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Evaluation of the effects of oak forest changes on Persian Squirrel *(Sciurus anomalus*) habitat selection

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Abstract

The Zagros region, with almost 5 million hectares of forest, accounts for about 40% of the total forests in Iran. The overexploitation of Zagros forests over many years has turned these valuable forests into sensitive and fragile ecosystems. Therefore, it is essential to plan for the future of forests based on their expansion trends over the past decades. The Persian Squirrel, a species of paramount significance among mammals in Zagros oak forests, plays a crucial role in the ecosystem. Acquiring comprehensive knowledge of the habitat needs of this species is imperative to formulate effective management policies aimed at its preservation. This study examined quantitative (surface and density) changes in the forests of Lorestan province using Landsat satellite images (1993–2022). The maximum disorder software (Maxent) was used to prepare habitat desirability maps of the Persian Squirrel. The classification was carried out using a supervised method, classifying educational samples, and using the normalized differential vegetation index (NDVI). The classification accuracy was 94% for TM imagery and 98% for OLI imagery, with Kappa coefficients of 86% and 98%, respectively. Forest and Non- Forest areas covered 560,955.072 and 2,268,422.076 hectares of the study area in 1993, respectively. For 2022, these amounts were 409,148.81 and 2,420,249.49, respectively. In total, a staggering 5.6% of the forest area in the study area has been destroyed in recent decades. The forest density change was estimated using the FCD model, with the highest values being 0–10% in the two periods. The results showed that the most suitable habitats for the Persian Squirrel were located in the south and southwest of the province (93% = AUC). The main variables affecting this species' habitat desirability included distance from rivers and precipitation during the driest three months of the year.

Keywords: habitat modeling, maximum entropy, vegetation cover, density

Introduction

Persian Squirrel (*Sciurus anomalus*) is a rodent and squirrel family whose primary habitat is the Zagros Oak Forests in Western Iran. The Persian Squirrels prefer tall and old trees over short, herbaceous ones. They play a crucial role in expanding and revitalizing these oak forests by collecting oak seeds and burying them beneath the soil (Khalili et al., 2017). Unfortunately, their population is threatened by the destruction of their habitat through human activities such as overgrazing, coal mining, mowing, collecting and selling oak seed, felling, and overhunting in most parts of Iran's oak forests, especially in central Zagros (Harington & Firouz, 1976). Considering the interaction of living creatures with their habitat, its destruction and alteration will naturally threaten these animals. Therefore, understanding wildlife's habitat and habitat needs can be very effective in protecting them and developing management plans. Determining changes using satellite imagery and aerial photography has become an imperative subdivision in forest science as a tool for monitoring and controlling all kinds of changes in the forest ecosystem (Singh, 1998). An accurate understanding of the trends in forest cover changes is crucial for different applications, such as resource management and environmental service assessment.

Various studies have delved into land cover/land use mapping and extensive forest land use changes using satellite imagery and products (Haghighi Khomami, 2004; Feritas et al., 2005; Bai al., 2005; Carreiras et al., 2006; Gizachew et al., 2016). Khalili et al., 2018 studied the suitability of the Persian squirrel (*Sciurus anomalus*) habitat in four protected areas in southwestern Iran using the maximum entropy method. According to the results, the most important factors affecting the presence of this species are the distance from roads, agricultural lands, and elevation. The mean area under the ROC curve (AUC) was 0.93, representing Maxent's optimal performance.

This study was conducted to bridge gaps in the literature and highlight the importance of studying the habitat of the Persian Squirrel.

Study Area

Lorestan province is located in western Iran, neighboring Markazi and Hamedan provinces to the north, Khuzestan to the south, Isfahan to the east, and Kermanshah and Ilam to the west. It lies in latitude 33.5818° N and longitude 48.3988° E, covering an area of 28.944 km^2. About 1.2 million hectares of Lorestan province are covered with forests, which make up the most valuable forest resource in the Zagros region. The main plant species in these forests is oak, which plays a vital ecological role and contributes to water and soil conservation (Fig. 1).

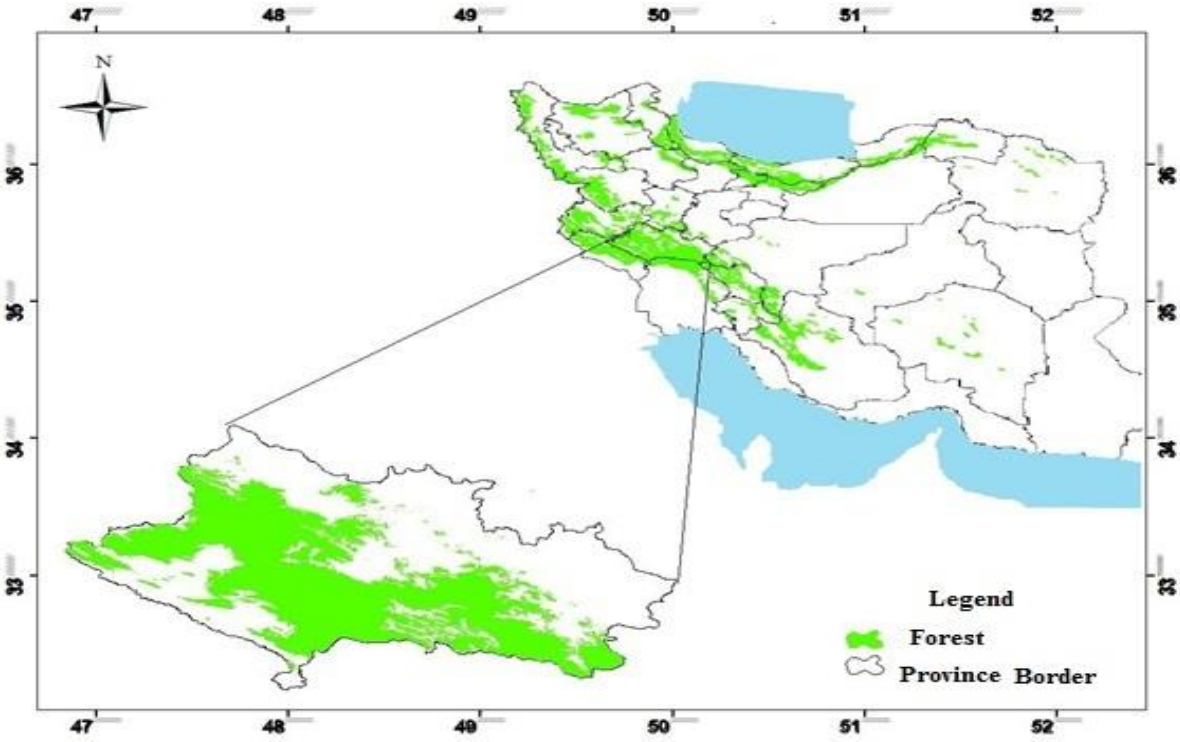

Figure 1. The location of forest areas in the study area

Material and methods

This study used images of OLI and TM sensors from Landsat 8 and 5 in June and July of 1993 and 2022. Four images were prepared for each period. Then, the maximum likelihood classification was performed after pre-processing the mosaic images by using ENVI software. A detailed map of the forest surface was extracted for 1993 and 2022 from available sources (satellite images) to investigate forest area changes. The images were obtained from the USGS website. Meanwhile, data on the distribution of squirrels was provided by Lorestan Environment Organization, which included 31 presence points. The climate maps used for assessing the habitat desirability were sourced from World Clime for the 1990–2020 period. Finally, the analysis was performed using seven climate

variables including annual rainfall (bio12), seasonal precipitation (bio15), precipitation of the driest three months of the year (bio17), average annual temperature (bio1), annual temperature changes (bio7), the average temperature of the coldest three months of the year (bio11), and the average temperature of the warmest three months of the year (bio10) as well as information layers of the slope, direction, elevation, river distance, and vegetation. The raster layer of the underground variables was prepared in ArcGIS 10.3 software and was pre-processed before input into Maxent. Considering the research area, all peripheral and climatic layers were masked and finally formed as ASCII and fed to Maxent for modeling. There are several ways to obtain forest changes, including using satellite imagery for image classification. The advantage of satellite imagery classification is showing the changes' location, type, and nature. Changes can be identified by combining the satellite-derived data with environmental factors in the GIS. Here, SPSS and QGIS were used to investigate the regression relationship between the species' presence points and other measured environmental variables to determine the effects of density changes and the forest canopy size.

Results

Classification accuracy indicates the level of confidence in the generated map. Meanwhile, the kappa coefficient shows the accuracy of the classification compared to a random classification. The verification was performed by selecting the areas that were assumed to be in the forest based on the verification points. Kappa and overall accuracy were determined with high accuracy (Table 1).

Table 1. Assessment of image accuracy (1993 and 2022)

kappa Coefficient	Overall Accuracy	Image
86.27%	94.32%	1993
98.08%	98.66%	2022

The changes in forest area were extracted by comparing the maps obtained from the 1993 and 2022 images to determine forest and non-forest areas in the two data series over the 24-year survey

period (Fig. 2). Overall, results show that 5.6% of the forest area is destroyed. This decrease is mainly seen in the western part of the province.

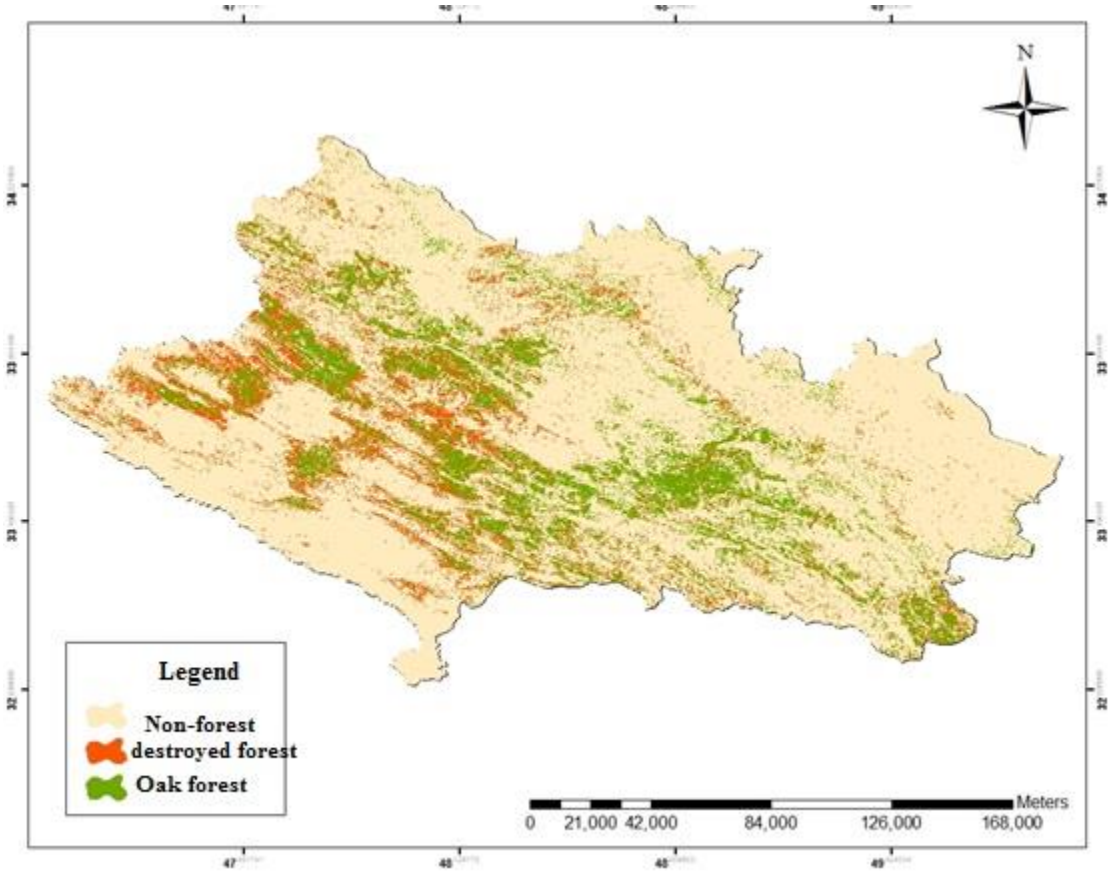

Figure 2. Map of forest changes in the study area

After calculating the density and determining the changes (Fig. 3), the density was calculated. A comparison of the obtained densities in two periods (Fig. 4) showed that the highest forest mass changes in 2022 compared to 1993 were in F2 (10–105%) and F3 (35–25%) densities. These changes were negative. F1 density (0–10%) had the highest percentage in the two periods under review.

To evaluate the model's capability, the produced canopy density classification map was compared pixel by pixel with the ground reality density classification map. The validity and kappa coefficient for 1993 were 0.96 and 0.93, respectively. The overall accuracy and kappa coefficient obtained from the forest canopy density classification for 2022 were 0.81 and 0.91, respectively. The model was able to estimate density successfully.

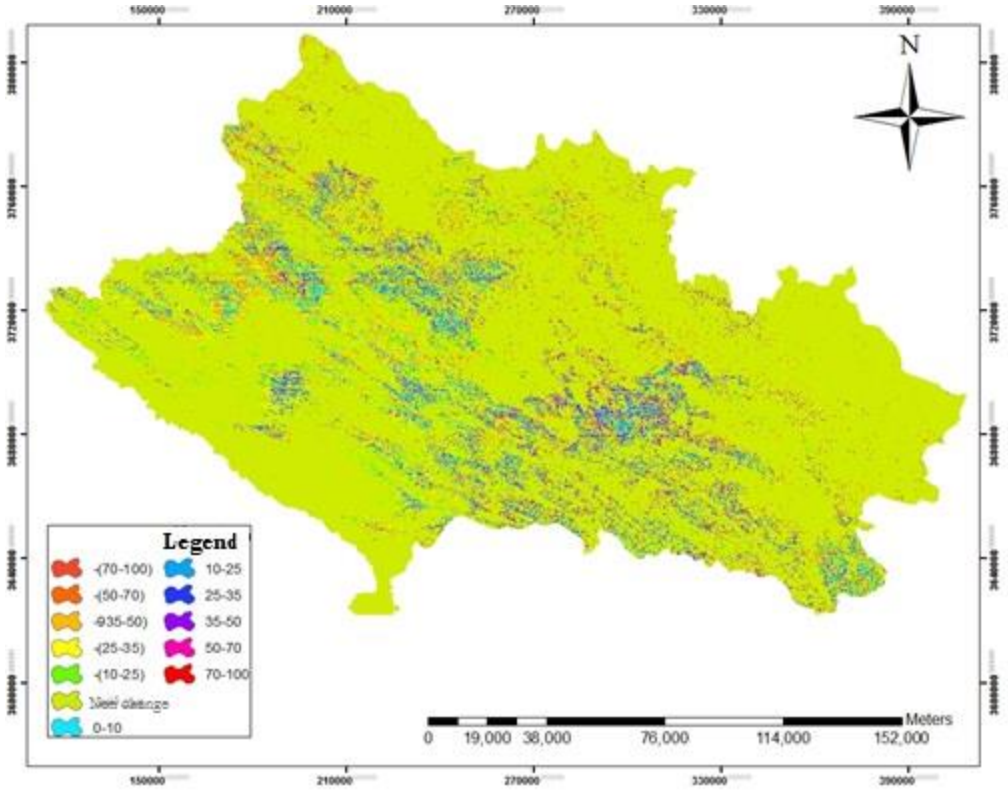

Figure 3. Map of forest density changes in two periods (1993 and 2022)

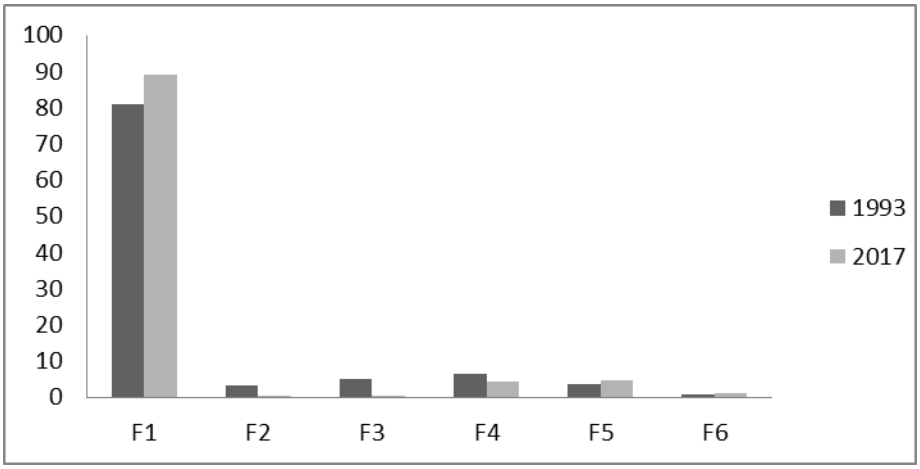

Figure 4. Changes in forest density in two periods (1993 and 2022)

By introducing 12 environmental layers and squirrel presence points to MaxEnt, the final map of the area was generated. The habitat suitability was between 0 and 1 (red = one & blue = zero). The most desirable location is in the southern and southeastern parts of the province (Fig. 3-6).
Figure 6 shows the model's capability in predicting the Persian squirrel habitat, with an AUC of about 93%, which indicates its excellent predictive power.

Figure 5. Habitat map of Persian squirrel in the study area

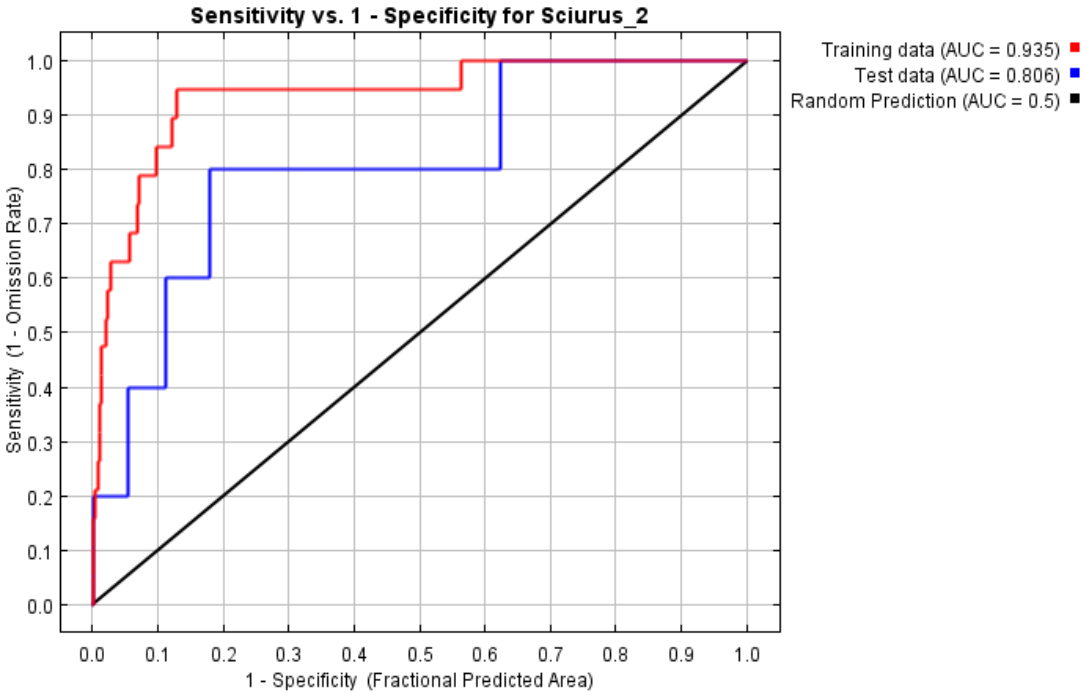

Figure 6. ROC curve diagram.

Based on the relation of the density map and the desirability map, the classification results showed that the first class had the highest density as it covered a larger area in the study area than other classes. However, given the variable area size of the classes, it is necessary to obtain the same unit for all classes, preferably as a percentage. The desired habitat area in each class was converted to percent to determine the habitat occupancy. The fourth and fifth classes were more desirable because they accounted for a larger percentage of the class area. The habitat suitability map by MaxEnt showed that the most suitable squirrel habitats were located at altitudes of 1500 to 2000, which also had desirable (i.e., medium) densities. Given that there are no significant changes in these areas, it can be concluded that these are suitable habitats for the Persian squirrel. The map of desirable habitats can be seen in Figure 7.

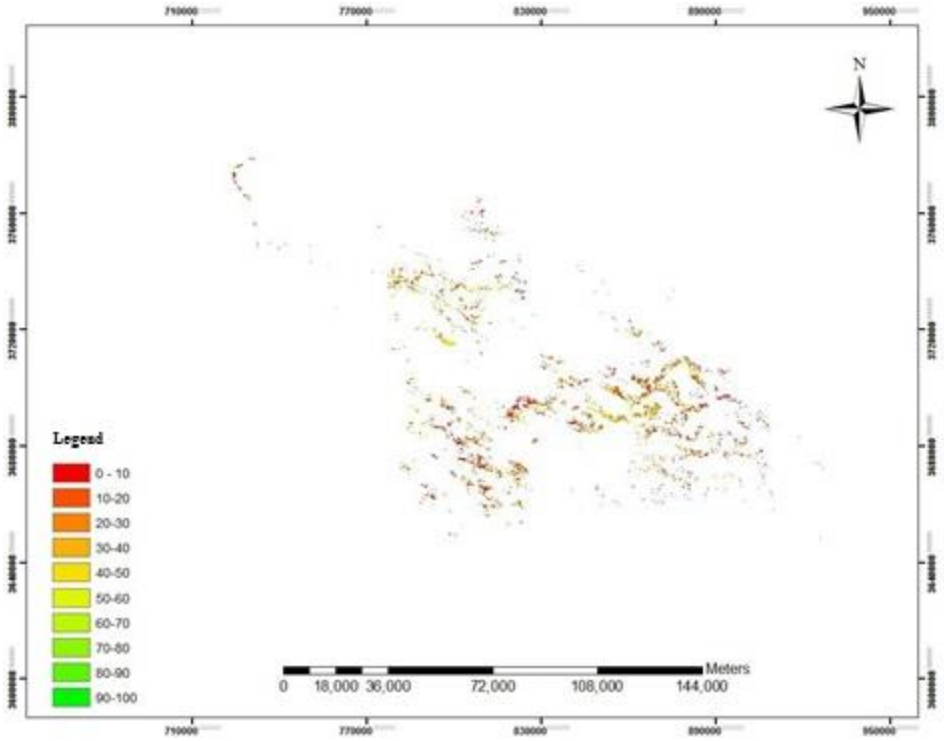

Figure 7. Desirability map of Persian squirrel distribution in different densities

Regression analysis (logical regression) between species presence points as a dependent variable and tree density in different classes shows that the Persian squirrel is dependent on high forest density (Table 2).

Table 2. Results of logistic regression analysis for habitat use.

Variables	β	Standard deviation	Wald	Sig.	Exp(β)	R^2
High vegetation density	0.346	0.085	18.17	>0.005	1.133	-
Medium vegetation	0.156	0.036	12.15	>0.005	0.551	0.931
D.f watersheds & rivers	0.121	0.061	9.13	0.005	1.214	
D.f open areas without trees	0.013	0.01	3.17	>0.005	1.320	

By excluding 25% of the presence and absence data, and implementing the model using the remaining 75%, the overall accuracy index showed that the model can predict at least 94% of the presence and absence points not included in the model.

Conclusion

This study aimed to assess the changes in forest area and density in Lorestan province over 24 years using Landsat satellite images (TM and OLI) to examine the relationship between the Persian squirrel habitat and forest changes. The multi-time NDVI index was used to determine the changes in vegetation. Next, the maximum probability method was used for classification. The validation results showed the high accuracy of the maximum probability classification method. The results of surface changes showed that in total, the province has lost 5.6% of its forest area, mostly in the western parts. The FCD model was used to determine forest density. The model results showed that the highest forest density was 0–10%. The desirability of the Persian squirrel habitat was well predicted using the Maxent model. The desirable habitats were located in the southern and southeastern parts of the province, with the most desirable habitat located in medium densities. Considering the relationship between habitat and oak forest density using logistic regression, it was found that the density of tree cover plays an important role in the use of habitat by squirrels and that the Persian squirrel is dependent on high forest density.

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