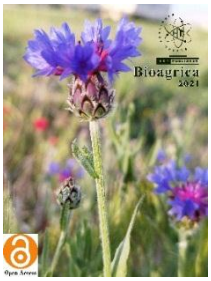
Article ID : *BioAgrica-2003312112246*

Bioagrica

Journal homepage: http://www.htpub.org/Bioagrica/



Habitat suitability modeling for wild goat *(Capra aegagrus)* in Kouh-Sefid Hunting Prohibited Area, Tehran Province, Iran

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Article information

Article history
Received: 14/09/2020
Accepted: 20/02/2020
Available online: 31/03/2020

Keywords
Wild goat
Kouh-Sefid
Hunting Prohibited Area
Habitat suitability modeling
maxent

Abstract

Understanding habitat requirements and distribution of species is critical to their effective management. Kouh-Sefid Hunting Prohibited Area (KHPA) with an area of 983 km^2 is located in Tehran Province, the Capital of Iran. Wild goat inhabits mountainous parts of this area. To assess the role of KHPA in the conservation of this vulnerable species, we applied a maxent habitat suitability modeling approach to relate the presence of wild goat to environmental variables representing topographic and anthropogenic characteristics of the area. Results indicate that the distribution of Species is positively related to elevation, slope, standard deviation of elevation, and slope. However, habitat suitability is negatively affected by roads and man-made structures. Finally, more than 34% of the area is suitable for wild goat, extending from east to west of the area. Considering the location of surrounding protected areas, KHPA could be a critical corridor for wild goat in the east of Tehran province.

1. Introduction

Understanding the habitat requirements of species is critical in their management. The habitats are considered the most important factors for protecting specie, especially endangered ones (Moradi *et al*., 2022). Habitat suitability modeling has incorporated the multivariate analysis and geographic information system to relate the distribution of species to their environment and therefore enhance our knowledge about their habitat associations (Guisan & Zimmerman, 2000). The results of these models are applied in various fields of wildlife studies such as conservation (Rodriguez-Soto *et al*., 2011), reserve planning (Tole, 2006), ecology (Marino *et al*., 2011), invasive-species management (Jarnevich & Reynolds, 2011) and reintroduction (Cassinello *et al*., 2006). Wild goat is one of the largest mountainous mammals in Iran (Ziaei, 2008) and is classified as vulnerable (IUCN Red List, 2013). This species inhabits 11 national parks, 11 wildlife refuges, and 48 Protected Areas (Darvishsefat, 2006). The major threats for wild goat are illegal hunting competition for food with livestock and habitat

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destruction (Genov *et al*., 2009, Weinberg *et al*., 2008). In Iran, poaching in various ways (shooting, trapping, and catching with dogs) is considered the main threat (Ziaei, 2008).

Wild goat habitat preferences are modeled in several locations in Iran (e.g. Sarhangzadeh *et al*., 2013; Shams-Esfandabad *et al*., 2010). This species is reported from the Kouh-Sefid Hunting Prohibited Area (KHPA). Hunting-prohibited areas receive the least conservation actions in Iran and are designated to areas with high potential to reach higher levels of conservation (Such as Protected Areas, W wildlife Refuge, or National Parks). KHPA is located in the east of Tehran Province, the capital of the country. The high population along with the high land price made this province severely susceptible to anthropogenic factors. Therefore, the conservation of remaining habitat through managing and protecting reserves plays an important role in the conservation of wildlife species in this province. However, little is known about the distribution and habitat preferences of wild goat across the KHPA. Moreover, KHPA is located among two other reserves which are habitats of wild goat. This increases the importance of KHPA as a potential corridor for populations of wild goat in these two areas. In this research, we developed a habitat suitability model using the Maxent approach (Phillips *et al*., 2006) based on occurrence records gathered in 2013 to achieve the following objectives: Understanding the habitat requirements of the species across the area. Determining suitable habitat distribution across the reserve and their effectiveness in the conservation of wild goat.

2. Materials and methods

2.1. Study area:

The study area covers 983 km2 of east of Tehran province. KHPA was designated as a Hunting Prohibited A rea in 2005. This reserve encompasses mountainous and flat areas in the east of Tehran. The elevation above sea level ranges from 1113 to 2643 m. Leopard Panthera pardus, wild sheep Ovis orientalis, and wild goat Capra aegagrus are the largest mammals inhabiting this area. Dominant vegetative forms of grasses and shrubs cover the KHPA. The main anthropogenic activities are farming and developing urban areas (Department of the Environment, 2012).

Table 1. Name and area of reserves located inside and around the Tehran Province

Code	Reserve name	Area (km^2)
1	Alborz Markazi Protected Area	399321.49
2	Lar Hunting Prohibited Area	455.3
3	Lar National Park	280.6
4	Varjin Protected Area	270.4
5	Jajrood Protected Area	758.0
6	Khojir National Park	99.7
7	Sorkhe Hesar National Park	92.0
8	Kouh-Sefid Protected Area	983.1
9	Kavdeh Hunting Prohibited Area	769.1
10	Kavir Protected Area	2487.2

A comparison of reserve areas inside and around Tehran Province (Fig. 1) indicates that KHPA stands in third place based on area (Table 1). It is also located between Jajrood and Kavdeh reserves and fills the gap between these areas.

2.2. Location data:

We recorded the localities of direct observations of wild goat across the KHPA during field surveys conducted across the reserve from the fall of 2012 to the end of summer 2013. The surveys were carried out at 1-month intervals in predetermined routes randomly selected from available routes throughout KHPA. These routes permitted a clear view of all slopes and aspects and crossed most of the potential habits of wild goat (Based on interviews with game guards and experienced local people). Surveyed routes varied from 15 to 27 km long, and each survey entailed 6 to 10 hours of observation. The same team of observers traveled all the routes on foot or by vehicles at low speeds. Therefore precise observation of the surrounding habitats was possible. In each season (spring: April-June; summer: July-September; fall: October- December; winter: January-March) sampling without replacement approach was applied (by excluding randomly selected routes previously surveyed in that season).

The coordination of the location of wild goat observations was recorded. As far as nearly all of the locations of wild goat observation were not accessible (Steep slopes), in each observation the coordination of the observer, the distance, and the compass bearing of the goats from the observer were recorded to extract the exact location of observation from a digitized 1:50000 topographic map of the area. For each group of wild goats only one point was recorded. For a large and/or scattered group, the center of the group was selected. Exact counting of herds was not possible for all groups. Therefore, we did not perform any analysis on the group size of wild goat. At the end of surveys, 31 observation records were gathered (Figure 2). Some observations could be due to a low population size of wild goat in KHPA (100 – 150 individuals based on estimations made by wildlife guards). The low sample size led us to develop a single habitat suitability model for all the years instead of seasonal models.

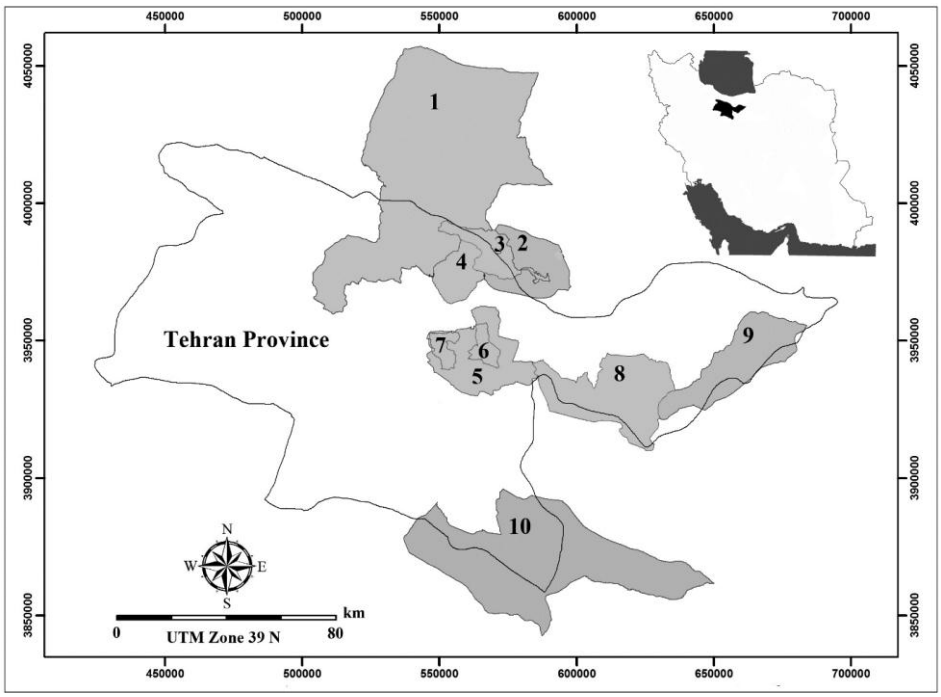

Figure 1. Location of KHPA (No. 8) among other under-protection areas in Tehran province (description and name of reserves are presented in Table 1).

The spatial and temporal autocorrelations are frequent in species distribution studies and may bias estimates made in this research (Legendre, 1993). To confront this problem we decided to keep locations that could only be related to one wild goat home range. However, there was no estimation of the wild goat home range. Therefore we considered the home range estimated for big horn as a minimum of 0.8 km2 (Geist, 1971) and used 1 km2 as the minimum possible home range for wild goat. Then, we checked for the data points located inside each 1 km2 to remove redundant points to lower the spatial autocorrelation. However, there was only one point inside each squared kilometer and we kept all the data points in the analysis. The one-month interval between each of the two subsequent surveys lowered the temporal autocorrelation.

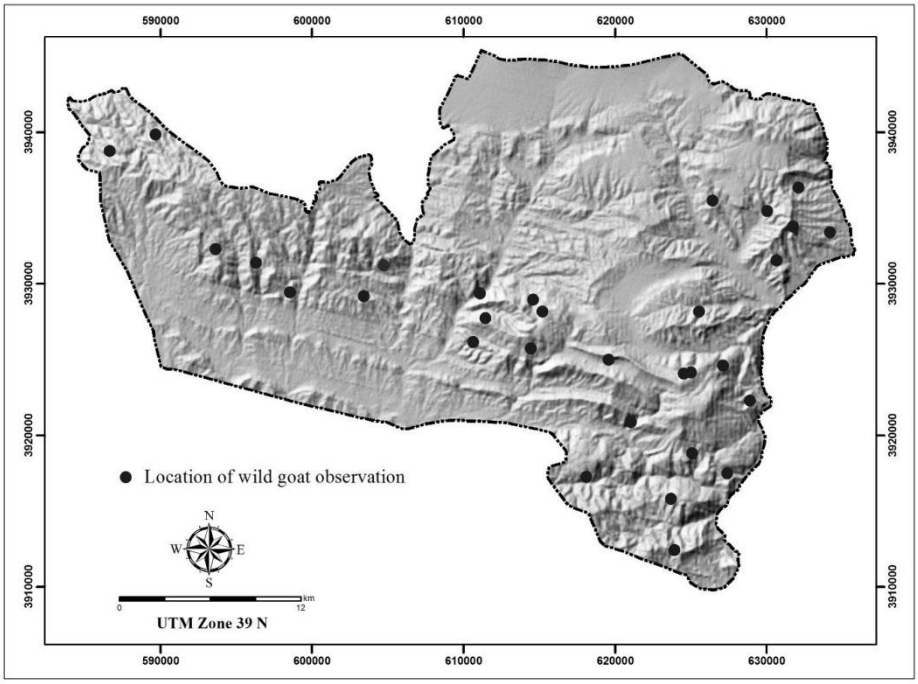

Figure 2. Hillshade map of the study area and location of wild goat observations

2.3.Habitat variables:

Several studies suggest that wild goat presence is affected by topographic ruggedness and the severity of development near and inside the reserve (e.g. Ziaei, 2008, Shams-Esfandabad *et al*., 2010). We incorporated eleven variables capturing variations in topography and anthropogenic factors across the study area in the model. The correlation between variables was considered using the Pearson correlation coefficient. No correlation coefficient was higher than 0.6. Therefore, we entered all the variables in the analyses (Table 2).

To study the effect of variations in slope and elevation, the standard deviation of these variables was calculated in an area equal to the wild goat guessed home range around each pixel of the habitat. The land use data: rivers, roads, settlements (cities and villages), and farms were digitized from 1: 50,000 maps. Then, the distance map for each of these layers was calculated. To account for the effects of anthropogenic sources adjacent to the boundary of KHPA, all the human sources located in a 5-kilometer buffer from the boundary of the study area were considered in the distance calculation. All habitat variable maps were produced using ArcGIS

(Ver.10). All maps were in raster format with a 100 x 100-meter pixel size so that each pixel would represent 1 hectare.

Table 2. Habitat variables used in modeling wild goat habitat in KHPA

Variable Name	
Elevation	Elevation for each 100-m pixel
Elevation (SD)	Standard deviation of slope calculated in an 1 km^2 circle around each pixel
Slope	Slope (degree) for each 100-m pixel
Slope (SD)	Standard deviation of slope calculated in an 1 km^2 circle around each pixel
Cosine of Aspect	Cosine of aspect varying from -1 (south) to +1 (north)
Sine of Aspect	Sine of aspect varying from -1 (west) to +1 (East)
Distance to road	Distance from nearest road for each 100-m pixel
Distance to village	Distance from nearest village for each 100-m pixel
Distance to river	Distance from nearest river for each 100-m pixel
Distance to city	Distance from nearest city for each 100-m pixel
Distance to farm	Distance from nearest farm for each 100-m pixel

2.4. Statistical model:

The maximum Entropy (Maxent; Phillips *et al*., 2006) approach was applied to observation records of wild goat to develop a habitat suitability model. Maxent requires few presence points to construct applicable models (Baldwin, 2009) and therefore is suitable for our study. MaxEnt software version 3.3.3k, www.cs.princeton.edu/~schapire/maxent/, was used to perform the maxent analysis. Model results were evaluated using a suitability threshold independent index, Receiver Operating Characteristic (ROC) analysis, generating the Area Under the Curve (AUC) measure of model fit where a random model would have an AUC value of 0.50 (Liu *et al*., 2009).

A suitable habitat map was classified based on the threshold maximizing the sum of sensitivity and specificity (as suggested by Jimenez-Valverde & Lobo, 2007) which are respectively the proportion of presence points and the proportion of background points (random points chosen from the study area by the software) predicted correctly by the model. The suitable patches larger than the guessed wild goat minimum home range size were depicted and were analyzed by the index of perimeter to area (P/A) ratio as an index of shape complexity and susceptibility to human activities. A higher ratio means higher complexity and susceptibility (Turner *et al*., 2001).

3. Results

Excluding the variables with a percent contribution of 0 from analysis, we produced the final model with nine variables with acceptable AUC (Table 3). Considering the percent contribution and jackknife analysis, four variables of standard deviation of elevation, slope, standard deviation of slope, and distance to farm were the most important in the model. Jackknife results indicated that the standard deviation of slope presented the most information about the species' presence and this information was unique and not presented by other variables. Slope and standard deviation of slope were important predictors and explained a large amount of information about the distribution of wild goat. However, other variables could present their information (see Table 3). The suitability threshold of 37.3 percent was used to classify the suitability map. As a result, 34% of the reserve was classified as suitable. However, the suitable habitats were highly patchy (Table 4).

Table 3. Percent contribution of environmental variables in wild goat habitat suitability model and AUC for ROC.

Environmental variables	Percent contribution
Elevation	81.7
Sine of aspect	5.4
Distance to road (m)	5.2
Elevation	1.3
Distance to city (m)	0.5
Slope	0.3
AUC	0.86

Therefore, to assess the capability of suitable habitats in sustaining the wild goat population patches larger than 1 km2 were identified (Fig. 4). As a result, there were eleven suitable patches with an area greater than 1 km2 (Table 5). They comprised 94.4% of the total suitable habitats across the KHPA.

Table 4. Descriptive statistics of suitable and unsuitable patches for wild goat in KHPA

Patch suitability	Patch Frequency	Min Area (km^2)	Max Area (km^2)	patch Area (Mean)	patch Area (SD)	patch Area (Sum)	Percent of KHPA
Suitable	*3854*	*0.06*	*180.8*	*0.09*	*3.2*	*335.8*	*34.2*
Unsuitable	*30026*	*0.06*	*531.5*	*0.02*	*3.1*	*646.6*	*65.8*

Three patches (numbers 5, 6, and 11: see Fig 4) were larger than 47 km2 and covered the middle and east of the KHPA. These patches with a total area of 299.4 km2 consisted of 89% of total suitable habitats and 30.4% of KHPA. Considering (P/A) ratio, these patches were relatively less susceptible to human activities in comparison with smaller patches (see Table 5).

Table 5. Characteristics of suitable habitat patches larger than 1 km2across the KHPA

Patch No.	Patch area (km^2)	% of KHPA	Patch perimeter (km)	Perimeter/Area (P/A) Ratio	(P/A) rank
1	*3.2*	*0.3*	*55.6*	*17.4*	*6*
2	*1.0*	*0.1*	*22.0*	*22*	*9*
3	*5.0*	*0.5*	*89.6*	*17.9*	*7*
4	*3.1*	*0.3*	*71.0*	*10.8*	*2*
5	*71.2*	*7.2*	*1085.2*	*15.2*	*5*
6	*47.3*	*4.8*	*547.6*	*11.6*	*3*
7	*1.4*	*0.1*	*39.7*	*28.4*	*11*
8	*1.4*	*0.1*	*31.6*	*22.6*	*10*
9	*1.5*	*0.2*	*30.8*	*20.5*	*8*
10	*1.5*	*0.1*	*22.9*	*2.0*	*1*
11	*180.8*	*18.4*	*2347.1*	*13.0*	*4*
Total	*317.0*	*32.3*			

Response curves for final model variables (Fig. 3) indicated that an increase in slope, standard deviation of slope, and standard deviation of elevation directly increased the habitat suitability for wild goat. However, the increase in elevation was positively correlated with habitat suitability to the elevation of 2250 meters. Moreover, wild goat prefer areas far from

cities and roads. However, after a 15-kilometer distance from the cities habitats became preferable for wild goat. Wild goat showed a tendency to northern and slightly western slopes (See Fig 3).

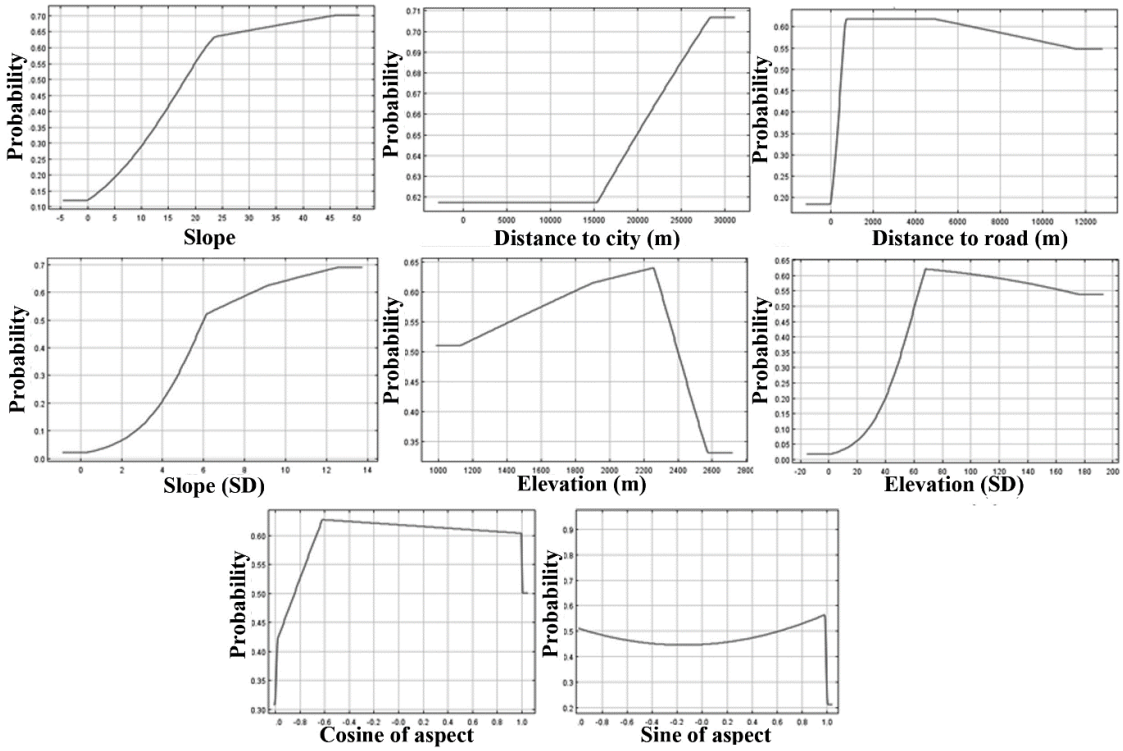

Figure 3. Marginal response curves showing how environmental variables affected the prediction of suitability for wild goat habitat.

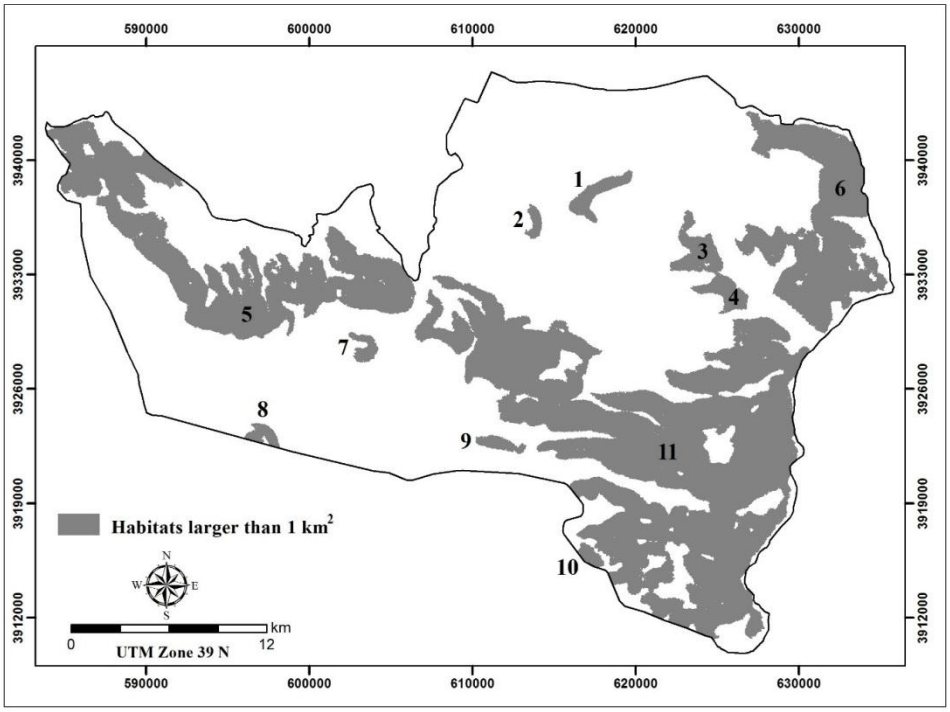

Figure 4. Distribution of suitable habitats larger than 1 km2 across the KHPA (areas and P/A ratios of these patches are presented in Table 5)

4. Discussion

Simply gathered field data and habitat variable layers of the study area led to a valid habitat suitability model which successfully presented the habitat selection and distribution pattern of wild goat across the KHPA. However, the low sample size prevented from differentiating the habitat associations of wild goat among seasons. A more intense study may achieve this goal. Nevertheless, considering the situation of the study area (High rate of human activities and low conservation status of KHPA) we decided to present the results of one one-year survey of the area. This may promote the conservation decisions regarding one of the few remaining habitats for wild goat inside the Tehran province.

Our findings about the habitat selection of wild goat approved the dependency of wild goat to high slopes and high elevations as suggested by several studies (e.g. Ziaei, 2008, Genov *et al*. 2009, Shams-Esfandabad *et al*., 2010, Sarhangzadeh *et al*., 2013). Wild goat are distributed mostly from 1200 to 2400 m above sea level in KHPA. However, Sarhangzadeh *et al*. (2013) reported 1400 to 2800 elevational range suitable for wild goat. This could be due to the colder climate of KHPA in comparison with their study area located in arid parts of Iran. Moreover, we suggested that variations in elevation and slope could be important predictable factors for the habitat suitability of wild goats.

The model indicates that anthropogenic factors especially urban development have not considerably affected the distribution of wild goat (low percent contribution and jackknife result for distance to city variable). This may be due to the dependency of wild goat on high slopes with high variations in elevation. These areas are potentially unsuitable for human activities. The distribution of suitable patches indicates a high conservation value of KHPA as it nearly attaches to the two neighboring reserves (Jajrood Protected Area and Kaveh Hunting Prohibited Area: see Fig 1 and Table 1) which are reported to be inhabited by a wild goat. However, further discussion about the role of KHPA as a corridor should be based on the analysis of suitable habitat contributions across these two neighboring areas. Moreover, there is no study conducted about the estimation of the home range size of wild goat in Iran. Understanding the home range size could be useful in the proper assessment of suitable patch capability in sustaining current and or potential populations of wild goat in KHPA. Finally, considering the high rate of urban development in Tehran province and consequently inside and around the study area, we suggest that at least, suitable habitat patches extended from east to west of KHPA should be considered to achieve a higher rate of conservation in decisions made by Department of Environment about the future of this area.

Acknowledgments

This research project was funded by Islamic Azad University, Damavand Branch. We also appreciate the Iran Department of Environment particularly the Tehran provincial office, for providing logistical support for this study. We thank the game guards of Kouh-Sefid Hunting Prohibited Area, for their assistance in the field.

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