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GIS AS A TOOL TO MAP HABITAT SUITABILITY FOR TWO LIZARD SPECIES USING ENVIRONMENTAL FACTORS

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ABSTRACT

Reptiles are key components of Mediterranean ecosystems. Climate change, forest management practices, agricultural activity, land degradation and forest fragmentation represent the greatest threats to reptiles. Therefore, efficient tools are necessary for monitoring these vulnerable species. Habitat suitability maps have been found to be valuable tools for the monitoring of reptilian species and conservation, particularly across broad landscapes. This study was undertaken to determine the relations between two species of lizard, *Stellagama stellio* (Agamidae) and *Ophisops elegans* (Lacertidae) and environmental variables in the Isparta-Sütçüler district (Turkey). Habitat suitability maps were then produced. The relationship between the two species and 21 environmental variables were analyzed using MaxEnt and mapped with ArcGIS. The study showed that bedrock, annual precipitation, slope, ruggedness, stream density, topographic position index, land cover/use classes and altitude are predictor variables for modelling *Stellagama stellio*. The environmental factors that create the optimum habitat suitability model for *Ophisops elegans* were bedrock, annual precipitation, slope, ruggedness, landform index, land cover/use classes and stream density. In conclusion, we found that environmental variables and geographic information systems can successfully be used to generate habitat suitability maps for *Stellagama stellio* and *Ophisops elegans*.

KEYWORDS:
GIS, Habitat suitability maps, Lizard, MaxEnt, Species distribution.

INTRODUCTION

Habitat suitability maps are highly influential tools for determining conservation priorities for decision makers when managing wildlife [1-2]. Species distribution models (SDM) created by geographic information systems (GIS) are used to estimate the probability of presence of a species at a given location as a function of environmental variables (climate, topographic etc.) regarding that location [3].

A species distribution model is implemented by running models over a designated landscape using environmental variables. This is done in order to predict the probability of a particular species occurrence thus enabling the production of a habitat suitability map for the targeted species. The statistical methods such as logistic regression and differential function analysis are mostly used for this purpose. However, these methods are run with presence-absence data of the target species. Broadly speaking, presence data is generally more reliable than absence data. Studies showed that the new approaches, such as Bioclimatic modelling (BIOCLIM [4], DOMAIN [5]), Genetic algorithm for rule set production (GARP: [6-7]) and Maximum entropy (MaxEnt: [8]), which only work with presence data, provide more reliable and accurate results for species distribution models. The application of MaxEnt for analysis is a preferred method in species distribution models because it gives more accurate results with less sample data than other methods [8-10].

Reptiles are ectotherm organisms; therefore they often have limited climatic tolerance and are strongly dependent on climatic conditions. Climatic changes may potentially cause differences in habitat structure in the future. The ability to predict the potential distribution of reptilian species under climate change is crucial in order to achieve a greater understanding of the future evolution of ecosystems – in particular Mediterranean ecosystems. Accordingly, habitat suitability maps can be extremely useful in predicting the distribution of critical species and monitoring future habitat differences [11-14].

There are 62 known species of lizards in Turkey [15]. Two of these species *Stellagama stellio* and *Ophisops elegans* were found to be distributed in our study area and detected as our target species for habitat suitability modeling. *Stellagama stellio*, rough-tail rock agama, first described by Linnaeus in 1758 as *Lacerta stellio*. The distribution areas of *S.stellio* are Greece, Turkey, Syria, Lebanon, Northwest Iraq, Northern Saudi Arabia, Cyprus, North and West Jordan, Israel and Northern Egypt [15-16]. *Ophisops elegans*, snake-eyed lizard described by Ménétriés in 1832, distribute throughout Bulgaria and Northern Greece, Turkey and South-Western Asia and North Africa [15, 17-18].

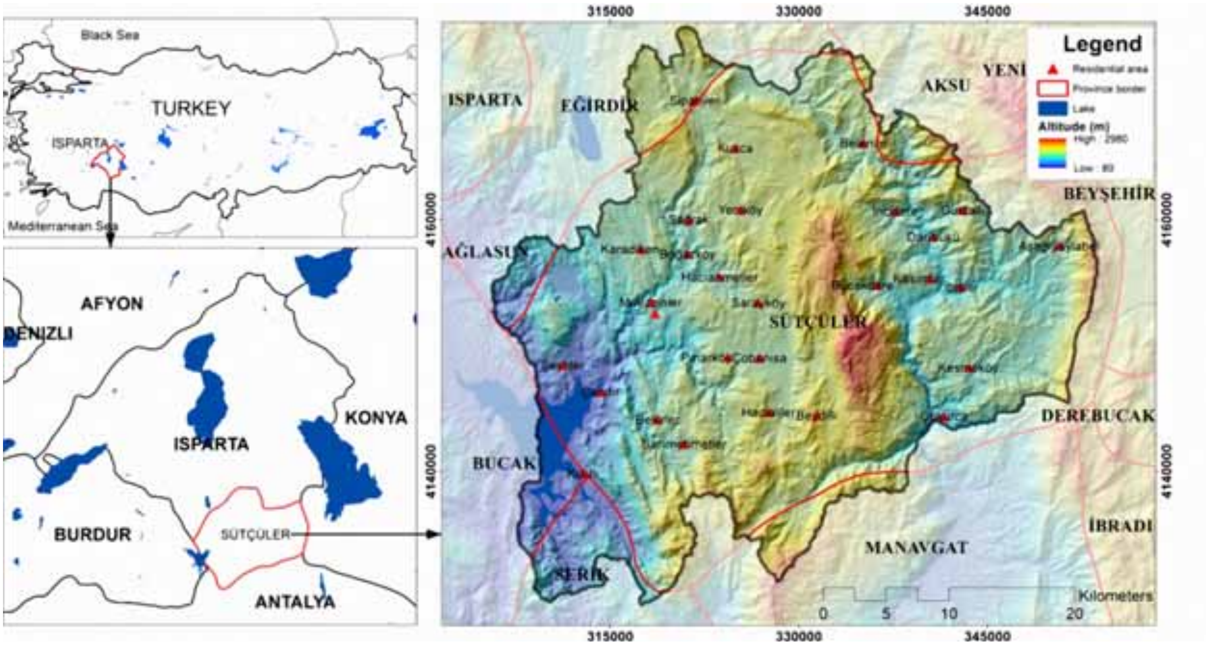

FIGURE 1
Location of study area in Mediterranean region, Turkey

This study aims at to determine the relations between *S. stellio* and *O. elegans* and environmental variables in the Isparta-Sütçüler district (Turkey), and to generate habitat suitability maps for the two species using MaxEnt.

MATERIALS AND METHODS

Study Area. Sütçüler district has been selected as study area due to the diversity of forest structures that can be found in the region such as; elevation steps, slope groups and aspect. The study area is located between 37° 29'17'' N latitude and 30° 59'46'' E longitude; with elevation ranging between 80-2980 m. The district is affected by continental and Mediterranean climates. The average annual precipitation is 950.1 mm, with the driest and hottest months being between July and August. The average annual temperature is 14.1ºC, ranging between 0º-50ºC and humidity 4 -57% (Fig.1).

Species Data. This study was carried out between May-October 2014 with a total of 251 sample plots. The study area was divided into 100 × 100 m sized cells. We wanted to give the same scale as all the environmental variables obtained as cellular data of 100 × 100 m in size. We recorded 146 presence data for *S. stellio* and 38 presence data for *O.elegans*.

Bioclimate and Environmental Data. In total 47 climatic and environmental data were used as predictors variables. Nineteen climate data were obtained from WorldClim data set [19]. The bioclimate data downloaded in "ascii" format on the world scale was then edited for the study area. The slope, aspect and altitude maps of the environmental variables were produced using the digital elevation model (DEM). The digital elevation model of the area was created with the use of 1/25000 scale topographic maps. In order to form a dataset for the stream density, the streams on the digitized topographic map were first drawn as a vector. The line density in ArcGIS 10.2 was calculated by considering the density and the distance of 2000 m around the line [20].

Topographic position index, landform index, roughness index, hill shade index, topographic wetness index, solar radiation index, ruggedness index and solar illumination index (6 am, 8 am, 10 am, 12 noon, 2 pm, 4 pm, 6 pm, 8 pm, total solar illumination index) were created using ArcGIS 10.2 software with the "topography tools" plugin. Using the formulas; Aspect favorable index (AFI), radiation index (RI), heat index (HI) values were calculated and "ascii" formats were obtained in ArcGIS 10.2. The equations for these indices are as follows;

$$AFI = \cos(A_{max} - A) + 1 \qquad (1)$$

In the above equation, A_{max} refers to 202.50, and A refers to the aspect. Aspect values were taken in radians. The values obtained as a result of this equation range from 0 - +2.

$$RI = \frac{[1 - COS((\pi/180)(Q-30))]}{2} \qquad (2)$$

Here, Q represents the value of the aspect. RI values range from 0 - +1. In the north-northeast areas, values approach 0 whereas in the warmer and drier south-southwest areas they approach +1 [21-24].

HI (Beer) = (cos(Amax-A)+1) x tan(slope) (3)

A_{max} refers to 202.5^0, and A refers to the aspect. 202.5^0 represents the warm south direction and is assumed to be the largest heat load on the southwest facing slopes. HI (Beer) values range from 0 to +2 [25-28].

Different bedrock types are shown as polygons on the digital bedrock map. In total, categorical data of 22 bedrock types were obtained. Numerical stand maps of the study area were used to obtain land cover/use classes data. The divisions within the map were classified as five different groups: agriculture, water, settlement, bush and forest.

MOD13Q1, one of the MODIS VI satellite data, has been developed for the spatial and temporal monitoring of terrestrial vegetation conditions globally. The data produced for Turkey has a resolution of 250 m. The vegetation data, the Normalized Difference Vegetation Index and Enhanced Vegetation Index data produced by this module were used in the study.

Statistical Evaluation and Habitat Suitability maps. In order to remove the negative effects that might result from multiple connection problem among the environmental variables, we applied Pearson Correlation Analysis (R^2<0.85) and Factor Analysis for 47 environmental variables, 19 of which were bioclimate data, nine were solar illumination index data, and 19 were other environmental variables. As a result of these analyzes, environmental variables prepared at the beginning are reduced to 21 environmental variables. These environmental variables are; annual precipitation (BIO12), slope (SLP), stream density (SD), topographic position index (TPI), topographic wetness index (TWI), solar radiation index (SRI), ruggedness index (RGDNS), land position index (LPI), solar illumination index at 8 am (8AM), solar illumination index at 12 noon (NOON), total solar illumination index (TSII), hill shade index (HSI), aspect (ASP), altitude (ALT), aspect favorable index (AFI), radiation index (RI), heat index (HI), bedrock (ROCK), Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI) and land cover/use classes (LCUC).

MaxEnt 3.3.3k software was used to assess the potential distribution of *S. stellio* and *O. elegans* in Isparta-Sütçüler region [8]. This method applies the approach of maximum entropy to calculate the most likely geographical distribution for a species [8]. MaxEnt aims to determine the ecological requirements of species by evaluating the existence variables of target species and environmental variables and to explain in what areas the likely distribution of a species will be according to ecological requirements. MaxEnt was selected as the most appropriate type of distribution modeling method for our study, due to it having a higher estimation power and delivering better and more accurate results with less presence data of target species in small areas. Another advantage of MaxEnt is that environmental variables of categorical data can be used in modeling [3, 29]. MaxEnt within on the information given before, runs by referencing on the relation of target species and environmental variables to distribute the probability of being located in any cell (100 × 100 m) for each cell in the study area over the whole area. Twenty-one environmental variables in the "ascii" format and presence data in the "csv" format of the target species were analyzed. Ninety percent of the presence data was set as training data and 10% as test data, with 10 repetitions. We used Area Under the Receiver Operating Characteristic (ROC) Curves (AUC) for evaluate model performance [3]. If the model has the AUC of 1, it is considered to be the perfect explanatory model. The AUC value of 0.7 is explained as descriptive, whereas the value of 0.5 is considered as non-informative model [8].

RESULTS AND DISCUSSION

Habitat Suitability Model and Map for *Stellagama stellio*. The training data of the species distribution model obtained for *S.stellio* were found to be AUC value of 0.942 and test data AUC value of 0.929. The most important factors affecting the distribution pattern were found to be the bedrock, annual precipitation, slope, ruggedness, total solar illumination index, distance to water, topographic position index, land cover/use classes and altitude. The environmental factors that make up the suitable habitat for *S. stellio* have been described as follows (Fig. 2).

When the *S. stellio* habitat suitability map is examined; areas between Şeyhler-Çandır and Karacaören Barrage villages, Karadiken and Müezzinler villages, Boğazköy and Hacıahmetler villages, Beydilli village and Sarp Mountain western foothills, Aşağıyaylabel and Kesme villages were found to contain suitable habitats. In addition, the area north of Belence village where we could not obtain presence data in field studies is potential habitat for *S.stellio* (Fig. 3).

Our results showed that *S. stellio* prefers bedrock types including clayey limestone, dolomite and limestone. These bedrock types have fissured, slotted, and perforated rock structures that provide special habitats for lizards for predator avoidance, feeding, nesting, and egg laying. *S. stellio* avoids the areas with very high and low annual rainfalls. The areas with an annual rainfall of 630-640 mm and moderate humidity are most suitable for this species. Another finding is that *S. stellio* prefer flat terrain with low slope and shelter from strong winds. This species is mostly observed in locations where solar illumination is high, as reptiles regulate their body temperature according to external environment [30]. By force of their dietary habits (insect, larva, snails), *S. stellio* chooses areas near to settlements, agricultural fields and water sources. Despite the findings of Baran et al. (2012) [15], stating that the distribution of *S. stellio* is restricted to between 0 - 2000 meters above from sea level, we only observed this species in areas ranging between 80-1500 meters above sea level. This difference in range could be due to the differences in environmental and habitat characteristics between study sites. In our study site, the mountainous areas (elevation >1500 m) with no vegetation in high altitude was found to be not suitable for both *S. stellio* and *O.elegans*. Unfortunately, we could not intensively compare and discuss our results with the relevant literature because there are no published results focusing on the relationships between environmental features and *S. stellio* distribution.

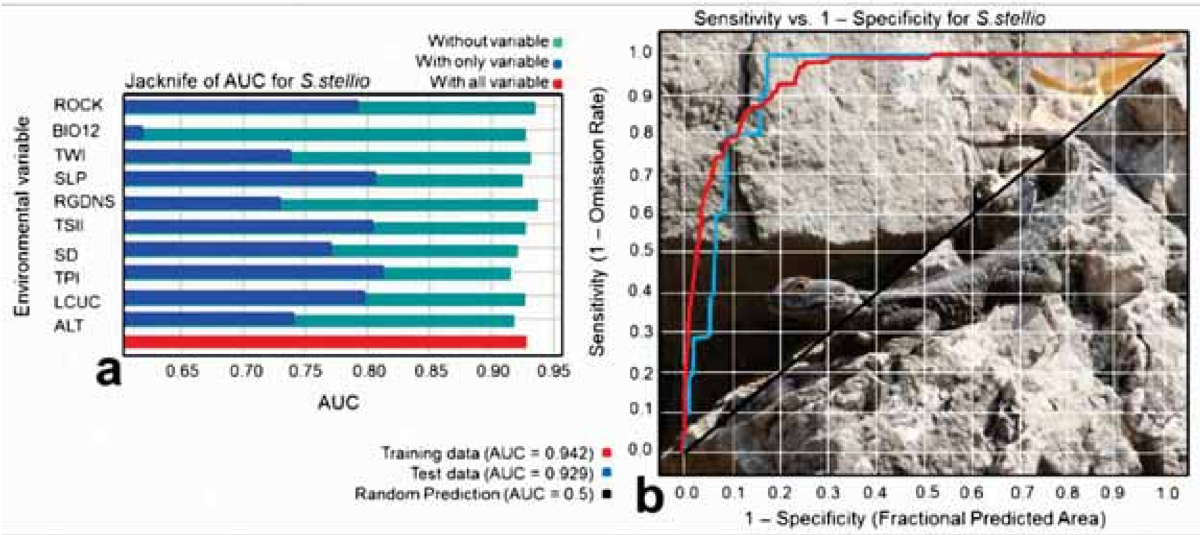

FIGURE 2
(a) Results of jacknife evaluations of relative importance of predictor variables for *S. stellio*, (b) Sensivity vs. 1- specificity graphic for *S. stellio*.

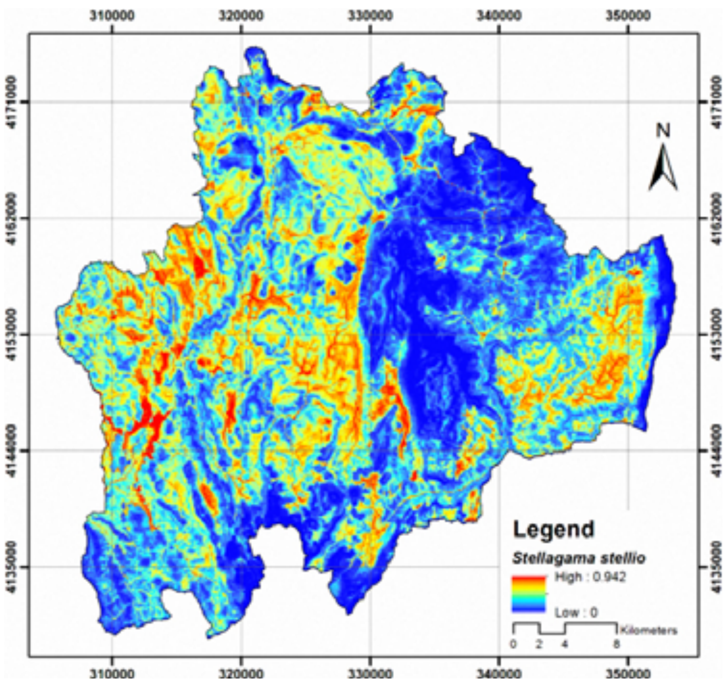

FIGURE 3
Habitat suitability map of *S. stellio*

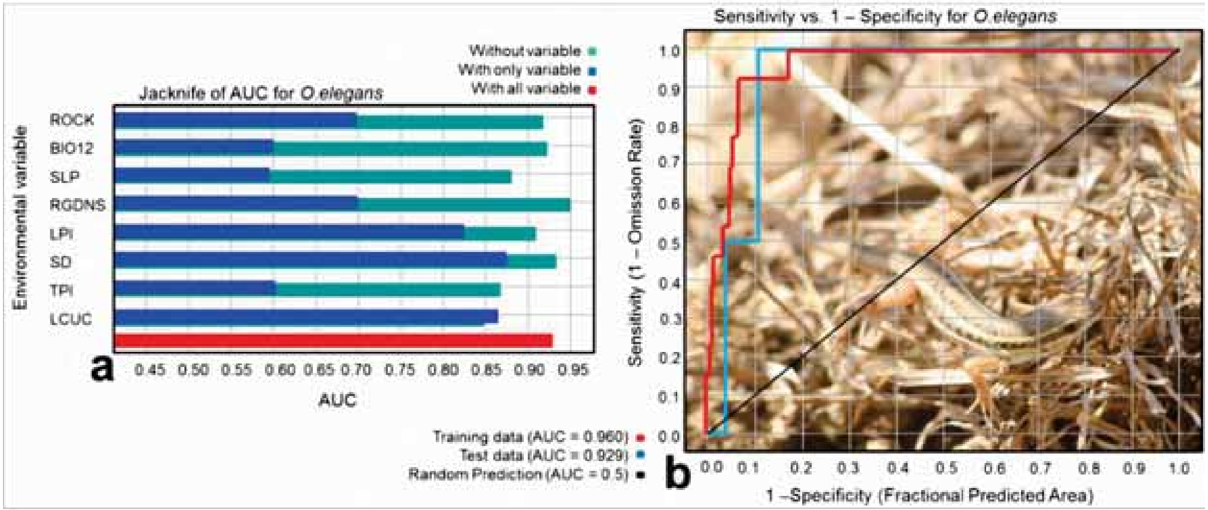

FIGURE 4
(a) Results of jacknife evaluations of relative importance of predictor variables for *O. elegans*, (b) Sensivity vs. 1- specificity graphic for *O. elegans*

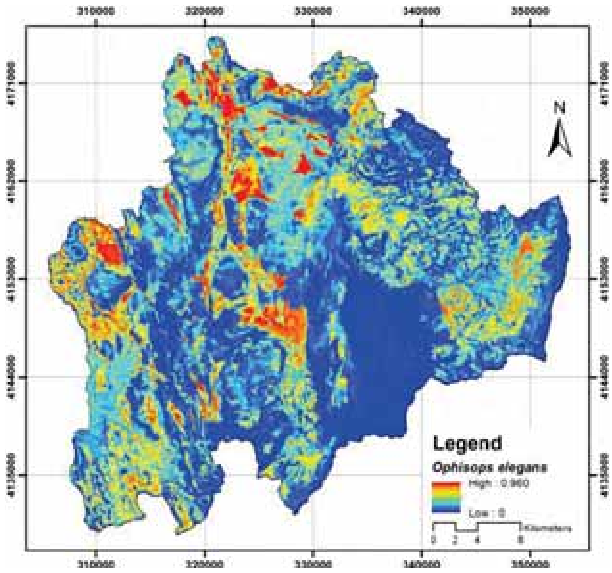

FIGURE 5
Habitat suitability map of *O. elegans*

Habitat Suitability Model and Map for *Ophisops elegans*. The training data of the species distribution model obtained for *O. elegans* were found to be AUC value of 0.960 and test data AUC value of 0.929. Environmental factors affecting the distribution of the *O. elegans* were determined as the bedrock, annual precipitation, slope, ruggedness, land position index, distance to water, topographic position index, land cover/use classes. The environmental factors that make up the suitable habitat for *O.elegans* have been described as follows (Fig. 4).

When the map of *O. elegans* habitat suitability is examined, it is seen that the areas between Bekirler and Sarımehmetler villages, the western part of Karadiken village and Eğirdir district, Kuzca-Çobanisa-Sağrak area, flat areas between Sarayköy, Çobanisa and Hacıaliler seem to be suitable areas for *O. elegans* distribution. Flat areas in the south of Sipahiler and Aşağıyaylabel villages offer potential habitats for *O. elegans* (Fig. 5).

The finding our study showed that the bedrock types including dolomite, alluvial fan, conglomerate and alluvial are most suitable for *O. elegans*. This result indicates that contrary to *S. stellio*, *O. elegans* does not depend solely on rocks for hiding and nesting habitat needs. Similarly to *S. stellio*, *O. elegans* prefers flat, windless terrain. Agricultural areas and shrub lands are suitable for this species. *O. elegans* also choose semi-arid areas with low humidity and low vegetation cover. Our results confer with those found in the the study undertaken by Oraie et al. (2014) [31], in that they also modeled the distribution of *O. elegans* using *MaxEnt* in Iran. Similarly, the results from that study found that this species prefers the semi-arid areas with low vegetation in the summer season and high winter precipitation. However, the other environmental variables that were found to be significant in our study were not found to play any roles on *O. elegans* distribution patterns in the study of Oraie et al. (2014) [31]. It may be explained by the differences in variables used for the models. Apart from our study, Oraie et al. (2014) [31] used a satellite-based NDVI. We propose that the NDVI may substitute for some environmental variables in the MaxEnt model.

CONCLUSIONS

We can conclude that MaxEnt method was successful in producing habitat suitability maps of *S. stellio* and *O. elegans* species. Climatic and environmental factors can be used for lizard species distribution modeling or habitat suitability maps. The habitat suitability maps of lizard species have the potential for guiding managers when undertaking forest and agricultural management practices and determining the initiatives for biodiversity conservation. In future studies, in addition to climate and environmental variables, remote sensing based variables such as image texture and vegetation indexes can be incorporated into modeling.

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