CJES Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

Evaluation of habitat quality and determining the distribution of Wild goat (*Capra aegagrus*) in Roodbarak prohibited hunting region, Kelardasht, Iran

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ABSTRACT

In this study, we assessed the seasonal habitat suitability of Wild goat, *Capra aegagrus* in Roodbarak prohibited hunting region, located in Kelardasht, Northern Iran. We applied environmental variables including topographic factors (altitude, slope, and aspect), climatic factors (average rainfall and average monthly temperature), anthropogenic factors (distance from villages and roads), vegetation type, and water resources to analyse the connection of the species presence with its habitat. To model the species distribution, we benefitted from the three following modelling algorithms using biomod package implemented in R programming language: Generalized Linear Model (GLM), Generalized Boosted Models (GBM), and Random Forest (RF). The results of all models indicated altitude as a determining factor in wild goat's habitat for all seasons in the studied area. In addition, climatic variables were critical in forming the species habitat in spring, summer and autumn. Moreover, in winter, distance to springs exhibited a significant impact. Applying the results of such ecological studies of habitat evaluation along with population surveys can be crucial in the species and consequently ecosystem conservation.

Key words: Wild goat, *Capra aegagrus*, Habitat modelling, Environmental factors, Mazandaran Province, Iran.
Article type: Research Article.

INTRODUCTION

Nowadays, researchers use species distribution models (SDM) to determine the suitable habitat for different plant and animal species to protect biodiversity and habitats (Fook *et al.* 2009). This type of spatiotemporal models predicts the distribution range of species and their habitat relationships. Therefore, they can be used as a proper tool for conservation, reserve design and management measures such as corridor construction (Guisan & Zimmermann 2000; Guisan & Thuiller 2005; Thuiller & Münkemüller 2010). Uncertainty is a recurring problem in distribution modelling. One of the major sources of uncertainty is different methods and algorithms for the purpose. They cause half to one-third of the uncertainty of the results of projected habitats (Heikkinen *et al.* 2007; Roura-Pascual *et al.* 2009). It is recommended to generate several models using different methods and then produce an ensemble model out of them, so that more reliable results can be achieved (Thuiller 2003). Biomod is a package implemented in R programming language for predicting species distribution. It reduces the uncertainty of modelling by producing ensemble models using several algorithms. It also designs response curves for variables and determines the importance of predictor variables (Thuiller *et al.* 2009). Excessive hunting, deforestation, planting, road construction, mining, power lines, illegal grazing, and military activities are among the threats to protected areas and wildlife habitats in Iran (Majnoonian 1993). Furthermore, habitat destruction and fragmentation have put many species on the brink of extinction since such phenomena can lead species to isolated and semi-isolated populations (Hirzel & Guisan 2002). Hence, species distribution is a wise practice to shed light on our knowledge about species habitats for management efforts. *Capra aegagrus* is one of the most prominent mammals in the mountainous regions, distributed in various habitats of Iran. This species is of great ecological

Caspian Journal of Environmental Sciences, Vol. 20 No. 5 pp. 863-870 Received: April 23, 2022 Revised: July 10, 2022 Accepted: Oct. 16, 2022
DOI: 10.22124/CJES.2022.6035

Publisher: University of Guilan, Iran

importance as it is assumed to be prey for leopards, and due to the endangered situation of leopards, it is critical to assess the habitat suitability for Wild goat. Given that this species is included in the Vulnerable category of IUCN Red List (Weinberg 2008), expanding knowledge on the factors affecting the desirability of the species habitat and the extent of its distribution is of fundamental importance in its conservation. Among the surveys performed on the habitat suitability of Wild goat in Iran, that of Shams Esfandabad *et al.* (2010) in the Haftad-Gholeh protected area using logistic regression model is considerable, who reported that elevation, slope, and anthropogenic factors exhibit the highest effects on the species. Moreover, Hosseini *et al.* (2016) used the maximum entropy to evaluate the habitat suitability for Wild goat in Golestan National Park, North-eastern Iran. They indicated that elevation, slope, and vegetation cover were among the most influential factors in determining the distribution of Wild goat. The habitat of this species was also examined in other parts of Iran (Moravati, 2014; Naderi *et al.* 2014; Shadloo & Naderi 2019). In all these studies altitude was reported to be highly effective in this respect. The purpose of this study is to investigate habitat suitability for Wild goat in Roodbarak, distinctively, in four seasons of the year, as well as to determine the most important factors affecting the process of habitat selection of this species.

MATERIALS AND METHODS

Study area

Roodbarak is a village in Kelardasht City, Mazandaran Province, Northern Iran, with an approximate area of about 56,000 hectares. The entire study area is located at longitude 51 degrees to 51 degrees and 5 minutes E and latitude 36 degrees and 20 minutes to 36 degrees and 25 minutes N. The elevation ranges between 2400 and 4200 meters above sea level (Abbasian *et al.* 2004).

Data sampling

We collected data on the locations of Wild goat presence for a year initiating in August 2017. These data were collected from the areas with potential for the existence of the studied species. Data were sampled regularly and at least once a month. We recorded the coordinates of the indices such as footprints, feces, horns, fur, teeth, carcasses, along with direct observations by binoculars and telescopes. All of the recorded data were marked as occurrence points using the Global Positioning System (GPS). To ensure that the occurrence points are not spatially auto-correlated, we ran the Global Moran's I test. The occurrence points are illustrated in Fig. 1.

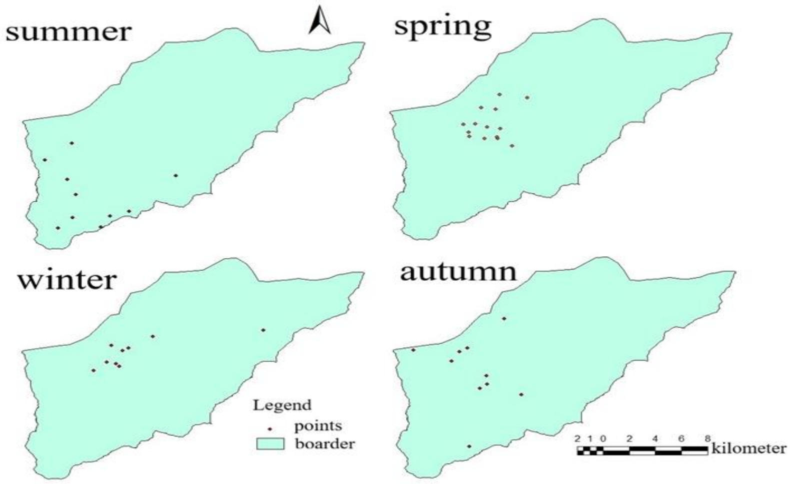

Fig. 1. Occurrence points of the species in different seasons.

Variables

Habitat variables were selected according to the behavioral and ecological characteristics of Wild goat, as well as the characteristics of the study area by reviewing similar studies conducted in Iran (Shams Esfandabad *et al.* 2010; Naderi *et al.* 2014) and other parts of the world (Gross *et al.* 2002; Khan *et al.* 2016). Finally, we selected ten variables, including topographic variables (elevation, slope, and aspect), vegetation type, distance from water sources (rivers and springs), anthropogenic variables (distance from roads and villages), and climatic variables (average temperature and average monthly rainfall). The variable layers were provided from the Department of

Natural Resources of Mazandaran Province, the Forests, Rangelands and Watershed Management Organization and the Meteorological Organization in Iran. Due to the lack of a weather station in the study area, we used the interpolation technique to provide precipitation and temperature layers. Therefore, we gathered the data available for the nearest meteorological station (Nowshahr, Ramsar, SiahBisheh and Taleghan stations). Then the IDW (Inverse Distance Weighted) method was implemented in ArcMap 10.3.1. In the next step, ArcMap was used to clip the layers according to the borders of studied area and convert them to ASCII. In the present study, there are two categorical variables namely vegetation type and aspect. The levels of vegetation type, obtained from Iranian Forests, Range, and Watershed Management Organization (IFRWMO) depicted in Table 1. In addition, the levels of aspect were considered as five different categories (0: Flat; 1: North; 2: East; 3: South; 4: West). According to different studies (Dormann *et al.* 2013; Feng *et al.* 2019), correlation coefficient higher than 0.7 between variables is associated with models being distorted and less accuracy in the results. One of the methods to avoid such a problem is to reduce the number of variables performing Principal Component Analysis (PCA). We applied PCA using ArcMap 10.5 in order to determine the correlation between variables. Then variables with high correlations (above 0.7), were omitted according to the results of PCA.

Table 1. levels of vegetation type in the study

1	*Astragalus goosypinus-Bromus tomentellus*
2	*Cynodon dactylon- Festuca ovina*
3	*Onobrychis cornuta- Astragalus gossypinus-Festuca ovina*
4	*Bromus tomentellus*
5	*Onobrychis cornuta*
6	*Astragalus goosypinus- Bromus tomentellus-Festuca ovina*
7	*Onobrychis cornuta- Bromus tomentellus*
8	*Astragalus goosypinus -Festuca ovina*
9	*Astragalus goosypinus- Bromus tomentellus*
10	*Onobrychis cornuta- Astragalus goosypinus*
11	*Onobrychis cornuta*
12	*Festuca ovina- Onobrychis cornuta*

Modelling

In this study, we used biomod package and run three modelling algorithms: Generalized Linear Model (Kienast *et al.* 2012), Random Forest (Breiman 2001; Breiman & Cutler 2007), and Generalized Boosted Models (Breiman, 1997; Friedman 2001). Using this package, we were also able to estimate the importance of the variables and then to plot response curve for each variable. Furthermore, we used AUC (Area Under Curve) metric to assess the accuracy of our models.

RESULTS

Correlations

From each pair of high correlated variables (> 0.7), we kept only one. Therefore, distances from rivers, roads and villages were omitted from modelling processes for all seasons. In addition, for spring and autumn, variables of the average rainfall and the average temperature were extracted, respectively, and both of these climatic variables were removed from further analysis in winter due to high correlations with other variables.

Models' performance

Using biomod, we could calculate the accuracy of each model (Table 2). The results show that in spring, all models have provided great predictions, among them, the ensemble and RF models were the best and the most accurate ones. In addition, in summer, all models provided great predictions for the species distribution, among them, the ensemble model and GBM performed the best. In autumn, all methods except GLM were able to show high accuracies. Finally, in winter, all methods were able to result in high precisions, with RF performance at the top.

Important variables

We calculated the importance of each variable in different seasons based on the ensemble method (Table 3). Based on the obtained results, elevation was a determining factor for the Wild goat's habitat, throughout the year. Also, climate variables, were crucial in the species' distribution. Noteworthy, in winter, distance to springs was too a critical variable. Furthermore, we depicted the first three variables' response curves for each season (Fig. 2).

Table 2. The accuracy of each model.

Season	Metric of accuracy	GBM	GLM	RF	Ensemble model
Spring	AUC	0.99	0.96	1	1
	TSS	0.97	0.90	0.99	0.97
Summer	AUC	0.97	0.89	0.97	0.98
	TSS	0.99	0.8	0.89	0.89
Autumn	AUC	1	0.86	1	0.99
	TSS	0.98	0.76	0.99	0.98
Winter	AUC	0.99	0.96	1	0.98
	TSS	0.97	0.84	0.98	0.85

Note: AUC: Area Under Curve; TSS: True Skill Statistic

Table 3. The importance of variables in different seasons

Variables	Spring	Summer	Autumn	Winter
Elevation	0.743	0.528	0.886	0.780
Average monthly rainfall	-	0.949	0.412	-
Temperature mean	0.553	0.383	-	-
Vegetation type	0.231	0.016	0.201	0.002
Slope	0.141	0.141	0.190	0.017
Aspect	0.115	0.058	0.289	0.002
Distance to springs	0.058	0.056	0.155	0.620

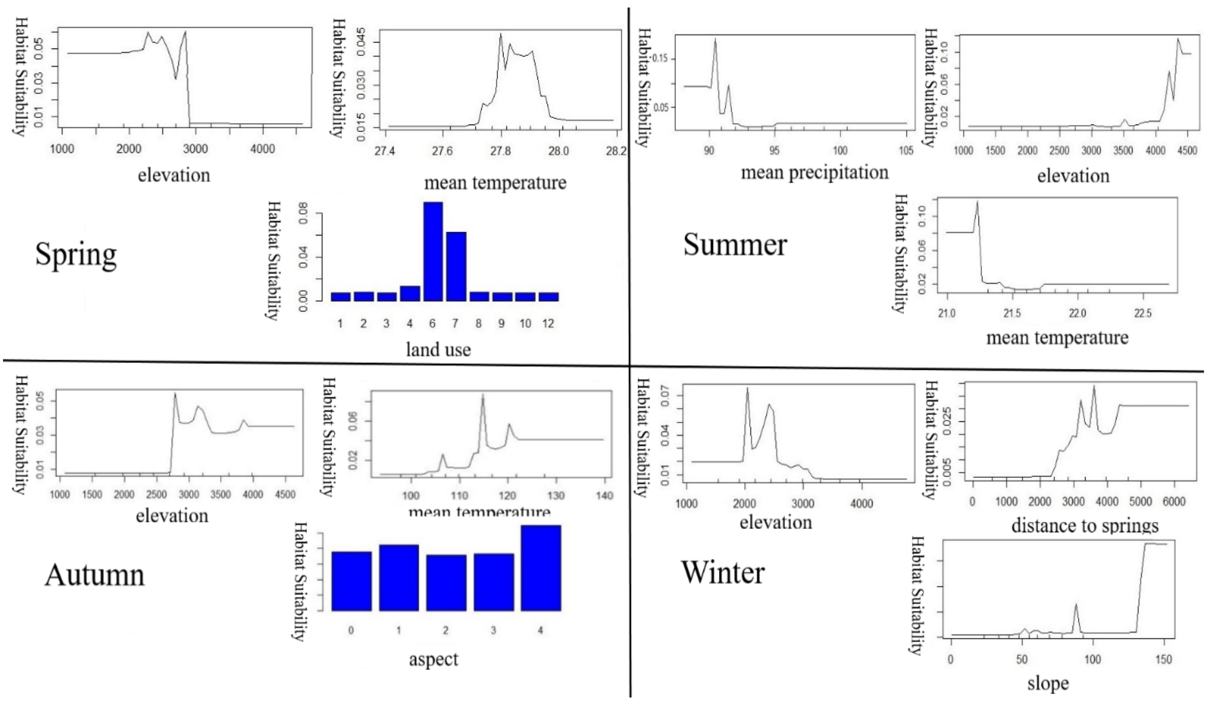

Fig. 2. Response curves for three most significant variables in different seasons.

Habitat suitability

The probability of the presence of Wild goat in all seasons, based on the ensemble models has been illustrated in Fig. 3. The results show that in spring, summer, autumn, and winter, regions in the center, southwest, mid-southwest, and a narrow range from northeast to southwest of the area are the most suitable habitat of Wild goat, respectively. Moreover, the binary maps for each ensemble model were generated (Fig. 4). Optimal areas, according to the ensemble approach, cover 19.5, 36, 80, and 33 km^2 in the spring, summer, autumn and winter, respectively.

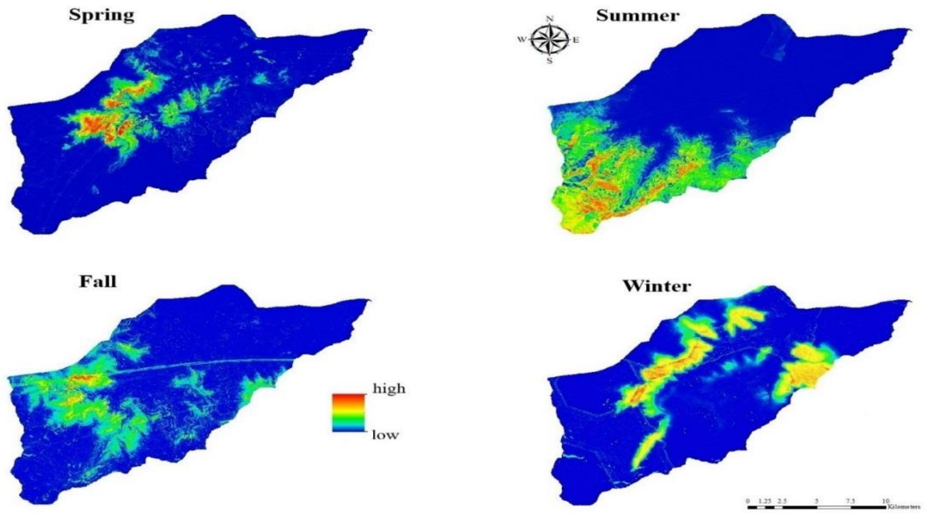

Fig. 3. The habitat suitability maps for Wild goat in different seasons in Roodbarak prohibited hunting region.

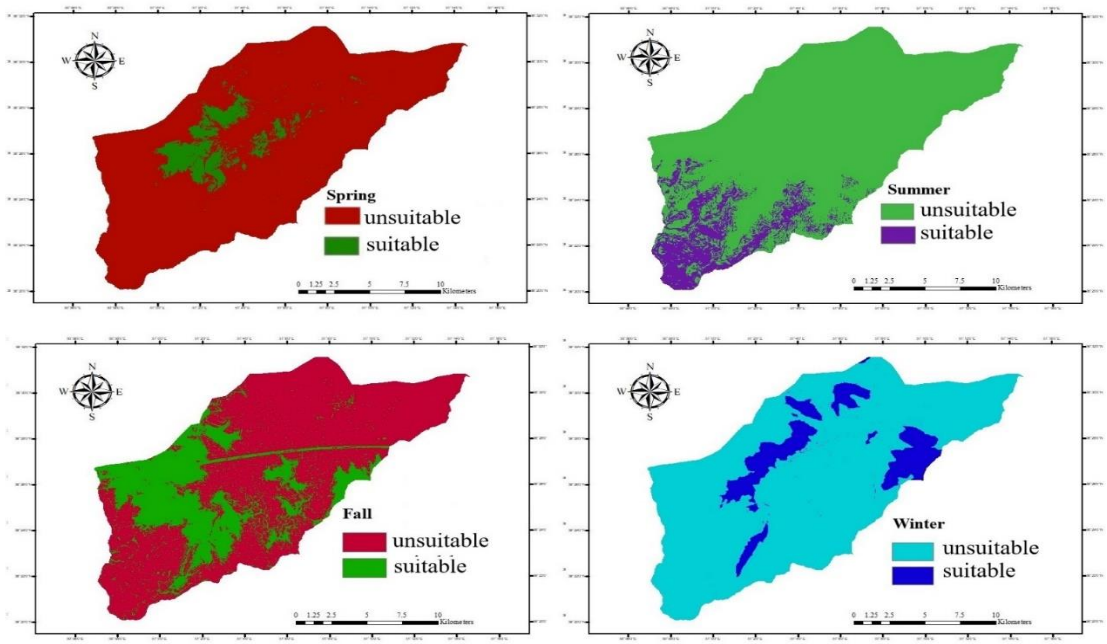

Fig 4. The binary habitat suitability map for Wild goat in different seasons in Roodbarak prohibited hunting region.

DISCUSSION

Our results showed that almost all individual models, as well as the ensemble model resulted in very good predictions (AUC > 0.75 and TSS > 0.6). The only exception is GLM model in fall which showed lower accuracy than the rest, and therefore, the results of this method are less valid. The results of ensemble models represented high accuracies and reduced the uncertainty which usually is resulted from several modelling methods. Also, the results of this approach are more reliable, and therefore, we proceeded our further analysis based on the ensemble models. Jones-Farrand *et al.* (2011) has shown that using only one separate model, even if it has a high validity, is very risky in protection and management operations, since the results of the models are different in many cases. They suggested using the results of ensemble prediction due to the outcomes with high accuracies. There are other studies (Thuiller & Münkemüller 2010; Le Lay *et al.* 2010) that have also suggested ensemble approach as a solution to increase certainty. The lowest accuracy among the methods used in this study was obtained by GLM method. This method has been able to provide two excellent models (in spring and winter) and two acceptable models (in summer and autumn). In one study by Marmion (2009) on 28 endangered plant species, GLM method succeeded in presenting an acceptable model in habitat modelling of 21 species and a weak model in 7 cases.

Thus, this method could not provide any excellent predictions in this study. The highest amount of suitable area occurred in autumn (Table 4).

Table 4. The percentages of suitable habitat for wild goat in different seasons based on an ensemble model.

Suitable habitat	Winter	Autumn	Summer	Spring
The whole area (%)	12	29	13	8

Roodbarak had the most precipitation in the autumn during the period of our survey. It seems that this is the main reason for Wild goat to be distributed more freely in this region in autumn. In spring and then winter, the region became significantly unsuitable for this species and almost half of the favorable areas were lost which can be due to the heavy snowfall in winter, and the insecurity of the habitat through spring because of the livestock and illegal hunting, particularly on May. Comparison of habitats in different seasons shows that in spring and winter, the wild goats prefer the central regions, while in summer and autumn they move to the southwestern parts of the area. The observed results in relation to the habitat selection behavior as well as the overlap and similarity of suitable areas in different seasons by wild goat are consistent with the results obtained by Shams Esfandabad *et al.* (2010), in Kooh-e Sefid located in Damavand, Northern Iran. In the present study, it was observed that in all seasons, altitude plays an important role in determining the habitat of Wild goat. Based on the ensemble models, altitude was the first important variable in spring, autumn, and winter and only in summer stands second after average precipitation. This species prefers altitudes above 4000 m in summer. It seems that high altitudes are more critical in summer due to the heat of the season. Also, the presence of livestock in this area from May to September at lower altitudes can be another reason for this species to take refuge in relatively higher altitudes. On the other hand, in winter, altitudes of 2000 to 2500 m exhibit the highest potential. The severe cold of this mountainous region in winter makes this species interested in relatively lower altitudes in winter. Elevation's scores in spring, summer, autumn, and winter were of 0.743, 0.528, 0.886 and 0.78, respectively. Devoe *et al.* (2015) studied Wild goat in Yellowstone National Park in the United States and showed that this species chooses higher altitudes in summer, since at higher altitudes the vegetation is higher, while the temperature is lower. In addition, in another study by Sarhangzadeh *et al.* (2013) in the Bafgh protected area in central Iran, it was found that altitude is one of the most important and influential variables in habitat selection by this species in winter. Mostafavi *et al.* (2010) proved that this species pays special attention to altitude in Lar National Park in north of Iran, and prefers high altitudes, above 3000 m above sea level. In Kolah Ghazi National Park, in central Iran, they prefer elevations of 1900 to 2300 m (Farashi *et al.* 2010). This species in Kavir National Park, in north of Iran has a similar behavior found in the present study; in the warm seasons, it chooses the areas with the highest altitudes while in the cold seasons, the relatively lower altitudes (Shadloo & Naderi 2019). The mean monthly temperature variable was used in spring and summer, while was removed in winter and autumn due to high correlation with other variables. Moreover, the variable of average monthly rainfall has only participated in modelling the summer and autumn habitats. These two climatic variables were very important in determining the habitat of the studied species and exhibited a high participation in the modelling process. The mean monthly temperature scores in spring and in summer were 0.553 and 0.383, while the average rainfall score in summer was 0.949 (as the most important variable) and in autumn was 0.412 (the second most important variable). This result contradicts with that of Shadloo & Naderi (2019) who examined the suitability of Wild goat habitats in Kavir National Park, Northern Iran. In their study, climatic gradients displayed a very little impact on habitat selection throughout the area in each season. However, in different time scales (warm- versus cold- seasons) they would change their habitat. It means that minor climatic variations in a short time scale are ineffective in determining the species distribution range. Another variable of great importance was vegetation types. This is the third most important variable in the spring and exhibits a score above 0.23. Also, in autumn, with a score of 0.201, the variable ranks fourth. However, in summer and winter, it displayed a little effect (0.01 and 0.002) on habitat modelling. The species prefers planted forests and dense areas (rangeland with canopy density of higher than 50% with the annual and perennial plants) in spring and low-density pastures (rangeland with canopy density of 5 to 25% with annual plants and perennial) in summer. In other studies, such as Mostafavi *et al.* (2010), Hosseini *et al.* (2016), and Shadloo & Naderi (2019) the variable of vegetation type has been significantly effective in the habitat suitability of this species. The distance-to-spring variable was very important in winter. According to its response curve, Wild goat is more interested in areas close to springs in winter. Since this variable exhibited the high positive correlations with the distance to river, we can assume that this variable would also be important determinant of habitat selection for the species. In this season, precipitation is mostly in form of snowfall rather than rainfall, and it makes wild goats become more likely to approach springs. However, in spring and summer, due to the melting snow, seasonal rivers are filled with water and in this case, water resources would not be a limiting factor. This finding was also verified by the game guards. Shams Esfandabad *et al.* (2010) reported that the species reacted strongly to the existence of water resources in Haftad-Gholeh protected area, in the center of the Iranian plateau. Slope was recognized as the third important variable in winter. Despite its relatively high scores in other seasons (0.147, 0.141 and 0.190 for spring, summer and autumn respectively) it was less effective in comparison to winter. Due to the response curve, in winter, slopes above 130% are suitable for Wild goat. Steep slopes for this species mean more security. The observed results about this variable are in accordance with previous studies (Sarhangzadeh *et al.* 2013; Moravati 2014; Shadloo & Naderi 2019). The last effective variable is aspect, ranged significantly from only 0.002 in winter and relatively high score in autumn (0.289), which can be due to the effect of receiving more light and better access to shelter and food sources. Due to the response curve, in autumn, the species is more likely to choose west aspects. Roodbarak prohibited hunting region is not considered among the four protected areas. Unfortunately, there is a lot of illegal hunting in this area which has created insecurity. It is better to set stringent rules to prevent illegal hunting. Also, climbers can cause isolation and drive Wild goats to areas with less suitability from May to September. Therefore, it is recommended to set some limitations for mountaineers and to raise awareness among them about how to be responsible eco-tourists. In addition, the entry of domestic animals should be more controlled and monitored in accordance with the law and grazing license. Providing appropriate facilities and equipment to the rangers can greatly help them in effective patrolling. These measures are very helpful in improving the situation and habitat of Roodbarak prohibited hunting region. According to our results, it is possible to use the suitability maps in all four seasons to provide special protection to these areas and to maintain suitable conditions for Wild goat. For example, due to the fact that this species prefers relatively lower altitudes in spring and winter, strict controls should be imposed on the lower altitudes of the mountains, in these seasons. Moreover, we suggest performing studies on habitat restoration in Roodbarak to prevent more damage.

ACKNOWLEDGEMENTS

The authors really appreciate Mazandaran Provincial Department of Environment for kind cooperation during sample collection. We are very grateful to the anonymous reviewers for their careful reading of the manuscript and their constructive comments.

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Bibliographic information of this paper for citing:

Koohestani, M, Naderi, S, Shadloo, S 2022, Evaluation of habitat quality and determining the distribution of Wild goat (*Capra aegagrus*) in Roodbarak prohibited hunting region, Kelardasht, Iran. Caspian Journal of Environmental Sciences, 20: 863-870.