



Habitat suitability modelling of Persian squirrel (*Sciurus anomalus*) in Zagros forests, western Iran

Farzaneh Khalili, Mansoureh Malekian*, Mahmoud- Reza Hemami

Department of Natural Resources, Isfahan University of Technology, Isfahan, Iran.
*email: mmalekian@cc.iut.ac.ir

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Abstract

Habitat is one of the key parameters for species conservation and having adequate knowledge of the habitat requirements of a particular species is inevitable for developing conservation plans. In the current study habitat suitability of the Persian squirrel (*Sciurus anomalus*) was evaluated in four protected areas in southwestern Iran, using maximum entropy method (MaxEnt). We combined presence-only field data with nine environmental variables including aspect, slope, elevation, distance to river, distance to road, distance to village, climate type, landuse and vegetation types to map the species probability of presence and determine the factors limit its distribution. MaxEnt performed well at predicting the potential suitable habitats of the Persian squirrel with a mean AUC of 0.937. Results of the model indicated that landuse, climate type and distance from roads had the most contribution to the model performance. Persian squirrels have a strong preference for forests, therefore, land cover change due to human activities seems to be an important threat to the squirrel viability. Consequently minimizing anthropologic disturbances is required to maintain the number of Persian squirrels in the region.

Keywords: Species distribution model, Habitat Selection, MaxEnt, Oak forests, Zagros Mountains.

Introduction

Habitat destruction and degradation are widely regarded as the main threats to biodiversity. Habitat suitability modelling using geographic information system (GIS) and multi-variable statistical analysis has attracted growing interest as a helpful tool to map the distribution of organisms (Guisan and Zimmermann 2000, Seoane *et al.* 2003, Fourcade *et al.* 2014). Identifying factors effecting the probability of presence of a species and describe the relationship between species and its habitat are essential for an effective conservation program (e.g. Anderson and Martí 2004, Kumar and Stohlgren 2009). This information is often inadequate for many species, particularly in developing countries. An important step in obtaining this information is to develop models that identify potential suitable habitat for a species. Developing such models is cost-effective and valuable where this knowledge cannot be obtained through field surveys (Guinotte and Davies 2014). Several models have been developed for this purpose (Guisan and Thuiller 2005). Some modelling techniques need both presence and absence data and some others use presence-only data. Since non-detection of a species does not necessarily imply absence of the animal (MacKenzie *et al.* 2002), presence-only methods such as maximum entropy (MaxEnt) (Phillips *et al.* 2006) is commonly used for predicting the distribution of a particular species (Hernandez *et al.* 2006, Fourcade *et al.* 2014). MaxEnt needs a set of presence-only records and environmental variables to establish a relationship between species occurrence and

environmental conditions of the study area (Phillips *et al.* 2006). MaxEnt model is not sensitive to sample size and performs well with different sample sizes (Wisiz *et al.* 2008). This method has been found to have the greatest performance among many different modelling methods with good efficiency and valuable outcomes for the conservation and management of numerous species (e.g. Kumar and Stohlgren 2009, Stabach *et al.* 2009, Sarhangzadeh *et al.* 2013, Mirzaei *et al.* 2014)

The Persian squirrel (*S. anomalus*) is the only tree squirrel in the Middle East, distributed in Turkey, Azerbaijan, Iran, Iraq, Palestine, Jordan, Lebanon and Syria (Albayrak and Arslan 2006). The species is inhabiting oak-dominated forests of western Iran and is regarded as the key species of these forests. These forests have witnessed high level of deforestation and poaching (Yigit *et al.* 2012). Consequently, the species has vanished from many parts of its habitats and restricted mostly to protected areas. The main causes of forest destruction in this region include population growth, underdevelopment and locals' dependence on forests for their basic needs. Inadequate knowledge about the quantity and quality of the Persian squirrels' habitat hampers effective conservation planning and species management. Ecological information, in particular habitat suitability concerning the Persian squirrel is scarce. For example, in southwestern Iran, an ecological niche factor analysis (ENFA) has been conducted in Dena protected area (Aghtari 2014). ENFA (Hirzel *et al.* 2002) combines presence localities with environmental data (obtained from the study area), but it is not currently the best option to use for presence-only data. There are several studies which demonstrate that MaxEnt have a better performance than ENFA for the same data (e.g. Tittensor *et al.* 2009, Monk *et al.* 2010). Therefore, we used presence points of the Persian squirrel from four protected areas in southwestern Iran to investigate the environmental factors affecting the species probability of presence and to develop a habitat

suitability model that classifies the suitable and non-suitable areas.

Materials and methods

Study area

For the purpose of this study, we surveyed Kohgiluyeh and Boyer-Ahmad province in South western Iran. Based on the observation of *S. anomalus* during field surveys, information from the department of environment and observations of local people, four protected areas including Dena Protected Area (DPA), Eastern Dena Protected Area (EDPA), Khamin Protected Area (KPA) and Dill Protected Area (DLPA) were selected (Figure 1). These are mountainous areas with different climatic conditions. A very cold and humid climate is observed in DPA and EDPA, a cold and semi-humid climate in KHPA and a Mediterranean to semi arid climate in DLPA. Annual precipitation is also varied and ranged from about 700 mm in DPA and EPDA to about 400 mm in DLPA. The dominated vegetation type in the study area is forest dominated by oak (*Quercus brantii*), however other species including *Pistacia atlantica*, *Amygdalus scoparia*, *Acer monspessulanum*, and *Juniperus exelsa* can be observed on upper slopes.

Data collection

In order to run a presence-only habitat suitability model, two types of data, i.e. species occurrences and environmental predictors, are required. We collected presence points based on direct observation of species, its nests and indices of species presence (such as the remaining of partly eaten acorn) in different seasons from 2013 to 2014. In total 65 presence points including 22 points from DPA, 20 from EDPA, 16 from KDA and 7 from DLPA protected area were recorded as presence points of *S. anomalus*.

Habitat suitability modelling

The above collected points were transformed into CSV format for use in the MaxEnt model.

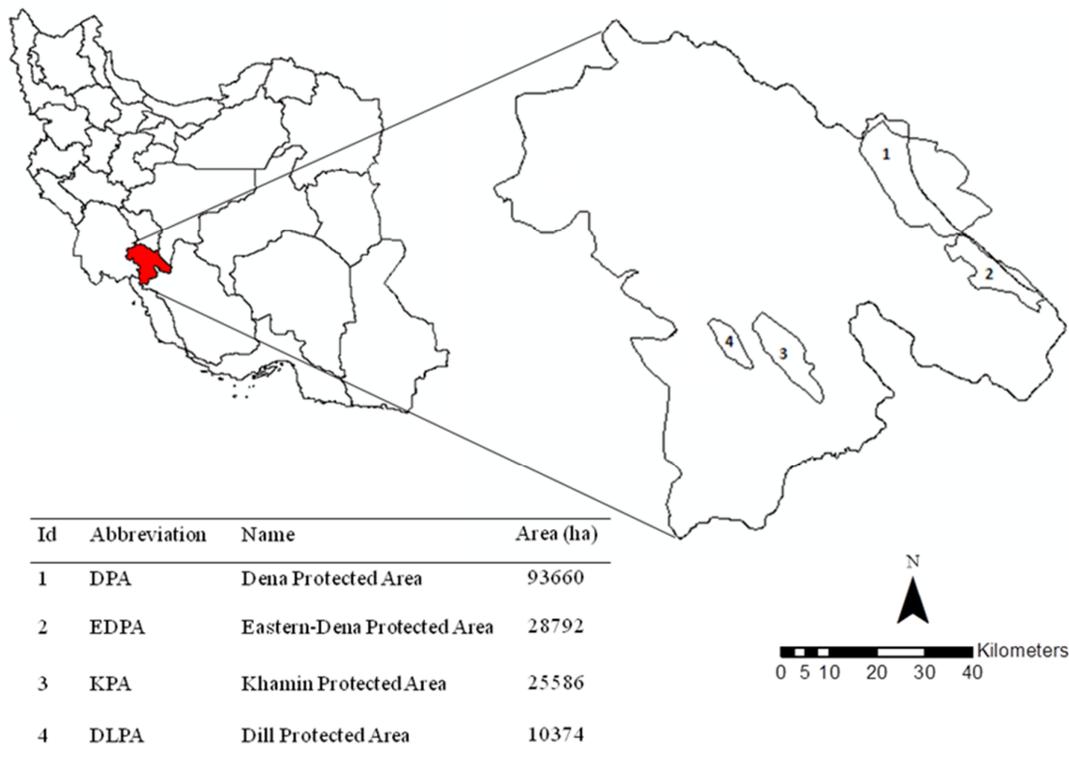


Figure 1. Geographical location and area (ha) of the four protected areas in Kohgiluyeh and Boyer Ahmad in south-western Iran used for habitat suitability analysis of the Persian squirrel.

We used independent environmental variables related to land cover types, topography, and climate, as the potential predictors of the Persian squirrel habitat distribution. These variables include proximal (landuse, vegetation types, distance to roads, villages and rivers) and distal (elevation, aspect, slope and climate type) variables.

Digital elevation model (DEM) with 30 meter resolution, obtained from National Cartographic Center of Iran (ncc.org.ir), was used to generate slope and aspect layers. Vegetation, landuse and climate classification maps were obtained from Forests, Range and Watershed Management Organization of Iran (<http://frw.org.ir>). Four climate types including semi-arid, Mediterranean, semi-humid and humid could be distinguished within the study area. The study area includes six vegetation types (medium quality pastures, high-quality and steep pastures, oak-dominated forests, hilly and mountainous pastures, non-irrigated

farmlands and irrigated farmlands) and nine landuse classes (agricultural areas, gardens, mixed farmlands and gardens, forests, mixed farmlands and forests, urban areas, rocky outcrops and water bodies).

We obtained road, river and village maps of Kohgiluyeh and Boyer-Ahmad Province from National Cartographic Center of Iran (ncc.org.ir) and distance metrics were calculated using the Euclidean distance analysis tool in ArcGIS 10.1.

Using SDMtoolbox (Brown 2014) to identify and remove highly correlated climatic variables showed that none of the variables were highly correlated ($r < 0.7$), therefore, all variables were included in the model. To avoid over fitting the test data, in all instances, a regularization parameter of 1.0 was used. The maximum number of iterations was set at 1000 or until the convergence threshold fell below 10^{-5} .

In order to assess variable importance, a jackknife procedure was applied. Furthermore, 25% of the samples were used for the evaluation of the model. Three methods including, cross-validation, bootstrapping, and subsampling, were employed to evaluate the model performance, and the model was replicated for 10 times. We utilized the MaxEnt logistic output (Elith *et al.* 2011) as the output type in the current research. Receiver operating characteristic (ROC) curves was used to assess model performance (Phillips *et al.* 2004). The area under the ROC curve (AUC) provides a single measure of model performance, independent of any choice of threshold (Phillips *et al.* 2006). As the output of MaxEnt is a probability of species occurrence, in order to produce presence-absence results a threshold value must be provided. We used the equal training sensitivity and specificity logistic threshold, which has been found to perform better than other commonly used thresholds (Liu *et al.* 2005).

Results

MaxEnt performed well at predicting the potential suitable habitats of the Persian squirrel. For the three model validation techniques: cross-validation, sub-sampling and bootstrapping, the AUC values were 0.89, 0.87, and 0.94 respectively. Since the AUC of bootstrapping was highest, we used this method for producing the final map of habitat suitability in the four protected areas. Using the equal training sensitivity and specificity logistic threshold, the model predicted about 28820, 11516, 6524 and 6224 ha of DPA, EDPA, KPA and DLPA respectively, as suitable habitats for the Persian squirrel (Figure 2).

The jackknife test (Figure 3) illustrates that the most important variables in the modelling were elevation, distance from roads, distance from rivers, climate type and landuse, while vegetation type had the least influence in the modelling process.

Evaluation of the percent contribution of each variable to the habitat suitability model (Table 1) indicated that landuse (32.2%) together with climate type (19.9%) and distance to road (19.4%) had the most contribution to the model performance, collectively contributing 71.5% to the model output. Vegetation type, aspect and distance to village proved to be important variables in the prediction, but with smaller individual contributions (7.4%, 6.7% and 6.3%, respectively). In total, the above six variables contributed about 92% to the model output, while the least contribution belonged to slope (1.5%) (Table 1).

Table 1. Percent contribution and permutation importance of environmental variables in the habitat suitability modelling of the Persian squirrel.

Variables	Percentage of contribution	Permutation importance
Landuse	32.2	5.5
Climate type	19.9	1.2
Distance from road	19.4	43.4
Vegetation type	7.4	7.9
Aspect	6.7	1.1
Distance from river	6.3	12.2
Elevation	3.6	23
Distance from village	3	2.3
Slope	1.5	3.4

Response curves of different environmental variables are shown in Figure 4. The model showed that Persian squirrels prefer to inhabit areas with humid, semi-humid, and mild dry climate. Amongst the landuse classes and vegetation types, the highest probability of presence was observed in forest class and oak dominated forests respectively. The aspect classes with the highest probability of presence were horizontal, south and west, while north and east aspects showed the lowest. A general decline in the probability of presence was observed for ascending distance from roads and villages (Figure 4.). In contrast, distance from river showed a positive response with the highest values of model observed at a 1157 m from rivers.

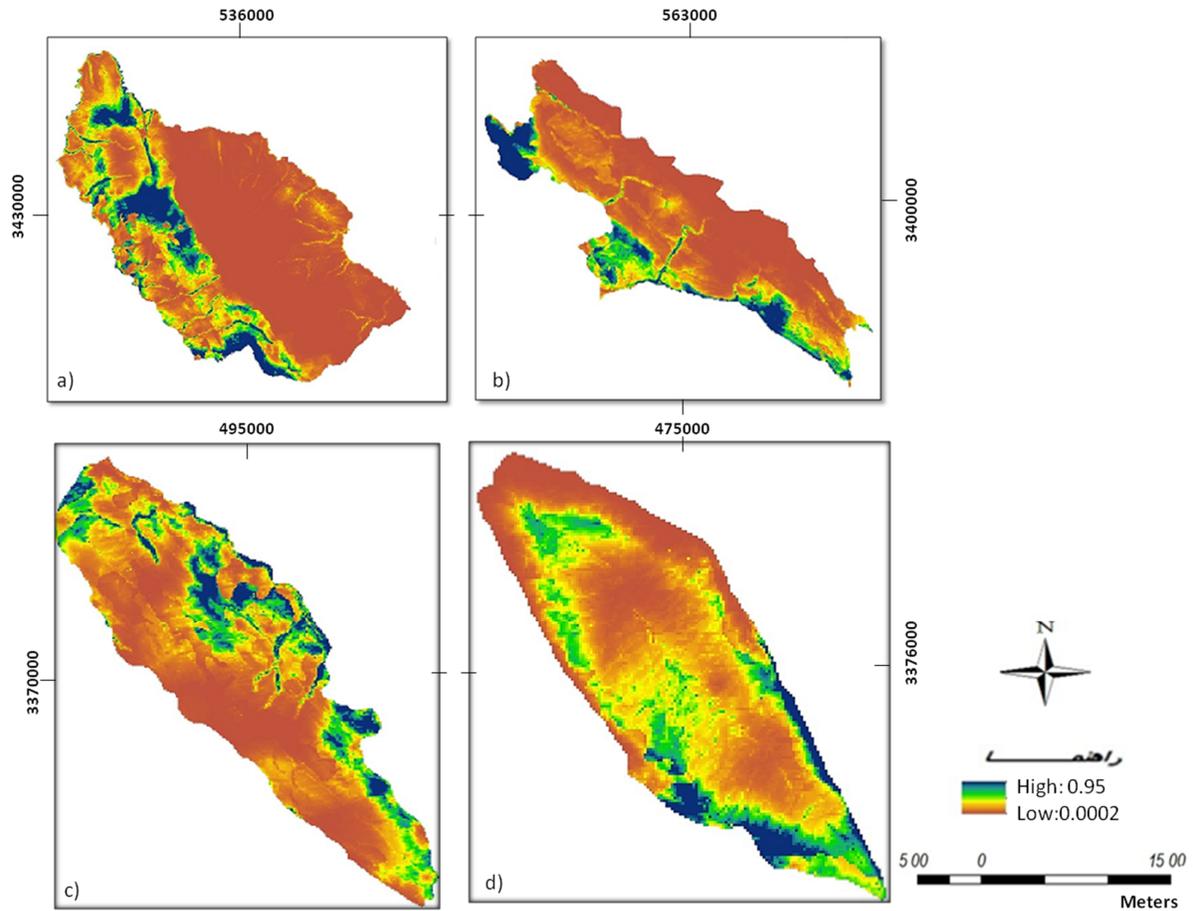


Figure 2. Predicted map of Persian squirrel distribution in Dena (a), Eastern Dena (b), Khamin (c) and Dill (d) protected areas in south-western Iran. Colors are indicative of the predicted suitability: blue indicates high probability of suitable conditions for the species, green indicates conditions typical of areas where the species is found, and lighter shades of red indicate low predicted probability of suitable conditions.

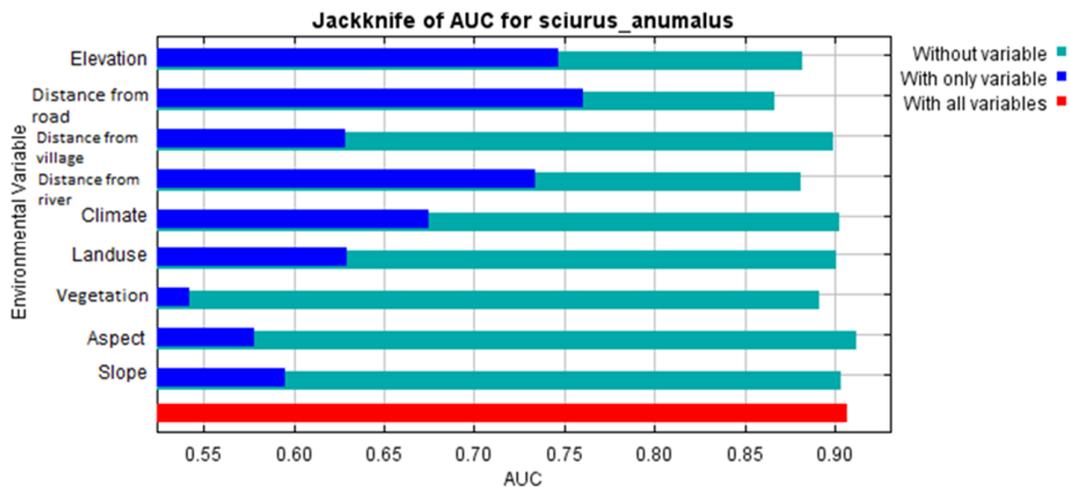


Figure 3. The results of the jackknife test of variable importance using bootstrap replications. Values are averaged over replicated runs.

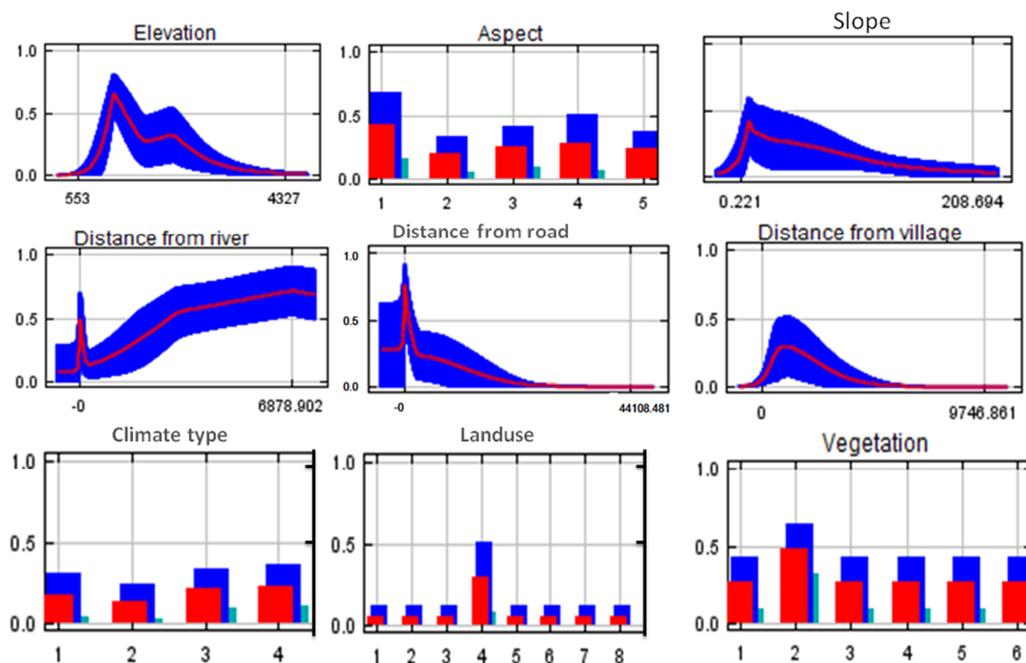


Figure 4. Response curves of the different environmental variables affecting the probability of presence of the Persian squirrel in southwestern Iran presented as means of 10 replicates with standard deviation. Values for aspect are (1) horizontal, (2) north, (3) east, (4) south, and (5) west. Climate types are: (1) semi-arid, (2) Mediterranean, (3) semi-humid (4) humid. Landuse classes are: (1) agricultural areas, (2) gardens, (3) mixed farming lands and gardens, (4) forests, (5) mixed farming and forests, (6) urban areas, (7) rocky outcrops and (8) water bodies. Vegetation types include (1) high-quality and steep pastures, (2) oak-dominated forests, (3) medium quality pastures, (4) hilly and mountainous pastures, (5) non-irrigated farmlands and (6) irrigated farmlands.

Discussion

In the current study, we used MaxEnt to evaluate environmental factors affecting the presence of Persian squirrels and predict habitat suitability of the species in four protected areas in southwestern Iran. Different model, larger area and a greater sample size of the current study compared to the previous research (Aghtari 2014) might have increased the accuracy of the developed model (Hernandez *et al.* 2006).

The model predicted that about 30, 40, 25 and 60 percent of DPA, EDPA, KPA and DLPA as suitable habitat for the Persian squirrel. However, MaxEnt can over-predict suitable habitats by including potentially suitable

isolated areas that are really not occupied due to limitations in specie's dispersal abilities (Pearson 2007, Muriene *et al.* 2009). The reasons for the absence of these animals in some suitable areas are not well understood. In other words, while the areas confirmed as suitable by the MaxEnt model are fundamental niche for the Persian squirrel, the squirrels have occupied the realized niche (Guisan and Zimmermann 2000).

Among the environmental variables, landuse seemed to play the greatest role in the distribution of the Persian squirrel. Persian squirrels have a strong preference for forests, preferably oak-dominated forests with old and tall trees (Ziaie 2009, Khalili *et al.* 2015).

These forests can provide the basic needs of the species. Therefore, forests destruction, which has been accelerated by bushfire and landuse changes in recent years, threatens the survival of the Persian squirrels. In addition, due to the symbiotic relationship between the Persian squirrels and oak trees, decreased number of squirrels can hinder the germination of oak trees and regeneration of Zagros forest (Ziaie 2009).

Climate type and distance from road were also significant factors in the habitat selection of the Persian squirrel. Persian squirrels seemed to inhabit areas with humid, semi-humid, and Mediterranean climate. Due to the relation between land cover and climate type, such trend was predictable (Wang *et al.* 2010, Mirzaei *et al.* 2014).

The Persian Squirrels' probability of presence decreased by increasing distance from roads. Persian squirrels in the region use cavities of large and mature oak trees for nesting (Khalili *et al.* 2015). Our observations proved that such trees are frequently found near roads. In addition, effects of roads on wildlife are associated with different factors such as road size and traffic volume (Forman 2006). Roads in this region are mostly narrow dirt tracks or fire roads instead of wide asphalt roads. These roads have infrequent traffic volume and low traffic noise and the species habitat might be less impacted. Paved roads such as highways with relatively high traffic volume have been shown to have substantial negative effects on species habitat (Fecske *et al.* 2002, Reynolds-Hogland and Mitchell 2007)

Based on our model, the relative habitat suitability of the Persian squirrels increases by increasing distance from rivers. Aghtari (2014) also found that density of squirrels was higher at a 2000 m distance from rivers. Squirrels are able to take moisture from food, dew on plants and succulent plant materials to satisfy water requirements (e.g. Yarrow 2009), therefore, the distance from surface water may be a less limiting factor in squirrel habitats (Allen 1987). In other areas such as Horsh Ehdn nature

reserve in Lebanon, however, Persian squirrels are frequently seen near water points (Abi-Said *et al.*, 2014), suggesting that the importance of free-standing water resources might be varied depending on the habitat conditions of a region. Aspect and elevation also proved to be important variables in this prediction, but with smaller individual contributions. Due to the presence of oak-dominated forests and greater heat in southern and western aspects and these aspects are the warmest the Persian squirrels tend to live in southern and western aspects (Rood *et al.* 2010).

In conclusion, the Persian squirrel is a forest dependent species in the region which its viability is threaten by land cover change due to human activities including, logging and clearing of forests for agriculture. It seems that successful management and conservation of this tree squirrel in the region will require that we increase our knowledge about this species and the impacts of habitat alteration on its viability. Consequently minimizing anthropologic disturbances in the habitats of the Persian squirrel are required if we want to have that species around for the next years to come.

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