a Torrential River. Land Degradation & Development, 27(2), 179-189. doi.org/10.1002/ldr.2294

Shaban, M., Ghehsareh Ardestani, E., Ebrahimi, A. and Borhani, M., 2023. Climate change impacts on the optimal habitat of Stachys inflata medicinal plant in central Iran. Scientific Reports, 13(1), 6580. doi.org/10.1038/s41598-023-33660-8

Soilhi, Z., Sayari, N., Benalouache, N. and Mekki, M., 2022. Predicting current and future distributions of Mentha pulegium L. in Tunisia under climate change conditions, using the MaxEnt model. Ecological Informatics, 68, 01533. doi.org/10.1016/j.ecoinf.2021.101533

Thuiller, W., 2007. Biodiversity: Climate change and the ecologist. Nature 448, 550–552. doi.org/10.1038/448550a

Valjarević, A., Milanović, M., Gultepe, I., Filipović, D. and Lukić, T., 2022. Updated Trewartha climate classification with four climate change scenarios. The Geographical Journal, 188(4), 506-517. doi.org/10.1111/geoj.12458

Xia, C., Huang, Y., Qi, Y., Yang, X., Xue, T., Hu, R., Deng, H., Bussmann, R.W. and Yu, S. 2022. Developing long-term conservation priority planning for medicinal plants in China by combining conservation status with diversity hotspot analyses and climate change prediction. BMC biology, 20(1), 89. doi.org/10.1186/s12915-022-01285-4

Zhou, Y., Zhang, L., Xiao, J., Williams, C.A., Vitkovskaya, I. and Bao, A., 2019. Spatiotemporal transition of institutional and socioeconomic impacts on vegetation productivity in Central Asia over the last three decades. Science of the Total Environment, 658, 922-935.