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Predicting potential sites of nine drought-tolerant native plant species in urban regions

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Summary

Drought and water scarcity are serious limiting factors for plant growth and can thus present an obstacle to development of the urban green areas in the cities in particular under climate change. Using native plants is a high-priority option to increase vegetation cover in areas facing global warming and water scarcity. In order to evaluate whether urban areas cover suitable habitats for nine native species in the east of Iran, species distribution models were developed and binary maps were generated. The model output indicated a relatively good performance. Most of the suitable habitats for the plant species are located in north, west and center of the study area. *Cercis griffithii* had the highest (46.63%) and *Acantholimon erinaceum* had the lowest (6.29%) proportion of suitable habitats among all studied species in the Khorasan region. Annual precipitation, annual mean temperature, and mean temperature of warmest quarter were the most important environmental variables in determining the potential geographic distribution for these species. Due to similar climate conditions, such as low rainfall, high temperature, low relative humidity and high solar radiation particularly in the summers, our findings showed that *Cercis griffithii*, *Iris songarica* and *Tamarix ramosissima* can be utilized in the development of green areas in the studied regions. According to the output of the species distribution models, planting of *Acantholimon erinaceum*, *Salvia abrotanoides* and *Rosa canina* is not advisable in the South and Razavi Khorasan provinces.

Keywords: Climate, Native plant species, Species distribution models

Introduction

Drought and water scarcity are a global crisis that affect a significant portion of the world's population. Climate data and models have projected increased frequency and severity of droughts in the future (WWAP, 2016). Research indicates that the world's most water stressed region is located in the Middle East, spanning countries such as Iran, Iraq, Egypt and Syria (Tropp and Jägerskog, 2006). Iran has a diverse climate, rainfall is frequent and abundant in the northern and northwestern parts of Iran, whereas in the other parts, in particular in the southern and eastern regions, precipitation is inconsistent and low (Madani et al., 2016). In recent decade, eastern part of Iran, an important and highly populated region which includes the Khorasan provinces, has suffered from severe drought and water scarcity (Raziei et al., 2006).

In addition to climate-related problems, other factors, such as population growth, urban development, water pollution and excessive use of energy resources have contributed to water scarcity (Hutter, 2015). Regarding population growth in the cities, living in a green and healthy city can be considered a basic citizenship right. However, in arid and semi-arid cities development of urban landscapes and greenery has faced many problems due to shortage of water resources. One of the large consumers of water in the cities are urban landscapes (Lazarova et al., 2005) which are important areas of a vital environment (Frank, 2003) in which vegetation plays an essential rule as it affects the microclimate in various ways, including creating shade, controlling humidity and wind speed (Ali-Touder, 2005).

In regions faced with drought and water scarcity as well as in other ones where plentiful, or reliable supplies of fresh water are not available, xeriscaping (=water-conserving) technique is promoted. Among the seven design principles of xeriscaping, appropriate plant selection is a key principle (Wade and Service, 1992). Utilization of native drought-tolerant plants in urban landscapes of arid and semi-arid regions can help with water resources management (Baltzoi et al., 2015). Native plants are not only adapted to local soils and climate conditions but also resistant to insects and diseases. Most important, native plants generally require less water, fertilizer and pesticide compared to non-natives (Britt et al., 2003), therefore native plants can be a smart option for urban landscapes in regions facing water scarcity (Britt et al., 2003).

It should also be borne in mind that in some plants, drought tolerance and resistance are usually associated with morphological changes such as decreased leaf number, leaf area and plant height, delayed bud and flower formation, colour change in leaves and the development of thorns (Jaleel et al., 2009). These morphological changes are sometimes not desirable in terms of aesthetics, therefore a plant that can survive in the wide habitats might not be a good and advisable option as an ornamental plant.

For two reasons native plants with decorative and drought tolerance traits can likely be considered for use in the urban landscape of arid and semi-arid regions of countries like Iran: (1) Iran has a rich resource of plant germplasm, its plant diversity rivalling that of Europe (Ghahraman and Attar, 2001). (2) Flora of Khorasan provinces belong to the Iran-Turani geographical area, which contains 69% of Iran's plant germplasm.

An understanding of the potential distribution of drought-tolerating native species and their habitat characteristics can play an important role in conservation (Engler et al., 2004). Improving the management of urban landscapes and greenery can be considered as one of the important uses of distribution and prediction mapping. Species distribution models (SDMs) have been in use since 1970 and are still a powerful tool for different applications. There are several algorithms used in species distribution modelling and habitat quality evaluation. These algorithms assess significant predictor variables and their links with response variables, along with predicting the potential distribution of species in the study area. Improvements in modelling algorithms have contributed to the adoption of SDMs in fields such as biogeography, ecology, evolution, and species conservation and management (Mikolajczak et al., 2015). SDMs have also

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been applied to predict potential distributions of plants (GUIDA et al., 2014; HU et al., 2018).

Therefore, the aims of this study were as follows: (1) to identify factors affecting the distribution of nine native plant species in the northeast of Iran, (2) to identify the potential range of nine native plant species in the northeast of Iran, and (3) to evaluate whether urban areas cover potential distribution of the species in the northeast of Iran.

Materials and methods

Study area

The north-eastern part of Iran, Khorasan, is selected due to considerable area (more 18% of Iran's area), high population, specific geography, economic importance and also urban development and migration. Its area is above 242670 km². Owing to its large size, Khorasan has different climates ranging from cold northern regions with mild summers to areas with scorching summers and cold winters. Weather conditions in Khorasan are variable; so temperature differences of 10 to 15 °C are not uncommon by day (BANNAYAN et al., 2011a, b). Average annual precipitation throughout the region during the last 30 years was about 222 mm, and varied from 131 mm in Nehbandan to 269 mm in the northern regions of Bojnoord. The lowest and highest amount of annul precipitation were observed for Nehbandan in 2000 (71 mm) and Bojnoord in 1992 (333 mm), respectively. Climate factores (in particular rainfall, temperature, solar radiation and relative humidity) plays an important role in the region's agricultural activities and has a key role in the environment and the economy of the region. Climate variations also lead to variations in production on a local and national scale (ARMANDPISHEH et al., 2015). Furthermore, in recent years, Khorasan's climate has changed to drier seasons with lower precipitation. During the period between the months of March to September, precipitation in the region is relatively low, and in most years, especially in the mid and late spring, when the maximum daily temperature exceeds 30 °C, a long drought stress period can be seen especially for rain fed plants (REZAEI et al., 2011).

Methods

In this study, three criteria were used to select the species: 1) Low water requirement 2) Being native Khorasan region 3) Possession of appropriate aesthetic features. Accordingly, nine species were selected (Tab. 1).

To evaluate the aesthetic characteristics of nine native plants including *Acantholimon erinaceum, Berberis integerrima, Cercis griffithii, Iris songarica, Juniperus polycarpus, Rosa canina, Salvia abrotanoides, Tamarix ramosissima,* and *Tulipa undulatifolia,* a questionnaire was used that reviewed by some experts such as landscape designer, landscape manager, horticulturist, and Botanist. Some of the questions comprise flower duration, flower time, flower size and color, plant size (height, diameter), plant color (leaf, stem, fruit) in the different seasons and etc. There are close and complicated relations between artistry and life sciences in landscaping (landscape design).

Khorasan region as the biggest province in Iran has more than 70 towns that 23 towns of them are bigger and more populated. These 23 towns have been investigated in the current study and are including Bojnord, Shirvan, Dar-e-gaz, Quchan, Jajarm, Esfarayen, Mashhad, Chenaran, Nishabur, Sabzevar, Sarakhs, Torbat-e-jam, Fariman, Torbat-e heydarieh, Kashmar, Bardaskan, Taybad, Khaf, Gonabad, Ferdows, Qaenat, Birjand, Nahbandan.

We collected recorded occurrence points of the nine species in their distribution range in the Khorasan region (Tab. 1) from recorded data in the eastern herbariums of Iran (FUMH, 2019). The occurrence records that were not available at the herbariums were extracted from library resources, especially several volumes from Flora Iranica (Rechinger, 1963-2015) and Flora of Iran (ASSADI et al., 1988-2017).

10 algorithms were applied to develop SDMs for the nine species in the Biomod2 package (THUILLER et al., 2014) for R version 3.1.25 (R Core Team 2014) (Tab. 2). The 10 algorithms can be placed into four categories: regression, machine-learning, classification and enveloping. Regression algorithms build linear models (general linear models, GLMs) and non-linear models (generalized additive models, GAMs) based on species occurrence points and environmental parameters. Machine learning algorithms use training data to directly determine environmental space of species. This study employed artificial neural networks (ANN), boosted regression trees, (BRT), multivariate adaptive regression splines (MARS), maximum entropy (MaxEnt) and random forest (RF) as its machine learning algorithms. The two classification algorithms used in the study, classification and regression trees (CART) and flexible discriminate analyses (FDA), consecutively partition data into homogenous partitions. Surface range envelope (SRE) is an enveloping method that first generates a description of ecological variables at the presence points of a species and then extrapolates the results to the rest of study area (MEROW et al., 2014). Models were evaluated using two criteria: (1) the True Skill Statistic (TSS), derived as the sum of sensitivity and specificity minus 1, which is not affected by prevalence (ALLOUCHE et al., 2006), and (2) the area under the curve (AUC) (FIELDING and BELL, 1997). TSS as a statistic is used to assess the accuracy of weather forecasts (ACCADIA et al., 2005) and can evaluate the predictive accuracy of a given species distribution model. A model with TSS and AUC ≤ 0.5 indicates a random prediction, while a model with AUC and TSS > 0.5 has a good predictive power (ALLOUCHE et al., 2006; FIELDING and BELL, 1997). To generate a binary map representing predicted presence and absence cells, first a threshold value for probability was selected by maximizing by both training sensitivity and specificity (LIU et al., 2011). All raster cells in the probability map with a value smaller than the threshold value were assigned a value of 0, signifying unsuitability. Similarly, all cells with values exceed-

Tab. 1: Studied plant species

English name	Scientific name	Family	Life form	Presence points
Persian Prickly thrift	*Acantholimon erinaceum*	Plumbaginaceae	Subshrub	28
Barberry	*Berberis integerrima*	Berberidaceae	Shrub	30
Afghan redbud	*Cercis griffithii*	Fabaceae	Shrub	22
Persian Iris	*Iris songarica*	Iridaceae	Bulbous plant	29
Persian Juniper	*Juniperus polycarpus*	Cupressaceae	Tree	33
Dog rose	*Rosa canina*	Rosaceae	Shrub	29
Russian sage	*Salvia abrotanoides*	Lamiaceae	Subshrub	28
Salt cedar	*Tamarix ramosissima*	Tamaricaceae	Tree	29
Tulip	*Tulipa undulatifolia*	Liliaceae	Bulbous plant	29

Tab. 2: The SDM algorithms in biomod^2 used in this study.

SDM	Variable	Type	Reference
ANN	Artificial neural networks	P/A	Lek and Guégan (1999)
CART	Classification and regression trees	P/A	Vayssières et al. (2000)
FDA	Flexible discriminant analysis	P/A	Hastie et al. (1994)
GAM	Generalized additive models	P/A	Guisan et al. (2002)
GLM	Generalized linear models	P/A	Guisan et al. (2002)
MaxEnt	Maximum entropy	P/B	Phillips et al. (2006)
MARS	Multivariate adaptive regression splines	P/A	Friedman (1991)
RF	Random forest	P/A	Breiman (2001)
SRE	Surface range envelope	P/B	Busby (1991)

P: Presence; A: Absence; B: Background.

ing the threshold value were given a value of 1, representing suitable areas for the target species.

Topographic and climatic variables characteristics were used to model species distribution. Topographic variables were obtained from a digital elevation model (DEM) that was generated by the national cartographic center of Iran (NCC) at 100 m resolution. The climatic variables were acquired from world-clim-global climate data as the initial set of 19 climatic variables at a resolution of 2.5′ (~ 5 km), (http://www.worldclim.org). The multicollinearity test was conducted using the Pearson correlation coefficient (r) to examine cross-correlation between variables. Variables with cross-correlation coefficient values higher than ±0.8 were excluded from the analysis.

Results and discussion

All ten models showed relatively good performance with regard to accuracy (AUC and TSS values >0.7). However, MaxEnt had the best performance for all studied species. The maximum TSS value (0.93) is reported for *Tulipa undulatifolia*, and the minimum TSS value (0.83) for *Berberis. integerrima*. Also the maximum AUC value (0.94) is reported for *Rosa canina*, and the minimum AUC values (0.80) for *Cercis griffithii*.

The potential distribution maps of the MaxEnt model for each species are presented in Fig. 1-11. The results showed that most of suitable habitats for the plant species are located in north, west and centre of the study area. Also, area of suitable habitats for the plant species in each city has been shown in Tab. 3. *C. griffithii* had the highest (46.63%) and *A. erinaceum* had the lowest (6.29%) proportion of suitable habitats among all studied species in Khorasan region. Also, Shirvan had the highest and Nahbandan had the lowest proportion of suitable habitats for all the species (Tab. 3).

The most important environmental variables in predicting habitat suitability for most of the species were annual precipitation (23% contribution), annual mean temperature (18% contribution), and mean temperature of warmest Quarter (15% contribution) (Fig. 10).

The results confirmed the significant role of climatic factors in determining suitable habitats for the studied species. Our results pointed to annual precipitation, annual mean temperature, and mean temperature of warmest quarter as the most important environmental variables in determining potential geographic distribution for the species. Khorasan provinces have highly diverse climatic conditions. In the northern part, more precipitation, colder winters and mild summers have been reported. Generally, from north to south, precipitation, mostly in the form of rainfall, declines and the mean temperature rises (Bannayan et al., 2010).

As can be seen in Fig. 1, 3, 7, 8 and 11, suitable habitats for *Rosa canina*, *Juniperus polycarpus*, *Berberis integerrima*, *Acantholimon erinaceum* and *Salvia abrotanoides* are nearly similar. These habitats are located in the central and northwestern part of the study area. Suitable habitats for these five plants were very limited and equal to 8.75% of total study area, on average. These areas include Northern Khorasan province and also northern part of Razavi Khorasan province.

According to Tab. 3, suitable habitat of *Rosa canina* in Khorasan provinces is small and covers less than 7% of the study area. Some resources indicate that *Rosa canina* has an extensive distribution in the world. Iran has also been reported as a distribution center of this species (Khatamsaz, 1992). *Rosa canina* can tolerate drought and soils with low fertility (Omidbeigi, 2006) and grows in the different regions. However, according to our results, suitable habitat of *Rosa canina* was not very large. The cities with the largest suitable habitat for this species were Chenaran and Dar-e-Gaz with 40.99% and 33.895% respectively. Cities of Nehbandan, Birjand, Ghaenat, Gonabad, Bardaskan and Sarakhs with 0% suitable area did not include any suitable habitats for *Rosa canina*.

Suitable habitats for *Juniperus polycarpus* in the current study were also narrow and limited to 11.1% of the three provinces (Tab. 3). The most suitable habitats of this plant species have been located in Shirvan, Bojnoord, Dar-e-Gaz and partly in Ghoochan with 75.63%, 74.07% 69.83% and 59.84% suitable area respectively (Tab. 3). According to the data in Tab. 3, cities of Sarakhs, Fariman, Torbat-e heydarieh, Kashmar, Bardaskan, Taybad, Khvaf, Gonabad, Ferdows, Qaenat, Birjand and Nahbandan, with 0% habitat suitability, are by no means the right regions to grow this plant.

According to Tab. 3, only 12.7% of the study area was suitable as a habitat for *Berberis integerrima*. The highest habitat suitability for this plant was found in Shirvan, Bojnord, Quchan, Chenaran and Dar-e-gaz with 99.57%, 67.61%, 64.99%, 59.28% and 51.02% suitable habitat coverage, respectively. Cities of Sarakhs, Bardaskan, Gonabad, Ferdows, Qaenat, Birjand and Nahbandan with 0% are not suitable habitats for *Berberis integerrima*.

Suitable habitat for *Acantholimon erinaceum* was very limited and encompassed only 6.3% of the study area. Nehbandan, Birjand, Qaenat, Ferdows, Gonabad and Bardaskan with 0% suitable habitat are the least suitable cities for the species. Other cities in the study are not suitable habitat for *Acantholimon erinaceum* either. Cities of Fariman, Shirvan, Dare-e-Gaz, Chenaran and Quchan indicated less than 50% habitat suitability, having the best conditions for growing this plant in comparison with other cities (Tab. 3). *Acantholimon erinaceum* has a relatively large distribution in Iran (Assadi, 2003) and like other species of the Plumbaginaceae mostly has been reported in dry plain areas with salty soils (Mabberley, 1987). The attractive appearance of *A. erinaceum* and its beautiful spring flowers have made it a potential ornamental plant.

As illustrate in Tab. 3, only 6.79% of the study area is suitable habitat for *Salvia abrotanoides*. The highest habitat suitability with nearly

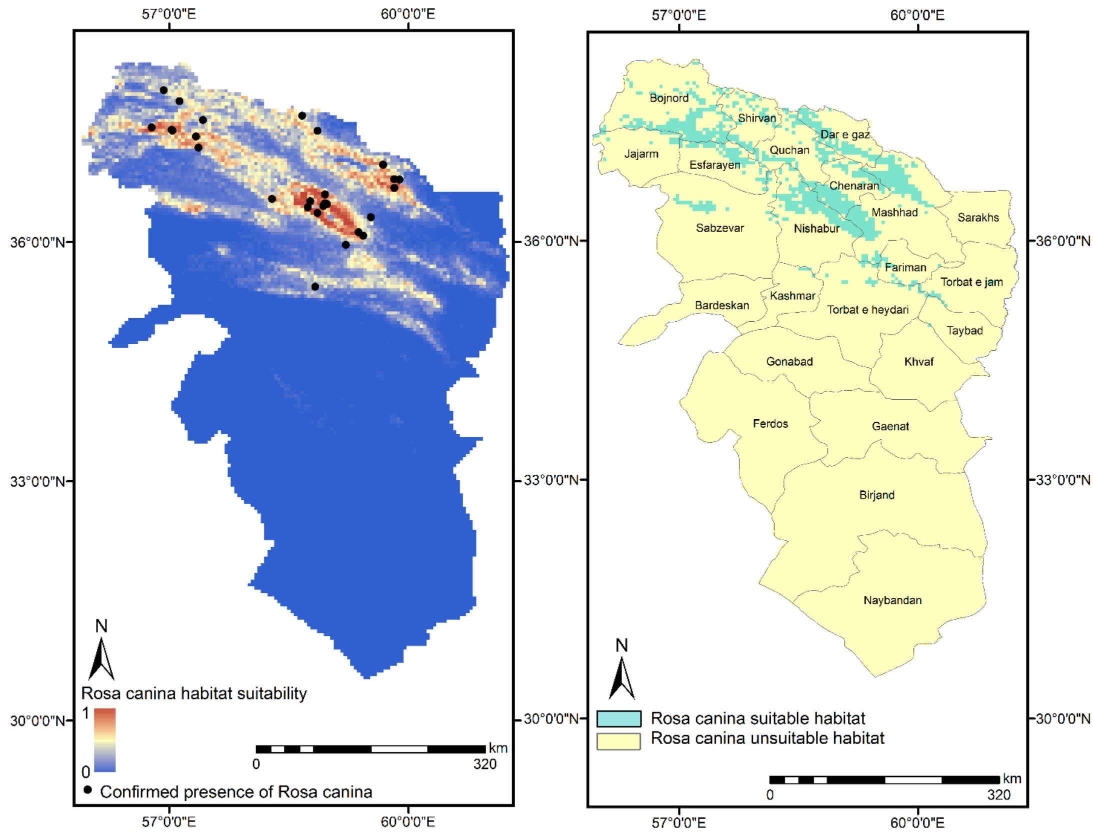

Fig. 1: Habitat suitability of *Rosa canina* and its suitable habitats in the cities of Khorasan region.

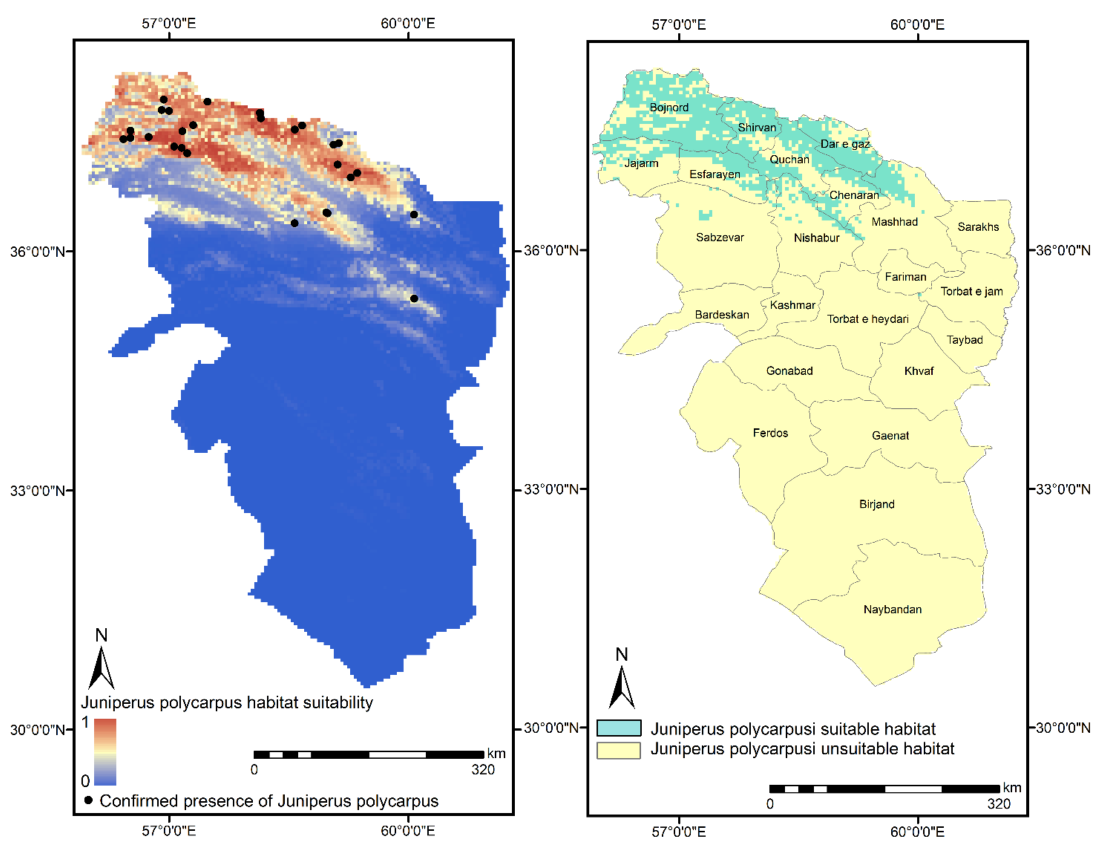

Fig. 2: Habitat suitability of *Juniperus polycarpus* and its suitable habitats in the cities of Khorasan region.

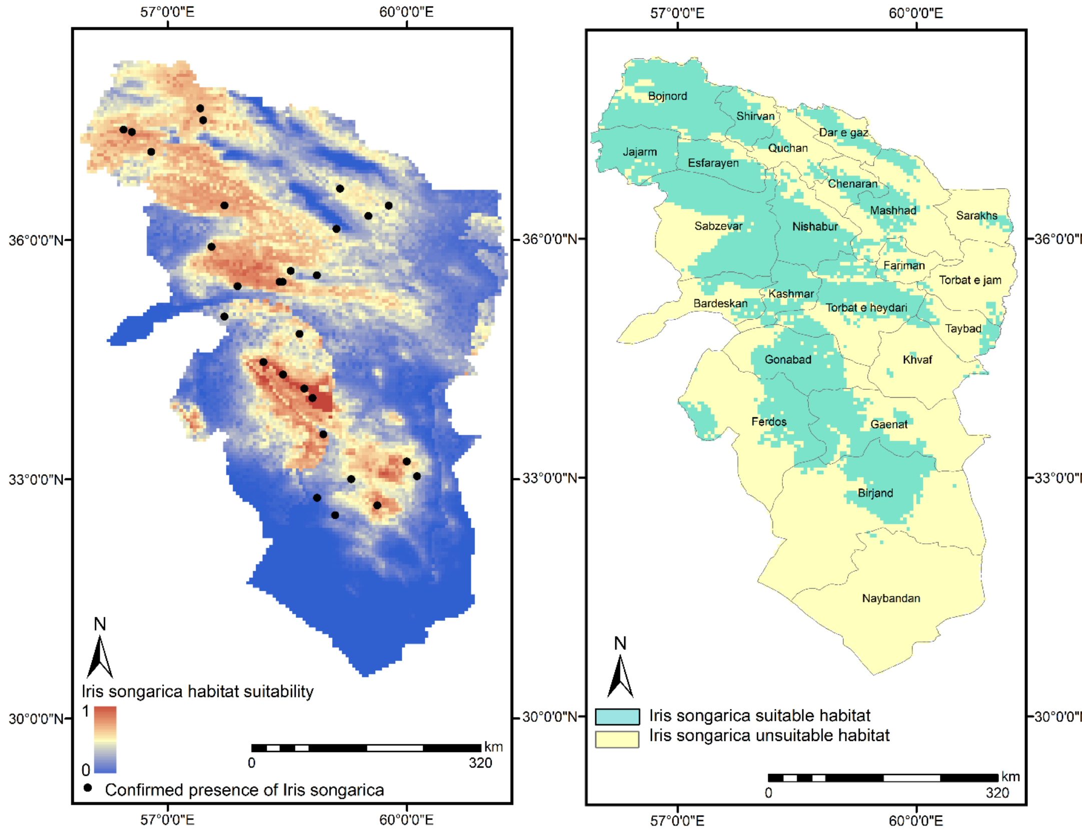

Fig. 3: Habitat suitability of *Iris songarica* and its suitable habitats in the cities of Khorasan region.

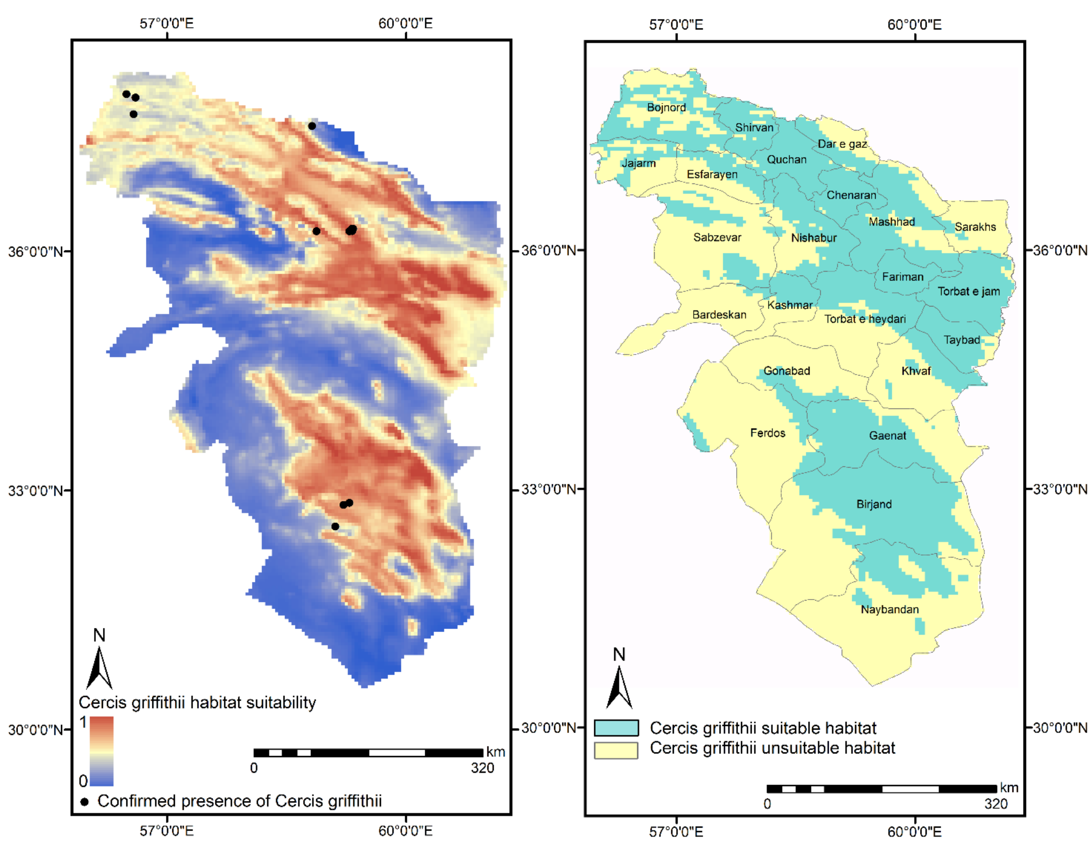

Fig. 4: Habitat suitability of *Cercis griffithii* and its suitable habitats in the cities of Khorasan region.

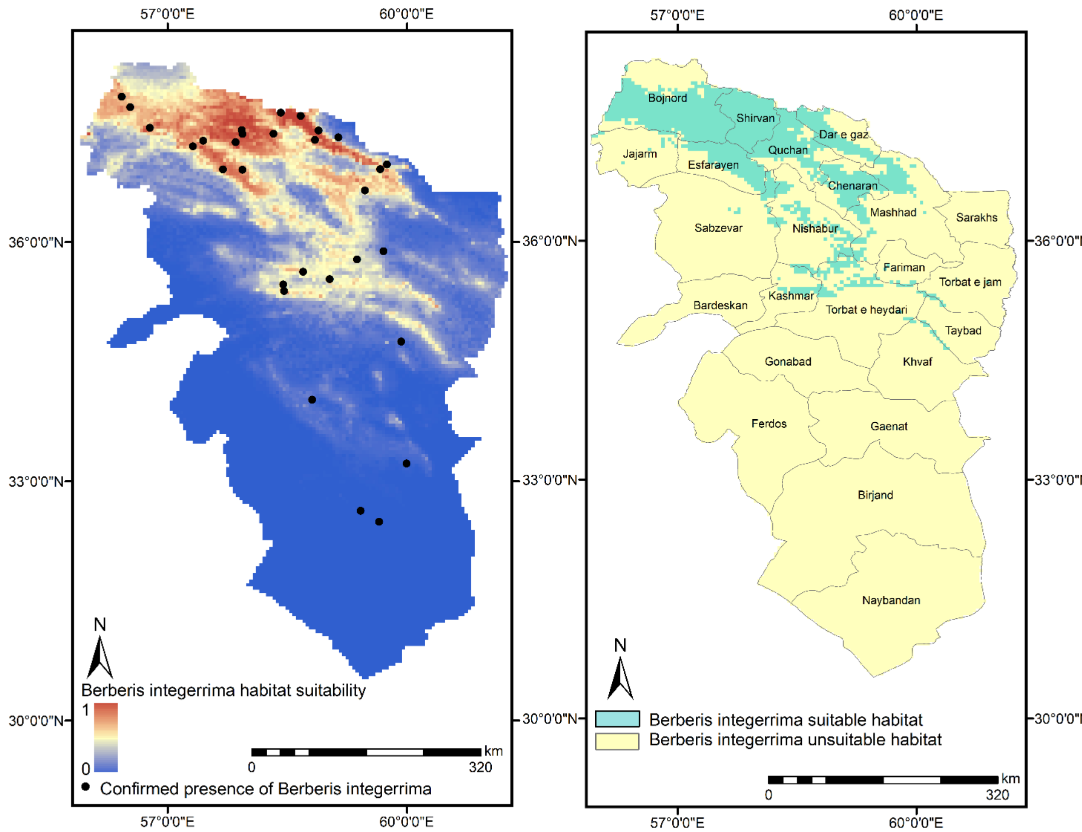

Fig. 5: Habitat suitability of *Berberis integerrima* and its suitable habitats in the cities of Khorasan region.

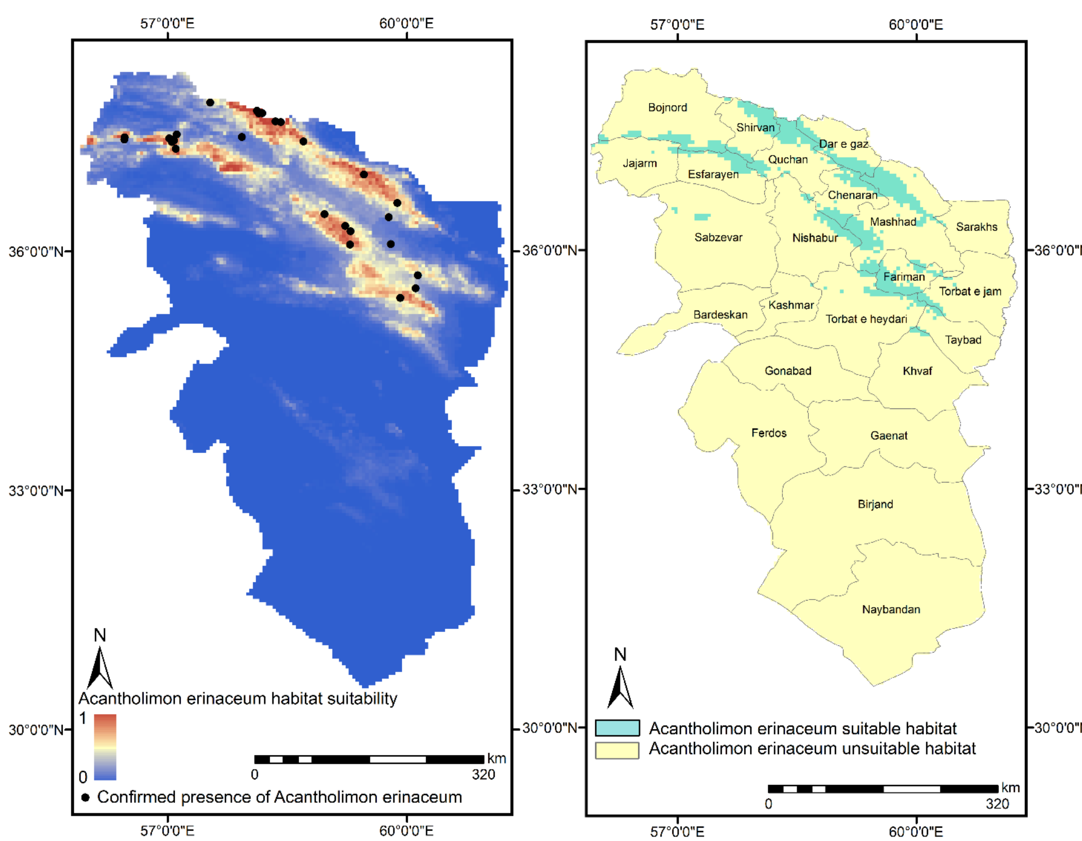

Fig. 6: Habitat suitability of *Acantholimon erinaceum* and its suitable habitats in the cities of Khorasan region.

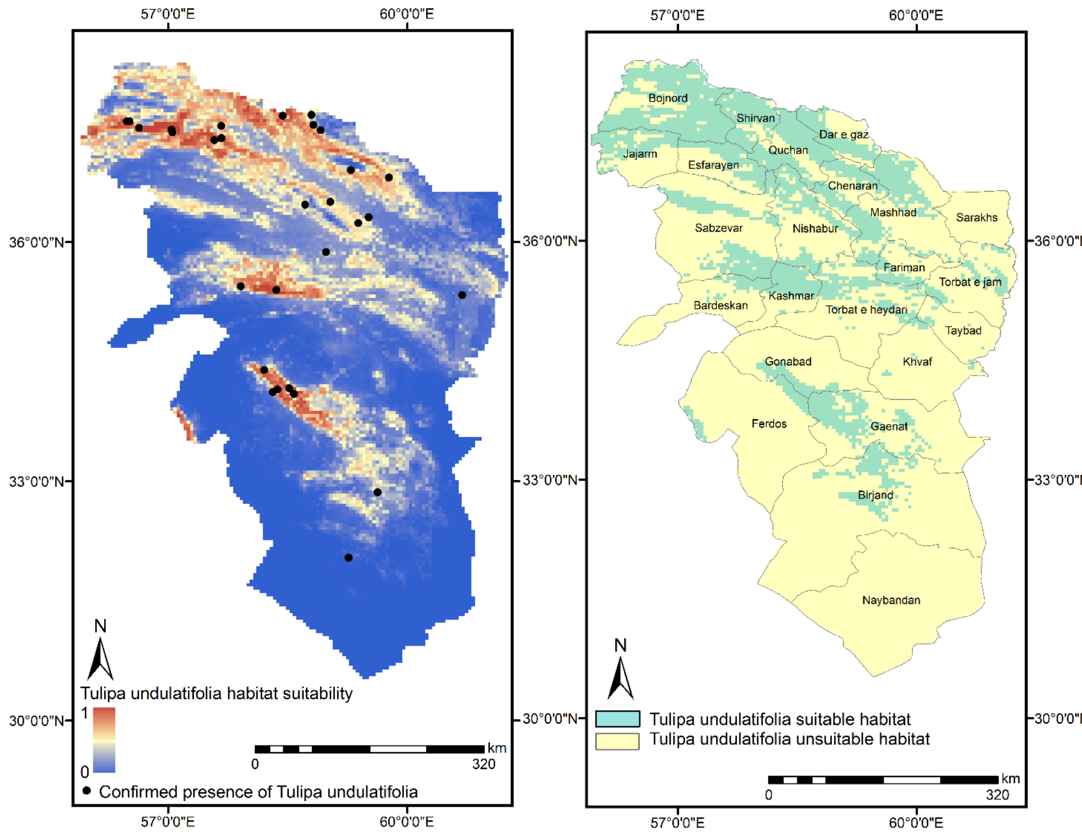

Fig. 7: Habitat suitability of *Tulipa undulatifolia* and its suitable habitats in the cities of Khorasan region.

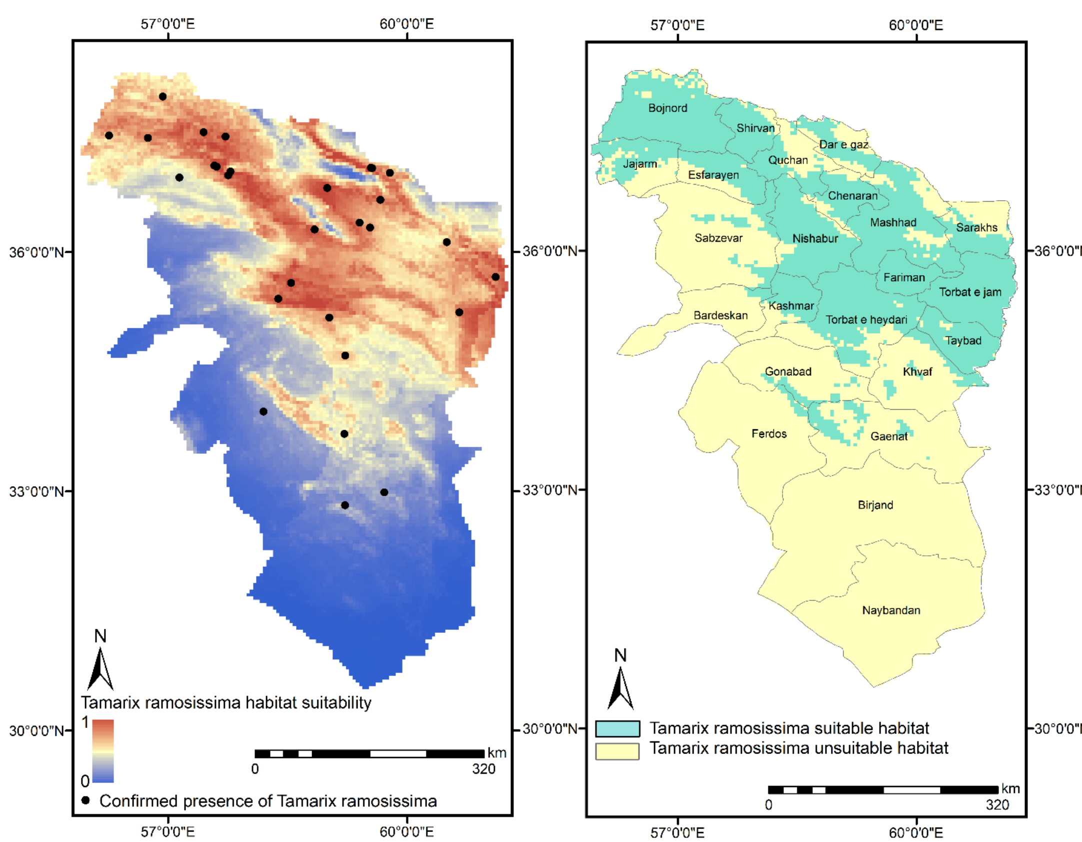

Fig. 8: Habitat suitability of *Tamarix ramosissima* and its suitable habitats in the cities of Khorasan region.

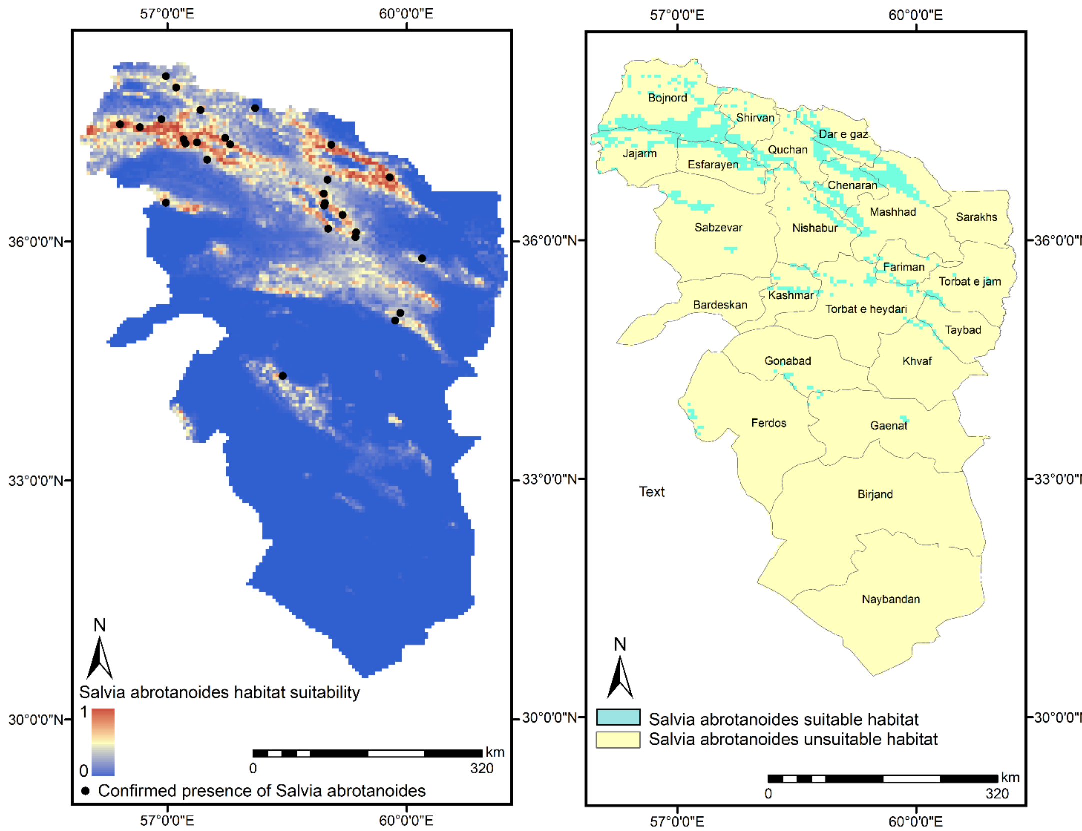

Fig. 9: Habitat suitability of *Salvia abrotanoides* and its suitable habitats in the cities of Khorasan region.

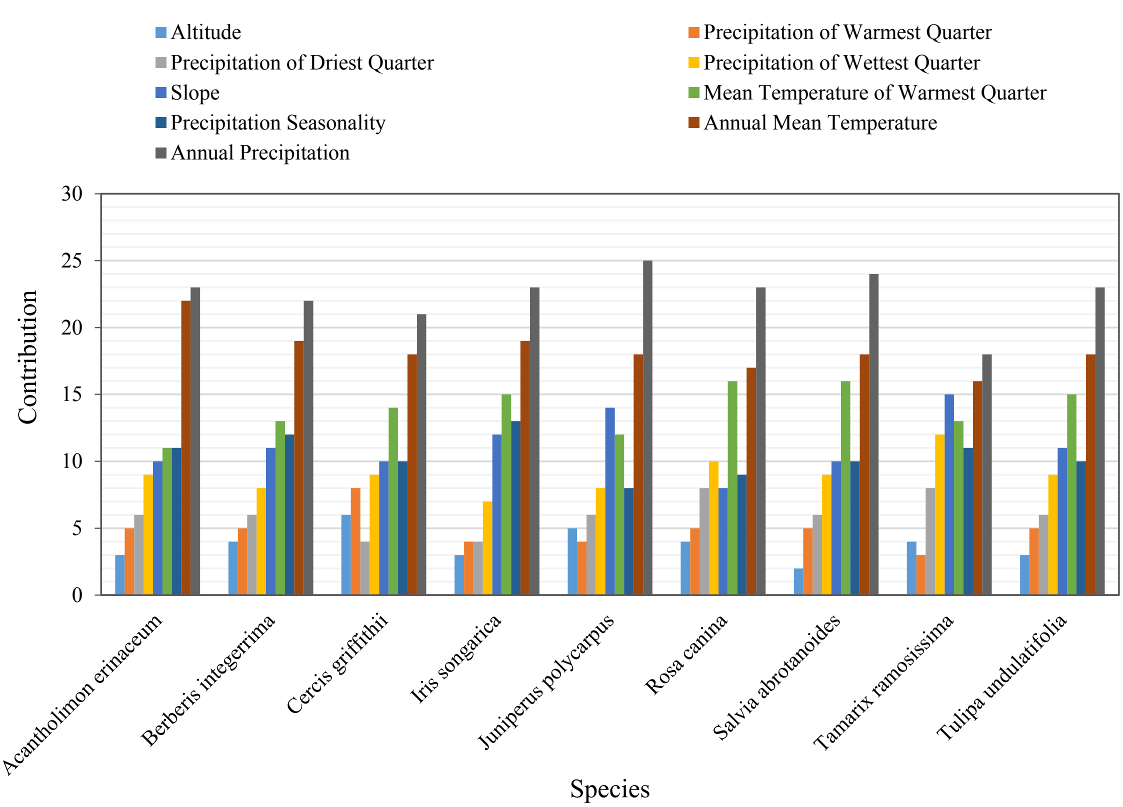

Fig. 10: Importance of environmental variables for all species.

30% was found in Bojnord, Shirvan and Chenaran. Although only in cities of Nehbandan, Birjand, Sarakhs and Bardaskan habitat suitability was 0%, most other cities in study were not very suitable habitats for this plant. *Salvia abrotanoides*, commonly known as a medicinal plant, grows in vast areas of Iran. Due to its resistance to drought and its long flowering period, it can be used in regions with water scarcity (Mohammadzadeh, 2016). Recently, *S. abrotanoides* has been introduced to the urban landscape of arid and semi-arid regions of Iran.

Although some studies indicated that five mentioned plants (*Rosa canina, Juniperus polycarpus, Berberis integerrima, Acantholimon erinaceum* and *Salvia abrotanoides*) can tolerate drought, according to the output of the MaxEnt model, suitable habitats in these plant species are relatively limited. The suitable habitats of the mentioned plants are located in the regions of Khorasan provinces that receive more precipitation.

According to Fig. 2, 4, 5, 6 and 9, suitable habitats of *Cercis griffithii, Iris songarica, Tulipa undulatifolia* and *Tamarix ramosissima* are more extensive in comparison with *Rosa canina, Juniperus polycarpus, Berberis integerrima, Acantholimon erinaceum and Salvia abrotanoides*. Suitable habitats of these six plants are about 38% of the study area, covering various parts of Khorasan provinces.

The highest proportion of suitable habitats among all studied species belongs to *Cercis griffithii* with 46.63% of study area. Cities of Fariman, Chenaran, Quchan, Torbat-e-Jam, Shirvan and Taybad with 100%, 98.67%, 98.06%, 95.58%, 90.87% and 88.79%, respectively, are the most suitable habitats for *Cercis griffithii* in Khorasan provinces. The most inappropriate habitats for this plant are located in the cities of Bardaskan, Sarakhs, Ferdows and Gonabad with 5.12%, 10.68%, 13.9% and 17.18% suitable area respectively (Tab. 3). Most of *Cercis* species have been reported as drought tolerant plants and some of them are commercially produced valuable landscape shrub (Sternberg, 2012). Due to its aesthetic value, this genus can play an important role in urban forestry and landscape architecture (Shabanian et al., 2015).

Suitable habitats of *Iris songarica* in the current study were 39.46% of Khorasan provinces. The highest proportion of suitable habitats for this plant are located in Jajarm, Bojnord and Esfarayen with 94.77%, 87.39% and 85.49% respectively. Cities of Nehbandan, Khaf and Torbat-e-jam with 0.28%, 5.41 and 4.81% respectively are not suitable habitats for *Iris songarica*. Iran is among the regions where various Iris species commonly occur (Azimi et al., 2016). Some species of this genus have good drought tolerance and can be found in regions with water scarcity. *Iris songarica* has aesthetic value because of its colorful and beautiful flowers and can be used in urban landscapes as a seasonal plant (Guo et al., 2013).

Suitable habitat of *Tulipa undulatifolia* was relatively small, spanning 15.45% of the study area. Cities of Shirvan, Bojnord and Quchan with 72.58%, 60.47% and 60.16%, respectively, are the most suitable habitats of *Tulipa undulatifolia* in Khorasan provinces. Cities of Sarakhs and Nahbandan with 0% habitat suitability are by no means the right regions to grow this plant (Tab. 3). Iran, where various types tulip naturally grow, is one of the main origins of *Tulipa* species. Tulips are among the most popular flowering bulbous

Tab. 3: Studied plant species' suitable habitats and results of model evaluation (TSS: True Skill Statistic for evaluating the model, AUC: Area Under Curve for MaxEnt).

Accuracy index	*Acantholimon erinaceum*	*Berberis. integerrima*	*Cercis griffithii*	*Iris songarica*	*Juniperus polycarpus*	*Rosa canina*	*Salvia abrotanoides*	*Tamarix ramosissima*	*Tulipa undulatifolia*	Total
AUC	0.91	0.86	0.80	0.89	0.92	0.94	0.85	0.83	0.84	-
TSS	0.92	0.83	0.87	0.88	0.91	0.87	0.88	0.84	0.93	-
Suitable habitat (%)										
Bojnord	10.63	67.64	56.28	87.39	74.07	25.00	30.37	92.79	60.47	635.12
Shirvan	34.33	99.57	90.87	71.76	75.63	23.92	15.68	87.85	72.58	665.67
Dar-e-gaz	31.07	51.02	51.47	46.51	69.83	33.89	31.05	53.06	46.95	469.53
Quchan	29.71	64.99	98.06	19.42	59.84	22.65	20.73	49.90	60.16	522.22
Jajarm	3.47	5.49	37.06	94.77	30.96	6.36	19.67	56.45	35.59	412.36
Esfarayen	17.26	55.68	45.64	85.49	40.79	22.80	25.56	68.48	34.21	504.93
Mashhad	27.34	18.39	71.70	32.15	13.68	24.43	15.77	79.42	24.43	391.24
Chenaran	30.97	59.28	98.67	40.28	40.25	45.16	32.73	80.98	38.48	558.84
Nishabur	8.86	21.70	68.58	74.66	12.17	25.96	9.65	90.73	16.73	452.17
Sabzevar	1.18	3.82	24.20	67.87	2.45	3.82	3.83	13.77	13.00	231.68
Sarakhs	0.67	0.00	10.68	10.68	0.00	0.00	0.00	50.42	0.00	76.78
Torbat-e-jam	4.65	1.33	95.58	4.88	0.22	2.44	3.10	99.78	4.43	281.44
Fariman	40.99	3.73	100.00	21.26	0.00	7.99	8.52	100.00	10.12	433.05
Torbat-e heydarieh	6.06	11.98	46.81	54.51	0.00	2.96	5.03	74.16	8.77	305.62
Kashmar	0.41	13.39	48.67	73.12	0.00	1.62	9.74	66.17	43.00	359.61
Bardaskan	0.00	0.00	5.12	29.38	0.00	0.00	0.00	5.59	9.08	90.64
Taybad	4.09	2.98	88.79	24.99	0.00	0.37	2.98	95.53	0.75	299.52
Khaf	1.44	1.80	31.59	5.41	0.00	0.18	1.98	18.05	0.18	96.52
Gonabad	0.00	0.00	17.18	65.41	0.00	0.00	1.93	9.99	9.12	139.19
Ferdows	0.00	0.00	13.90	34.83	0.00	0.00	1.11	2.31	5.55	84.25
Qaenat	0.00	0.00	65.29	43.75	0.00	0.00	0.80	13.37	14.18	232.47
Birjand	0.00	0.00	54.45	24.86	0.00	0.00	0.00	0.00	3.81	147.36
Nahbandan	0.00	0.00	25.03	0.28	0.00	0.00	0.00	0.00	0.00	47.66
Region	6.29	12.70	46.63	39.46	11.01	6.98	6.79	36.05	15.49	-

plants and have high ornamental value.
36.05% of the study area was suitable habitat for *T. ramosissima*. More than 90% of Fariman (100%), Torbat-e-jam (99.78%), Taybad (95.53%), Bojnord (92.79%) and Nishabur (90.73%) were suitable habitats for this plant. Two cities of Nehbandan and Bijand with 0% suitable urban area were the most unsuitable habitats of *T. ramosissima* (Tab. 3). The most abundant species of *Tamarix* in Iran is *T. ramosissima* which can survive in hard climates and grow in salty soils and dry regions (Matinkhah and Kaveh Sedighi, 2017). *T. ramosissima* is used as an ornamental plant worldwide.

Conclusion

Accordingly, we recommend that managers use this study to develop conservation strategies directed toward maintaining or ameliorating the quality of the urban landscapes. According to the output of the models and also exacerbating climate conditions in the study area, it is suggested that three plants species (*Cercis griffithii, Iris songarica* and *Tamarix ramosissima*) be planted and their cultivation area expanded in the Khorasan provinces. In contrast, planting of three shrubs (*Acantholimon erinaceum, Salvia abrotanoides* and *Rosa canina*) in particular in the South Khorasan and Razavi Khorasan provinces is not advisable. SDMs may help to understand habitat characteristics of species. Results of the current model need refinement and further investigation to clarify the role of different factors in determining species distributions. Future studies should address niche shift and resolve the most important factors underlying species distribution.

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Conflict of interest
No potential conflict of interest was reported by the authors.

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