www.biodicon.com Biological Diversity and Conservation

ISSN 1308-8084 Online ISSN 1308-5301 Print

Research article/Araştırma makalesi
DOI: 10.46309/biodicon.2024.1397693
17/3 (2024) 216-228

The effect of micro topographic features on the site selection of European ground squirrels (*Spermophilus citellus*): A case study from Tekirdağ province, Thrace Peninsula (Türkiye)

Emre ÖZŞAHİN [*1], Mikayil ÖZTÜRK [2]
ORCID: 0000-0001-8169-6908; 0009-0007-6703-9267

[1] Tekirdağ Namık Kemal University Faculty of Arts and Sciences Department of Geography, 59000 Tekirdağ, Türkiye
[2] Tekirdağ Namık Kemal University Institute of Natural and Applied Sciences, 59000 Tekirdağ, Türkiye

Abstract

The scientific determination of the habitat selection of European ground squirrels (*Spermophilus citellus*), whose population has decreased significantly in recent years due to various human activities, is essential for the survival of this endangered species. Micro topography is one of the main factors affecting the habitat selection of this creature, which hibernates in its individual caves for a long period of time from early fall to early spring. Therefore, the aim of this study was to investigate the effect of micro topographic features on the nest selection of European ground squirrels. The study was shaped according to the results of a sample area in Tekirdağ province in the Thracian Peninsula of Türkiye (Turkish Thrace), one of the southernmost distribution areas of European ground squirrels in Europe. The main data of the study consisted of high-resolution digital elevation model (DEM) and ortho-photo images obtained using an unmanned aerial vehicle (UAV) during field studies. These data were processed with Geographic Information Systems (GIS) techniques using an ecological niche modeling (ENM) approach. As a result of the study, it was determined that among the micro topography features in the sample area, the aspect factor was more important (56.412%) in the nest preference of the species. The results of the study shed light on the plans to be made for the maintenance and protection of potential and existing habitats, as well as supporting specific measures to be taken to strengthen the population of the species, which is under threat of extinction, and to improve habitat features. It can also be used to expand areas important for the conservation of the species and improve the success of future reintroduction or introduction programs.

Keywords: Micro topography, aspect factor, GIS, DEM, Mediterranean climate.

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Avrupa yer sincaplarının (*Spermophilus citellus*) yer seçiminde mikro topografya özelliklerinin etkisi: Tekirdağ ilinden örnek bir çalışma, Trakya Yarımadası (Türkiye)

Özet

Çeşitli insan aktivitelerine bağlı olarak son yıllarda popülasyonunda ciddi bir azalma görülen Avrupa yer sincaplarının (*Spermophilus citellus*) habitat seçiminin bilimsel bir şekilde belirlenmesi, nesli tükenme tehlikesi altında olan bu canlının hayatta kalması açısından çok önemlidir. Sonbaharın başlarından ilkbaharın başlarına kadar uzun bir süre boyunca bireysel yuvalarında kış uykusuna yatan bu canlının habitat seçiminde etkili temel faktörlerden birisi de mikro topografya özellikleridir. Dolayısıyla bu çalışmada Avrupa yer sincaplarının yuva seçiminde mikro topografya özelliklerin etkisinin incelenmesi amaçlanmıştır. Çalışma, Avrupa yer sincapların Avrupa'nın en güneyindeki dağılım alanlarından birisi olan Türkiye'nin Trakya Yarımadasındaki (Türkiye Trakyası) Tekirdağ ilinden örnek bir alan üzerinden yapılmış sonuçlara göre şekillendirilmiştir. Çalışmanın temel verilerini, arazi çalışmaları sırasında insansız hava aracı (İHA) kullanılarak elde edilmiş yüksek çözünürlüklü sayısal yükselti modeli (SYM) ve orto-foto görüntüleri oluşturmaktadır. Bu veriler Ekolojik Niş Modelleme (ENM) yaklaşımıyla Coğrafi Bilgi Sistemleri (CBS) teknikleriyle işlenmiştir. Çalışma sonucunda örneklem alanındaki mikro topografya özelliklerinden bakı faktörünün türün yuva tercihinde daha önemli (%56.412) olduğu belirlenmiştir. Çalışmanın sonuçları yok olma tehdidi altında bulunan türün

* *Corresponding author* / Haberleşmeden sorumlu yazar: Tel.: +902822502696; Fax.: +902822502661; E-mail: eozsahin@nku.edu.tr
 Received: 17.11.2023; Published: 15.12.2024 BioDiCon. 1130-171123

popülasyonunun güçlendirilmesi ve habitat özelliklerinin iyileştirilmesine yönelik spesifik önlemlerin alınmasına destek olmasının yanında potansiyel ve mevcut habitatların bakımı ve korunması için yapılacak planlamalara ışık tutmaktadır. Ayrıca türün korunması için önemli alanların genişletilmesi ve gelecekteki yeniden yerleştirme veya tanıtım programlarının başarısının artırılması için kullanılabilir.

Anahtar kelimeler: Mikro topografya, bakı faktörü, CBS, DEM, Akdeniz iklimi.

1. Introduction

Old World ground squirrels (*Spermophilus* sensu stricto) are one of the most intensively studied mammalian groups regarding their ecology and behavior [1]. Only three species of this mammal group (Anatolian ground squirrel - *Spermophilus xanthoprymnus* [2], European ground squirrel - *Spermophilus citellus* [3] and Taurus ground squirrel - *Spermophilus taurensis* [4]) occur in Türkiye [5]. European ground squirrels are distributed in the Thracian Peninsula of Türkiye [6]. However, in recent years, especially the natural habitats of European ground squirrels have been dramatically decreasing due to human impacts [7]. In fact, the species is considered "Near Threatened" and "Vulnerable" due to the estimated population decline of 30% or more per decade [8]. Furthermore, according to the IUCN Red List, the European ground squirrel is listed as an endangered (EN) species [9].

To explain the existence and dynamics of animal colonies, it is ecologically important to determine the geographical distribution of species and the factors that control this distribution [10]. Thus, the habitat choices of animal species, which are their natural habitats, are more accurately understood scientifically [11]. Knowing the habitat selection of wild animal species, especially those under threat of extinction, is also essential for understanding why many have disappeared or for the planned conservation of the species against negative impacts [12]. For this purpose, many different innovative approaches have recently been used [13]. The most preferred of these is Geographic Information Systems (GIS) based Ecological Niche Modeling (ENM) [14]. Thus, inferences based on the biology and landscape features of the species can be easily made [11].

The scientific determination of habitat selection of European ground squirrels is very important for the survival of this endangered species [15]. In this respect, revealing the relationship between the density and distribution of European ground squirrels and natural environmental factors has become an important scientific goal [16]. In the related literature, it has been reported that climate, topography and vegetation/land use conditions are more effective in the habitat preference of the species [7]. However, it was also emphasized that more research should be carried out to reveal especially micro topography features in habitats with similar features in terms of other environmental conditions [15]. In this context, although there have been studies on both habitat features of European ground squirrels outside the borders of Türkiye [14, 7, 15] and nest selection using Unmanned Aerial Vehicle (UAV) based Remote Sensing (RS) technology [14], their habitats in Türkiye have not been sufficiently studied. Therefore, it is very important to examine the habitats of European ground squirrels in Türkiye regarding microconditions of some natural environmental features using UAV-based UA technology to fill the gap in the literature.

This study aimed to investigate the effect of micro topography features on European ground squirrels' nest selection. The study was shaped according to the results of a sample area in Tekirdağ province in the Thracian Peninsula, corresponding to one of the southern distribution areas of European ground squirrels in Europe. In this study, for the first time, the effect of micro topography features on nest selection of European ground squirrels in the Thracian Peninsula was determined using UAV-based UA technology. The study, which uses highly sensitive data with very high resolution, is very important in terms of guiding decision-makers in planning for the conservation and future of European ground squirrels.

2. Material and method

21. Study Area

The study area corresponds to the habitat of European ground squirrels in the pasture of Köseilyas rural neighborhood of Süleymanpaşa district of Tekirdağ province, located in the Thracian Peninsula (Turkish Thrace) (Figure 1). The study area's surface area, suitable for the ecology of the European ground squirrel, is 3.06 ha.

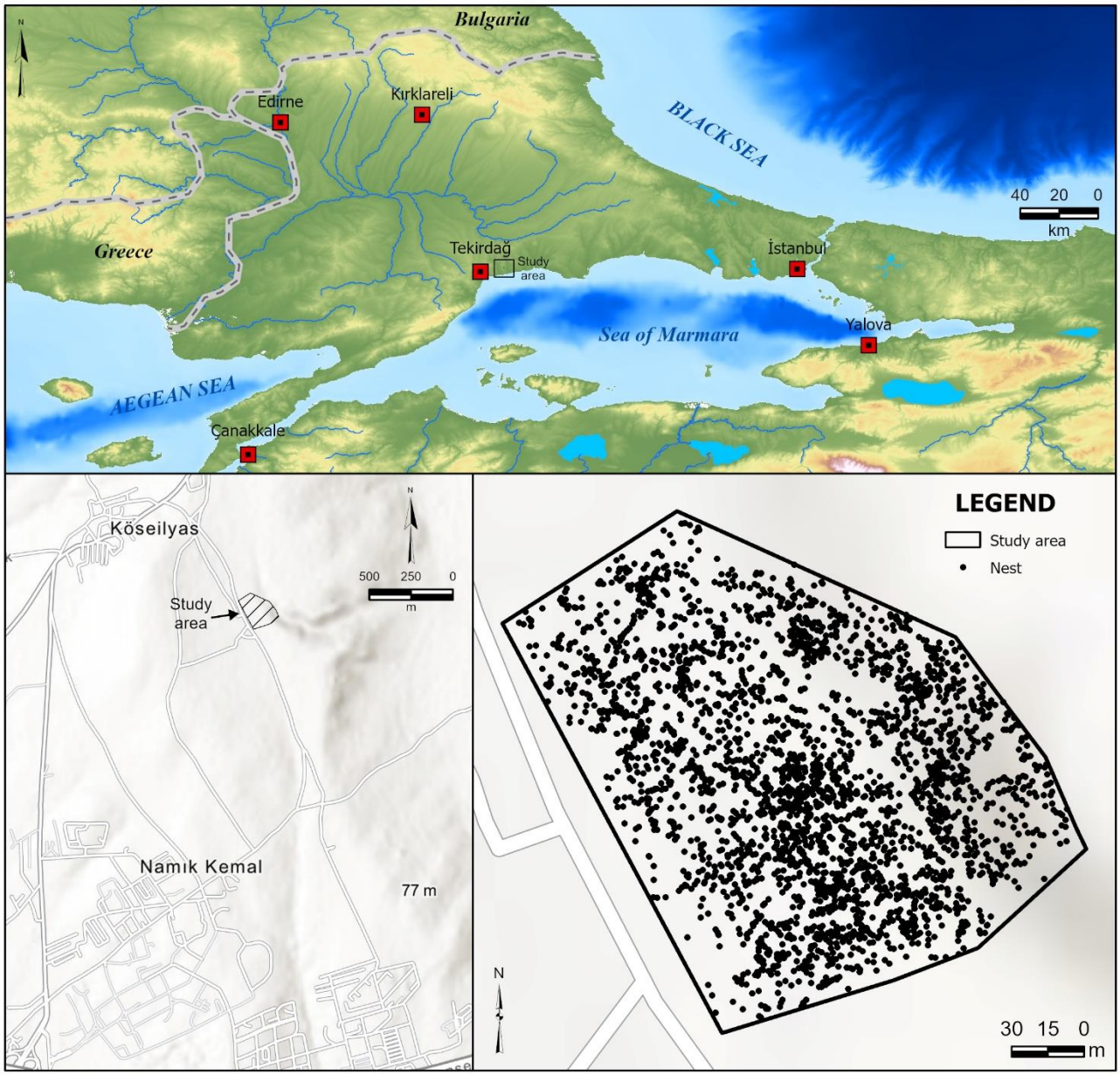

Figure 1. Location map of the study area (base map accessible using ArcGIS Pro provided by ESRI [17])

The study area has a homogeneous habitat features suitable for European ground squirrels in terms of factors other than micro topography (Figure 2; 3). In the study area, where the average annual temperature is 13.7 ˚C, and the total annual precipitation is 560 mm [18], pasture plants (wheatgrasses and legumes) characterized by local climatic features [19] are distributed [20]. The study area has a southeast-facing orientation, where the average altitude is 101.45 m, and the average slope is 7.24%. The soils in and around the study area are mostly heavily textured and rich in organic matter and nutrients (N, K, Fe and Zn). The soil reaction is acid since the study area is a grazed pasture [21]. The pastures in the region where the study area is located generally show a feature where animals are grazed lightly with free grazing from the end of May [20].

Figure 2. The study area provides a suitable habitat for European ground squirrels

2.2. Method

ENM method was used in this study. With this method, the distribution of a species in a geographical region where presence information is limited or incomplete can be estimated, as well as its relationship with ecosystem elements that are considered key to maintaining ecological functioning [14]. In this context, the habitat selection of European ground squirrels and its relationship with some environmental factors, especially micro topography features, were discussed. For this purpose, field studies determined a sample habitat that is homogeneous in terms of environmental factors other than micro topography features. Thus, it was tried to understand how much the micro topography features change and its effect on the nest selection of the species.

The study data were generated from a combination of field studies and UAV-based UA technology. First, digital aerial photographs of the study area were taken using an autonomous UAV system. The images were taken from a height of 20 m using 80% transverse and 75% longitudinal overlap ratios, respectively. After the photography, topsoil (0-20 cm) samples were taken randomly and systematically from some points of the site. The data obtained were processed in computer and soil analysis laboratories. Climate data were obtained from the long-term (1991-2022) average data of Tekirdağ Meteorological Station, which serves under the General Directorate of Meteorology [18]. Land use was created using data made available by ESRI [22]. Thus, basic data on the habitat features of European ground squirrels in the study area were obtained.

Using high-resolution (70 cm) ortho-photo images produced by computerized fusion of images taken using UAVs, nests of European ground squirrels were identified in the study area. These burrows are located in a geography where climate, soil and vegetation/land use factors are homogeneous, and micro topography features are heterogeneous. Therefore, this study analyzed the relationship between the nests in the study area, where topographic heterogeneity is high, and micro topography (altitude, slope and aspect) features. At this stage, the Average Nearest Neighbor Index was

based on GIS techniques, and the Forest-based Classification and Regression analysis of the Random Forest (RF) algorithm, one of the machine learning techniques, was used. Thus, a new perspective was gained on the effect of micro topography features on the nest site selection and spatial distribution of European ground squirrels [23]. The analyses and thematic maps in the study were carried out using ArcGIS Pro (Version 3.0.1), one of the GIS software packages.

Figure 3. Data in the study area was collected through field studies

3. Results

The sample habitat of this study was selected from the Thracian Peninsula, which corresponds to one of the distribution areas of European ground squirrels in the south of the European continent [24]. In this habitat, 3116 nests were identified. The spatial distribution of these nests is clustered according to the nearest neighbor index result (0.755260), which is based on the average distance. In addition, considering that the z value of these index results (-26.135698) is less than 1%, it can be said that this clustering pattern is not random (Figure 4).

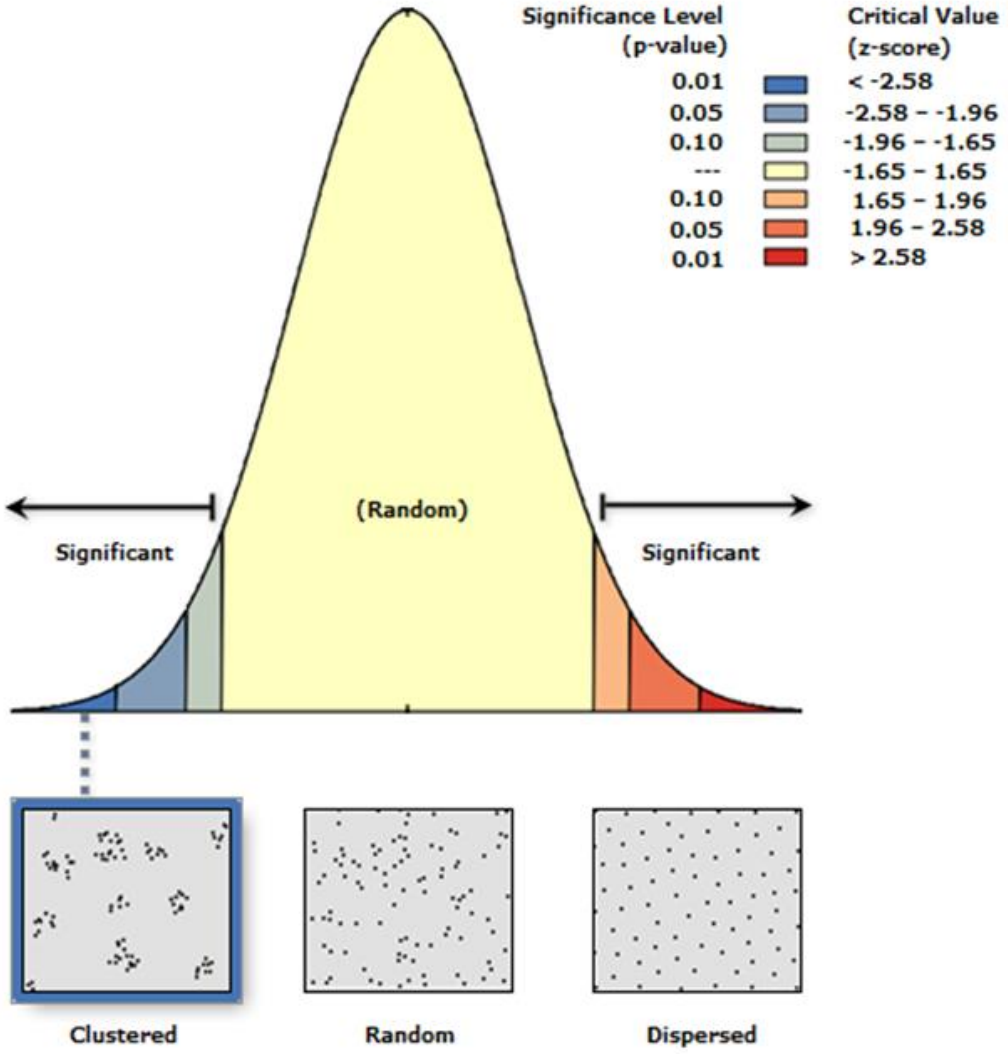

Figure 4. Representation of the Nearest Neighbor Index result of European ground squirrel nests in the study area using the standard distribution form [25]

In the study area, climate (precipitation and temperature), soil and land use factors that constitute the habitat features of European ground squirrels are homogeneous, while micro topography features are more heterogeneous. Gür [26] reported that the concept of heterogeneity, which is accepted as a measure of how much habitat features change, increases to the extent of the change in micro topography features in a given area. The study area, where the average annual temperature is 13.7 ˚C, and the average yearly total precipitation is 560 mm, corresponds to a roadside pasture area with clay loam soil characteristics (Figure 5; Table 1). Rammou et al. [14] stated that the species' nests are generally found in roadside pastures where the Mediterranean climate is effective, heavily textured soil characteristics are observed, and transportation is provided. In this respect, the nests of European ground squirrels in the study area are located in similar conditions that are effective regarding climate, soil, and land use factors.

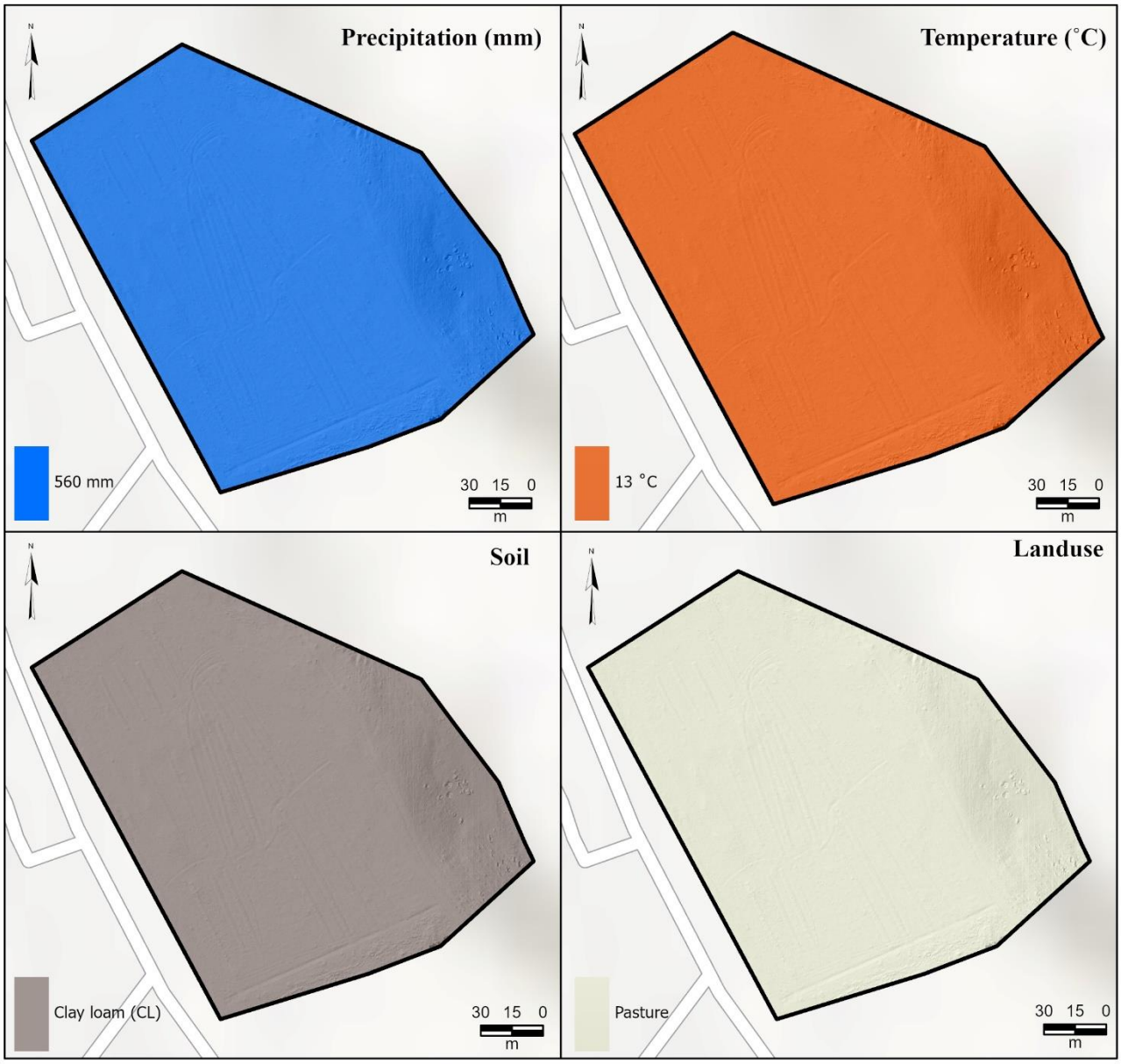

Figure 5. Map of homogeneous environmental factors affecting habitat features in the study area

Table 1. Distribution of some factors affecting habitat features at the study area and nest level

Some factors affecting habitat features		Study area		Nest	
Factor Name	**Value**	**Area (ha)**	**Rate (%)**	**Number (units)**	**Rate (%)**
Precipitation	560 mm	3.062	100	3116	100
Temperature	13 ˚C	3.062	100	3116	100
Soil	Clay loam (CL)	3.062	100	3116	100
Landuse	Pasture	3.062	100	3116	100

Micro topography features play a more decisive role in the spatial distribution of European ground squirrel nests in the study area. According to the micro topography features in the study area, 89% of the nests are located above 100 m, 77% are located below 10% slope and 50% are located in south-facing directions (Table 2; Figures 6; 7; 8; 9). This finding also indicates that European ground squirrel burrows in the study area are more related to aspect and slope features than altitude. Indeed, Zaharia et al. [7] noted that slope and aspect factors influence European ground squirrel density more than altitude (Table 2). Rammou et al. [14] emphasized that the nests of European ground squirrels are typically located in south-facing and gently sloping landscapes.

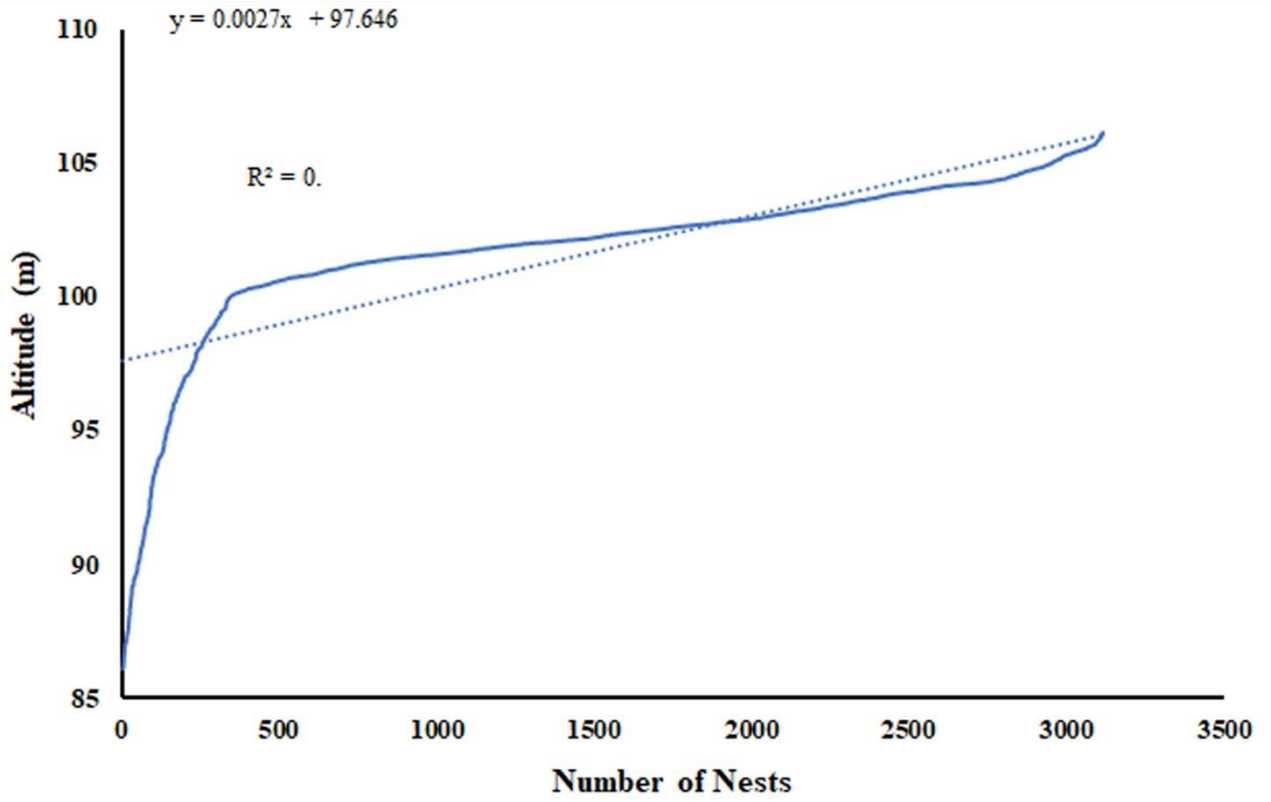

Figure 6. Graph of the relationship between European ground squirrel burrows and altitude factor in the study area

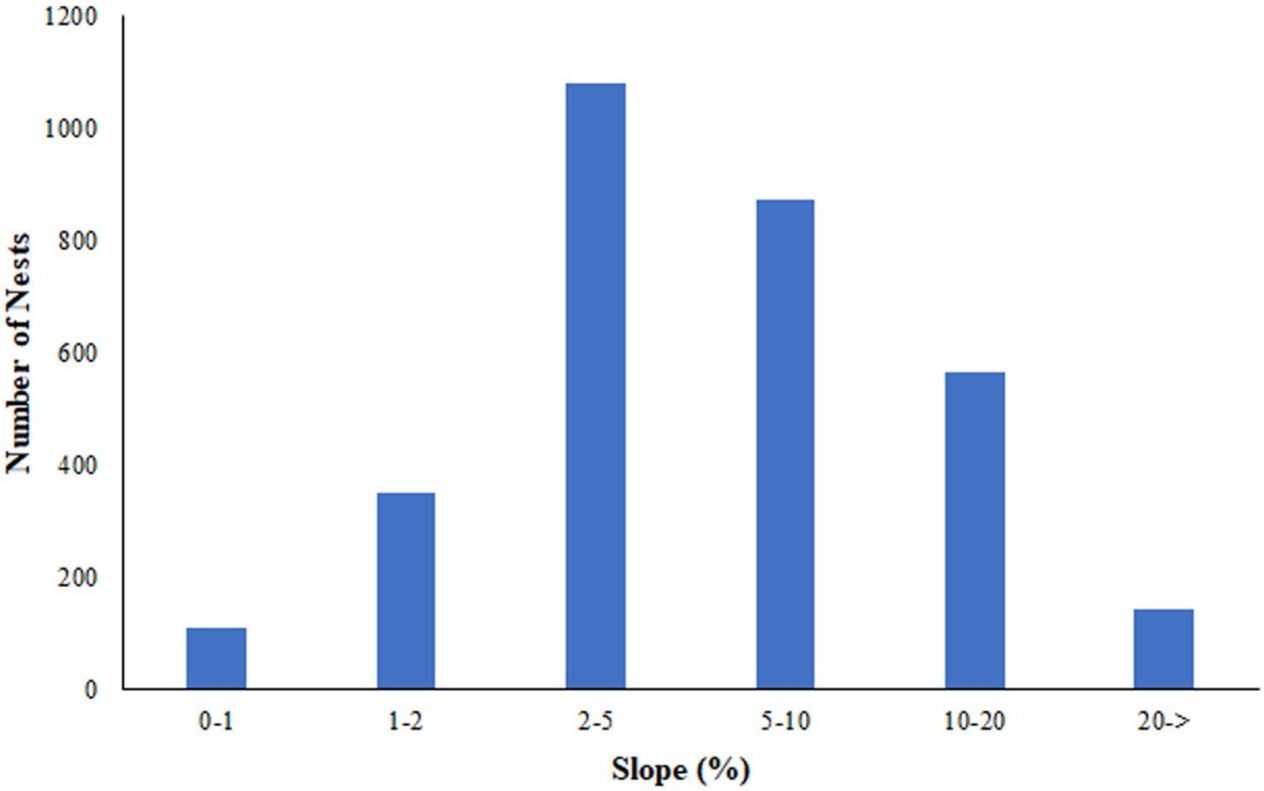

Figure 7. Histogram of the relationship between European ground squirrel burrows and slope factor in the study area

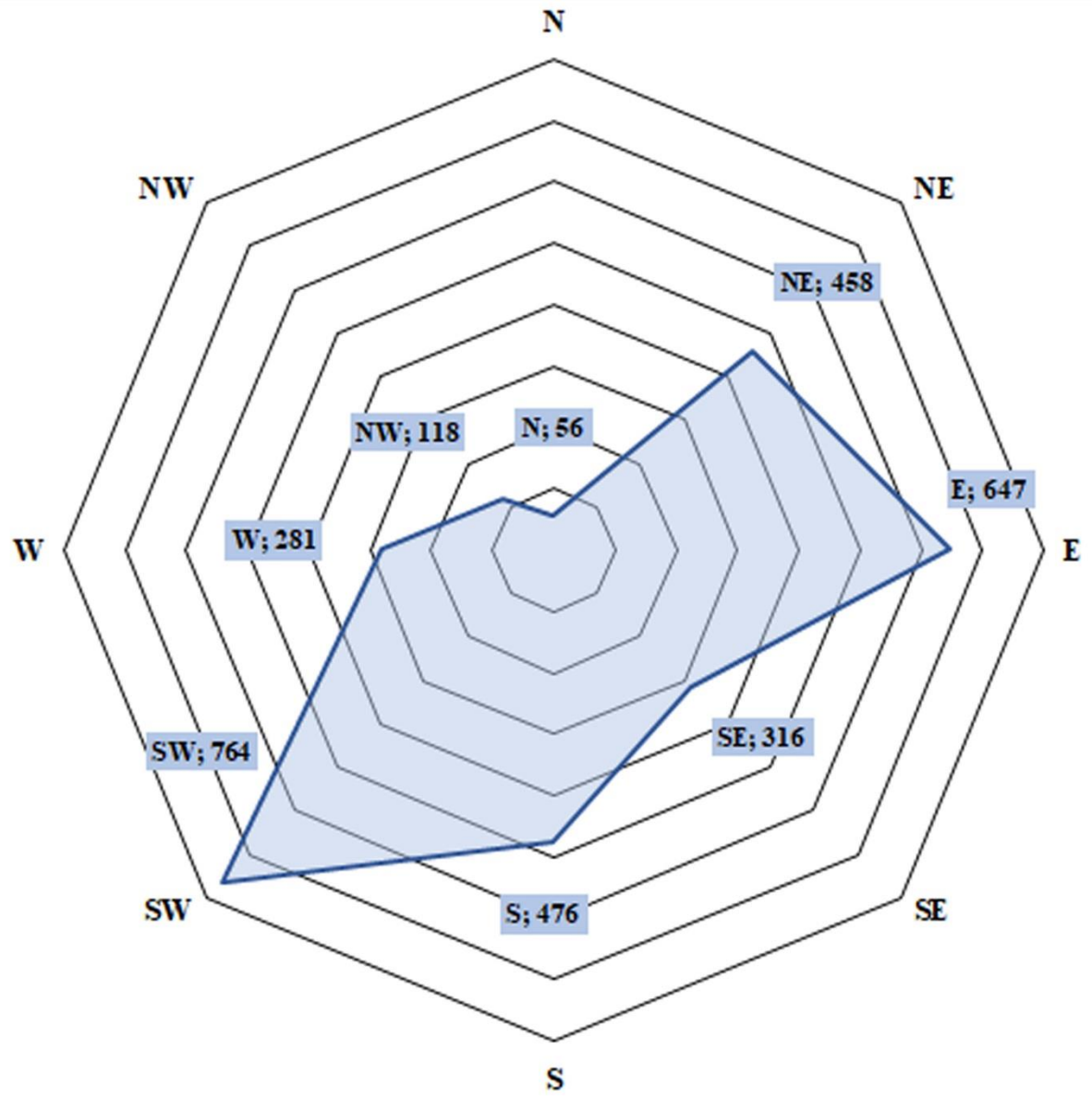

Figure 8. Rose diagram of the relationship between European ground squirrel burrows and aspect factor in the study area

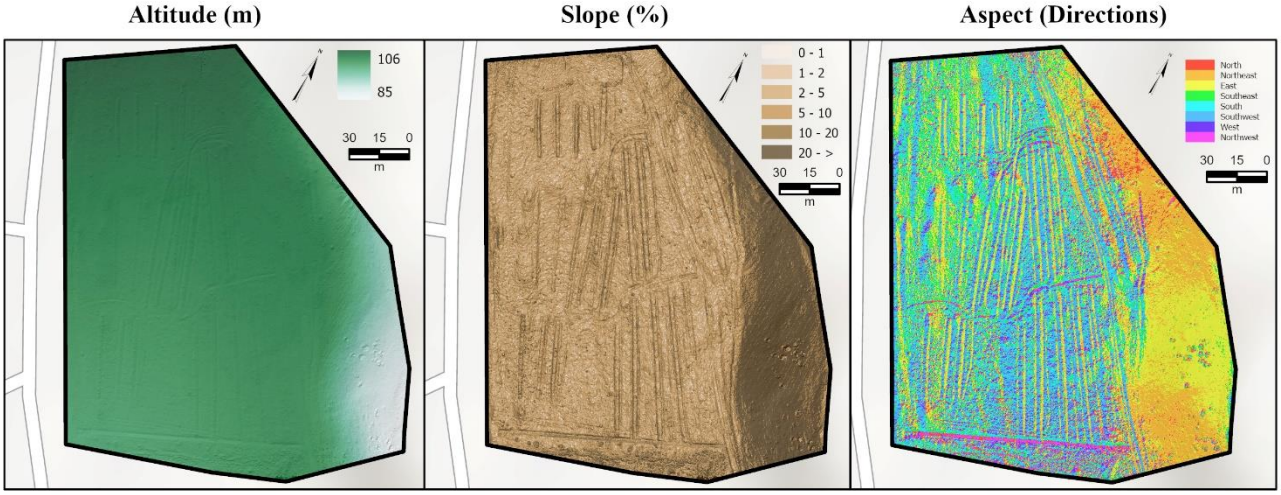

Figure 9. Distribution map of micro topography features that are effective in the spatial distribution of European ground squirrel nests in the study area

Table 2. Distribution of altitude, slope and aspect factors affecting habitat features according to the study area and nests

Altitude (m)	**Study area**		**Nest**	
	Area (ha)	**Rate (%)**	**Number (units)**	**Rate (%)**
<-100	0.415	13.6	342	11.0
100->	2.647	86.4	2774	89.0
Total	**3.062**	**100**	**3116**	**100**
Slope (%)	**Study area**		**Nest**	
	Area (ha)	**Rate (%)**	**Number (units)**	**Rate (%)**
0-1	0.360	11.7	109	3.5
1-2	0.272	8.9	349	11.2
2-5	0.631	20.6	1081	34.7
5-10	0.865	28.3	873	28.0
10-20	0.606	19.8	563	18.1
20->	0.328	10.7	141	4.5
Total	**3.062**	**100**	**3116**	**100**
Aspect (Directions)	**Study area**		**Nest**	
	Area (ha)	**Rate (%)**	**Number (units)**	**Rate (%)**
N	0.125	4.1	56	1.8
NE	0.545	17.8	458	14.7
E	0.698	22.8	647	20.8
SE	0.411	13.4.	316	10.1
S	0.461	15.1	476	15.3
SW	0.526	17.2	764	24.5
W	0.191	6.2	281	9.0
NW	0.105	3.4	118	3.8
Total	**3.062**	**100**	**3116**	**100**

According to the Forest-Based Classification and Regression analysis, the degree of importance of micro topography features in the study area differs. Accordingly, the most important variable in the study area is aspect (56.412%). The other factors are slope (26.697%) and altitude (16.892%) from more important to less important (Table 3). This finding coincides with the study's findings in the nests of European ground squirrels recorded in Eastern Romania [7].

Table 3. Importance and percentage values of micro topography features in the study area

Micro Topography Features	**Variable Importance**	
Variable Name	**Importance**	**Percentage**
Aspect (Directions)	62052176	56.412
Slope (%)	29365969	26.697
Altitude (m)	18580981	16.892

4. Conclusions and Discussion

In recent years, the population of European ground squirrels has declined significantly due to various human activities. For this reason, it has become an important scientific objective to determine the relationship between the density and distribution of the species and natural environmental factors. Many studies have been conducted to determine the habitat features of various wild mammal species. However, studies on this subject in Türkiye are quite new [28]. In this study, the effect of micro topographic features was examined in a sample site located at the southernmost border of the habitat of European ground squirrels. Until today, no study has been carried out to determine the species' habitat selection in the Thracian Peninsula [29]. Moreover, the study area is even more important since it is one of the biogeographically designated "ancestral areas" [30] for the origin of the S. citellus lineage.

In this study, where the results supporting the literature were obtained, it was understood that the factors of aspect and slope were very effective in the nest preference of the species. Especially the aspect factor was found to be the most important variable. This is because the features of these aspects also shape the micro climate conditions. The fact that the slopes of the topography-oriented S-SE-SW-E are exposed to more solar radiation leads to the emergence of favorable features for the photosynthesis and productivity of the plants in the habitat area of the species. Thus, it controls the vital attributes of the species, such as body mass, reproductive success and survival rate [31]. In addition, the species' colony density is positively influenced by higher temperature and strong light on S-SE-SW-E oriented slopes [32] and negatively influenced by more humid conditions on N-NE-NW-W slopes that favor the occurrence of

mass movements of various species [7]. The slope factor also played a decisive role in the nest preference of the species. This must be related to the fact that the current habitat of the species typically corresponds to south-facing pastures with short-stature vegetation showing a lowland character with a slight slope (<3°) [14]. Because in such pastures, the low slope and short vegetation cover enables the species to easily detect predators. On the contrary, higher slope and vegetation conditions prevent the animal from seeing its surroundings [33]. Therefore, for the species, which is an important prey for a wide variety of carnivores, to easily detect predators and survive, it is important that the vegetation in the habitat area is short and the slope is low [7].

In this study, for the first time, the effect of micro topography features on the habitat selection of the species in a sample location selected from the Thracian Peninsula was determined using UAV-based UA technology. Because it has recently been reported that UAV-based image processing techniques have replaced traditional research methods for the evaluation of habitat features of the species [34], it has been suggested that more reliable results with better prediction accuracy and precision can be obtained [35]. In this study, the effect of micro topography features on the nest selection of the species was investigated and mapped using the GIS-based ENM method. There is a great need for studies on mapping the habitat features of wild animal species and their potential distribution in their habitats using GIS techniques [28]. In addition, the study and mapping of natural environmental features in ecological landscapes has become a standard and important tool for assessing an animal's habitat [27]. In this study, GIS techniques and very high-resolution data were utilized to determine the effect of micro topography features on both the nests of the species and habitat selection. Therefore, this study proves that the data obtained with new generation methods and techniques offer a different perspective for habitat assessment of endangered species.

The results of the study shed light on the planning to be made for the maintenance and protection of potential and existing habitats, as well as supporting specific measures to be taken to strengthen the population of the species, which is under threat of extinction, and to improve habitat features. For this reason, ecological plans should be made with a sustainable approach for the conservation of the species in the study area, taking into account the results of this study. These plans should be supported by biotope mapping and assessment method, which is considered one of the most important tools of nature conservation [36]. On the other hand, potential distribution areas in the immediate vicinity should also be determined for the conservation of the species. Thus, it is possible to get more practical and effective results in the planning process [37]. The results of the study will help researchers identify areas where action plans and conservation projects can be implemented to ensure the survival of the species [38]. In addition, these assessments can be used to expand the areas important for the conservation of the species and increase the success of future relocation or introduction programs. In future studies to be conducted with similar methods and techniques, it is recommended that the effect of micro topography features on the habitat selection of the species should be done comparatively according to different habitats.

Acknowledgements

We would like to thank Assoc. Prof. Dr. Hüseyin SARI for his technical support, the editor and the referees for their constructive criticism and guidance.

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