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The effect of topography on the distribution of rodent nests in the enclosed and non-enclosed pistachio forest pasture of Khajeh Kalat in Northeast Iran

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Abstract

The order Rodentia is the largest among other groups of mammals in terms of the number of species and number of individuals and is widely seen in different types of habitats. Various factors affect the spatial distribution of these animals. In this study, according to the same conditions in the two areas in terms of topography, soil, and vegetation type, the distribution of rodent nests in the enclosed and non-enclosed regions of woody pasture in the pistachio forest pasture of Khajeh Kalat in Khorasan Razavi province of Iran has been studied. For this purpose, sample plots with the variable region that had at least 15 trees were used. Inside of each sample plot and under the crown of any tree, rodent nests were identified and counted. Finally, the data obtained from the total sample plots have been analyzed. The results showed that the number of rodent nests in the two regions was significantly at 99% confidence level related to each other, as well as in elevation, slope and aspect was significantly at 99% confidence. Rodent nest distribution is also related to the soil characteristics of the region, and rodents prefer deeper, more fertile soils with a lighter texture and better drainage so that they can dig in easily and rain does not flood their nests. Slope also has an effective role in runoff, infiltration, flood intensity, erodibility, and sedimentation which are not ineffective in rodent release. The north and south aspect are more suitable for rodents due to their moisture and shading and better soil for nesting, and therefore the number of nests in the north and south aspects is higher than in other aspects. Of course, other factors also affect rodent distribution, including ecological relationships, and environmental variables between species, and animals.
Keywords: Enclosed, non-enclosed region, Pistachio forest, rodent nest, topography

Introduction

Grasslands are one of the most important biomes on earth. Grassland ecosystems cover over 40% of the earth's landmass; contain 17% of worldwide plant diversity (Gibson, 2009; Zhao, Liu & Wu, 2020). Rodents are accustomed to different living conditions and live in different places. Most of them build nests for themselves. Apart from some nests built on trees, rodent nests are generally found on the ground (Chellappan, 2021). Nesting and living in the depths of the earth are very important in the life of rodents. Therefore, they are very careful and selective in choosing their habitat and nests (Elliott *et al*., 2019). The type of soil and topographic conditions of the land are very effective in their nesting and if the conditions are suitable in terms of land and food, in large parts of the land, countless holes of rodent nests can be seen and the surface of these lands as a network and their main food is plant materials (Forman, 2019; Jafari *et al*., 2018). Various parts of the plant, such as seeds, fruits, sprouts, leaves, stems, and roots, are eaten by rodents. Rodents can produce high generation, and therefore, with all the many enemies, that they have in nature and inflicted heavy losses on them, they are innumerable. If living conditions are particularly favorable in terms of climate and food, rodents increase rapidly and become pests (Mondal *et al*., 2020). In various studies, their role in terms of damage to agricultural products and vegetation and disease transmission to humans and animals is well known (Fisher *et al*., 2020). Rodents also have beneficial properties, including aeration of the soil and the movement of nutrients and plant seeds in different soil layers, control of insect populations, use in laboratory and medical research, and maintaining the balance of the environment (Zaller, 2020). The natural habitat of edible pistachio in Khorasan Razavi province is one of the forest pasture covers of the country which in addition to its important role in the lives of the people of the region is the habitat of various wild animals, especially burrowing animals and rodents (Fadaei, 2020; Huss *et al*., 2020; Marzluff, 2020). According to studies conducted in this region, different species of rodents can be observed, which are generally from the genus Like *Cricetidae* and mice (*Muridae*) (Hamidi & Bueno-Marí, 2020). Khajeh Kalat Pistachio Forest pasture is currently the densest wild pistachio forest pasture in Iran and perhaps in the world, which despite its importance has been neglected over time and has been reduced quantitatively and qualitatively (Fadaei, 2020; Fadaei, Sakai, & Torii, 2011; Fadaei *et al*., 2010). Climate and topography was the most important predictor variables explaining rodent species richness and abundance patterns (Novillo & Ojeda, 2014). Davis et al (2020) evaluate the potential use of normalized difference vegetation index (NDVI) from satellite-derived remote sensing data for monitoring rodent abundance in semi-arid regions of Tanzania. The results demonstrated a strong linear relationship between NDVI and actual rodent abundance within grids ($R^2 = 0.71$). NDVI-predicted rodent abundance showed a strong positive correlation ($r = 0.99$) with estimated rodent abundance (Chidodo *et al*., 2020). Hieronimo et al (2014) investigated the relationship between land-use types and practices and small mammal abundance and distribution using three different landscapes. The results showed with ($p \leq 0.05$) small mammal abundance among land-use types was identified. Plantation forest pasture with farming, natural forest pasture, and fallow had higher populations of small mammals than the other aggregated land-use types (Hieronimo *et al*., 2014). Guidobono et al (2019) the effect of environmental factors on the abundance variations of two native rodents in agricultural systems of Buenos Aires, Argentina has been investigated. The result showed, meteorological variables did not have a direct effect on abundance variations, but were probably influenced through vegetation characteristics and were expressed in seasonal variations (Guidobono *et al*., 2019). In general, if the plant community is not influenced by humans, the activity of the rodent community will increase and the density of the plant community will be

an increase (Bishop *et al*., 2020; Kang *et al*., 2020). Generally, there is a significant relationship between the frequency of rodents with plant type, height, slope and direction of each region (Madden *et al*., 2019).
The goals of this study are; 1- investigating the relationship between rodent nest number and topography, 2-investigation the distribution of rodent nests in two protected and non-protected regions, and 3-also examine the correlation between rodent nest number and topography. Therefore, this study can be an effective step in understanding the current situation of this habitat and proper planning and principles for improving its condition by studying the effect of topography on rodent nesting.

Materials and methods

The study area is located in Khajeh Kalat pistachio forest pasture with an area 13,250 ha (hectare), in the northeast of Khorasan Razavi province (Fadaei *et al*., 2020). In 1996, the forest pasture resources management plan was implemented in this region and Khajeh Kalat pistachio forest pasture was separated and under the management of natural resources and Astan Quds Razavi. Politically, it belongs to Sarakhs and Kalat cities, but in terms of management, it is under the supervision of the Kalat Natural Resources Department (Khesht *et al*., 2021). One year after the start of the project: The forest pasture was confined under the management of natural resources and the part of the forest pasture that was under the management of Astan Quds is managed freely without any protection operations (Rahmanian *et al*., 2020). Figure 1 shows the location map of the Khajeh Kalat pistachio forest pasture in two parts: enclosed and non-enclosed. The minimum altitude of the region is 500 meters and the maximum altitude is 1243 meters above sea level (Ramezani *et al*., 2008). The vegetation of the region includes the main species of wild pistachio (*Pistacia vera* L.) along with the species of *Tamarix aphylla*, *Ephedra sinica Stapf*, *Juniper polycarpos*, *Zygophyllum coccineum L.*, *Amygdalus Scoparia Spach*, *Atraphaxis spinosa L.* and *Prunus L.* (Ahani *et al*., 2013). The forest pasture part of the region is 7393 hectares and its rangeland part is 3100 hectares. This forest pasture has 1,445,553 pistachio trees with a density of 640 plants per hectare. According to meteorological studies, the climates are arid (DoMarton method) and cold dry (Ambergeh method).

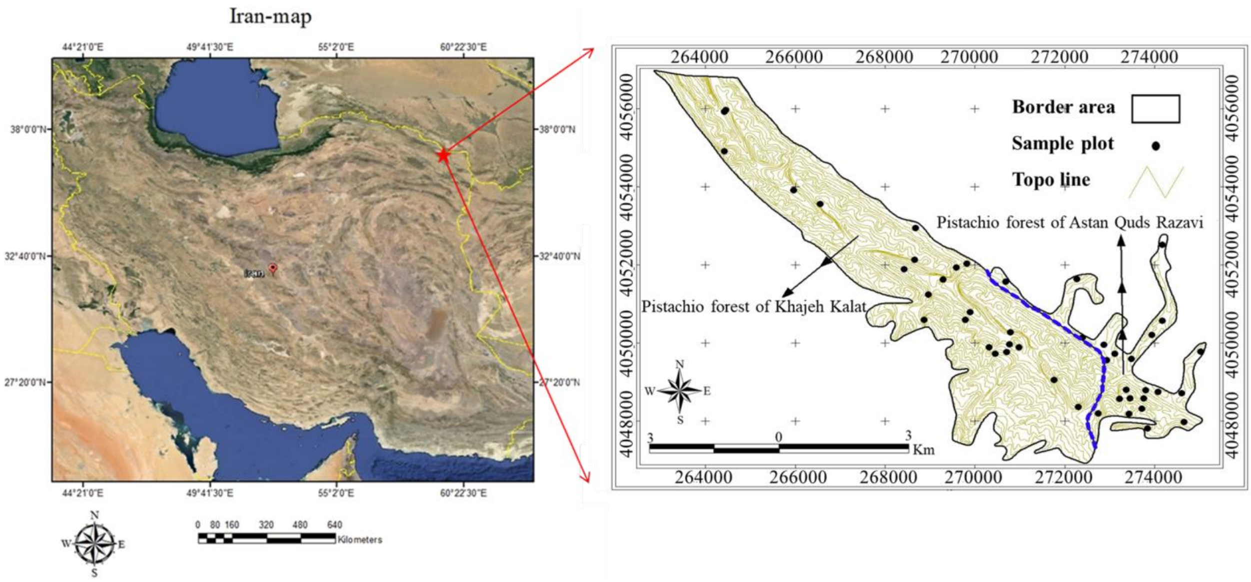

Figure 1. The location of Pistachio forest that (belongs to two organizations; 1- Natural resources 2- Astan Quds Razavi) with GPS points of sample plot

The soil of the region is weakly alkaline with a pH of 7.5-7.8, clay texture and shallow structure with 20 to 47% sand (Table 1).

Table 1. The properties of Pistachio forest of Khajeh Kalat

	Properties	Condition
Pistachio region	Forest	7393 (ha)
	Rangeland	3100 (ha)
	Climate	Arid (DoMarton)
		Cold dry (Ambergeh)
	Soil	Weak alkaline 7.5-7.8 pH
		Clay with 20-47 % Sand

To conduct the research, first, a map of land units using the capability of Geographic Information System (GIS) was prepared (Ghorbani *et al*., 2021). A digital elevation model with a 10-meter pixel size from the topographic map for this purpose was prepared (Saboori *et al*., 2021). From the DEM, the elevation, slope, and direction classes' maps were prepared in the desired classes. So that the elevation map was created in two classes (1) 540-800 meters and (2) 800-1184 meters, slope map was created in three classes (1) 0-30%, (2) 60-30%, and (3) > 60% and the directional map was created in five classes: (0) flat, (1) north, (2) east, (3) south, (4) west (Figs 2, 3 and 4).

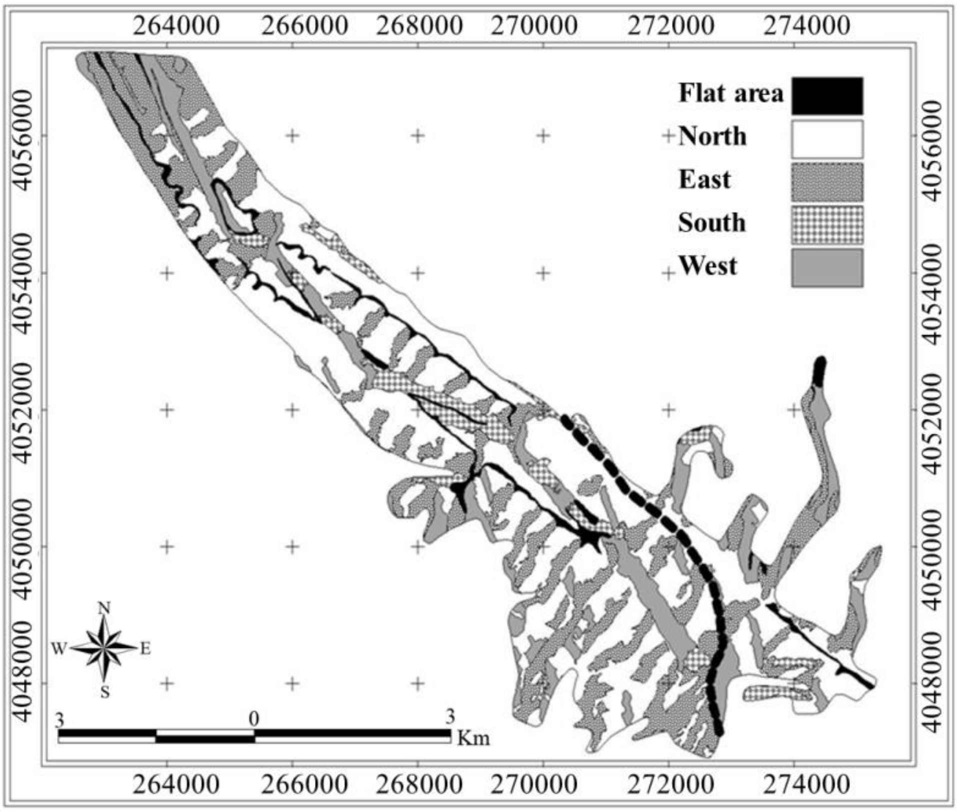

Figure 2. The aspect map

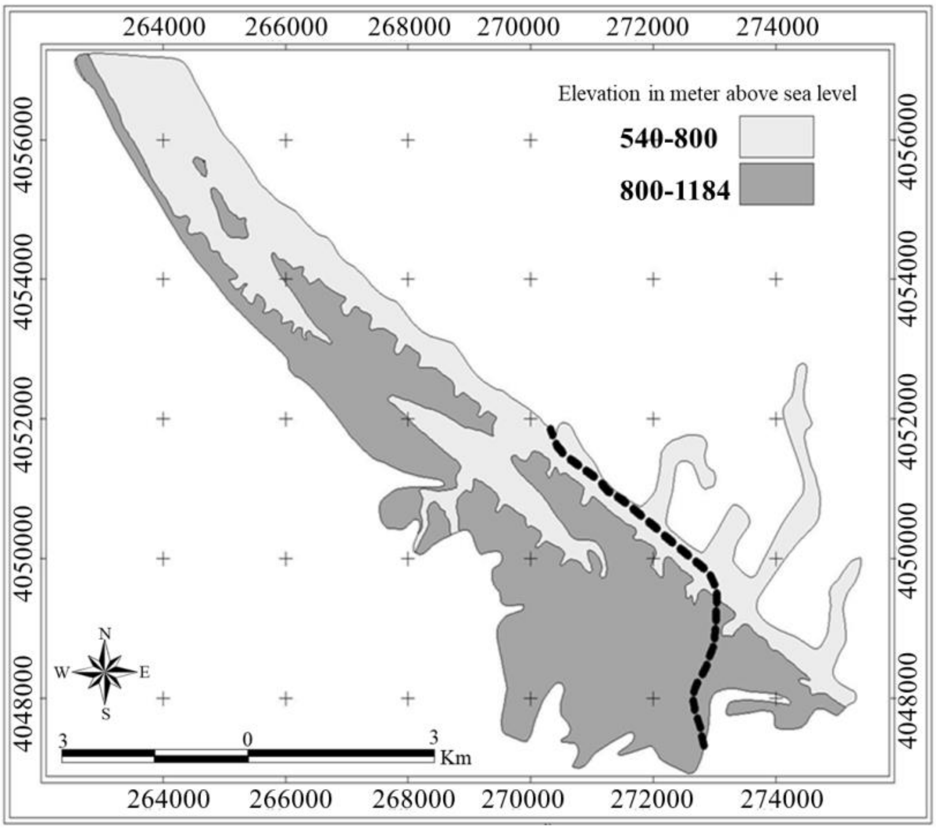

Figure 3. The elevation map

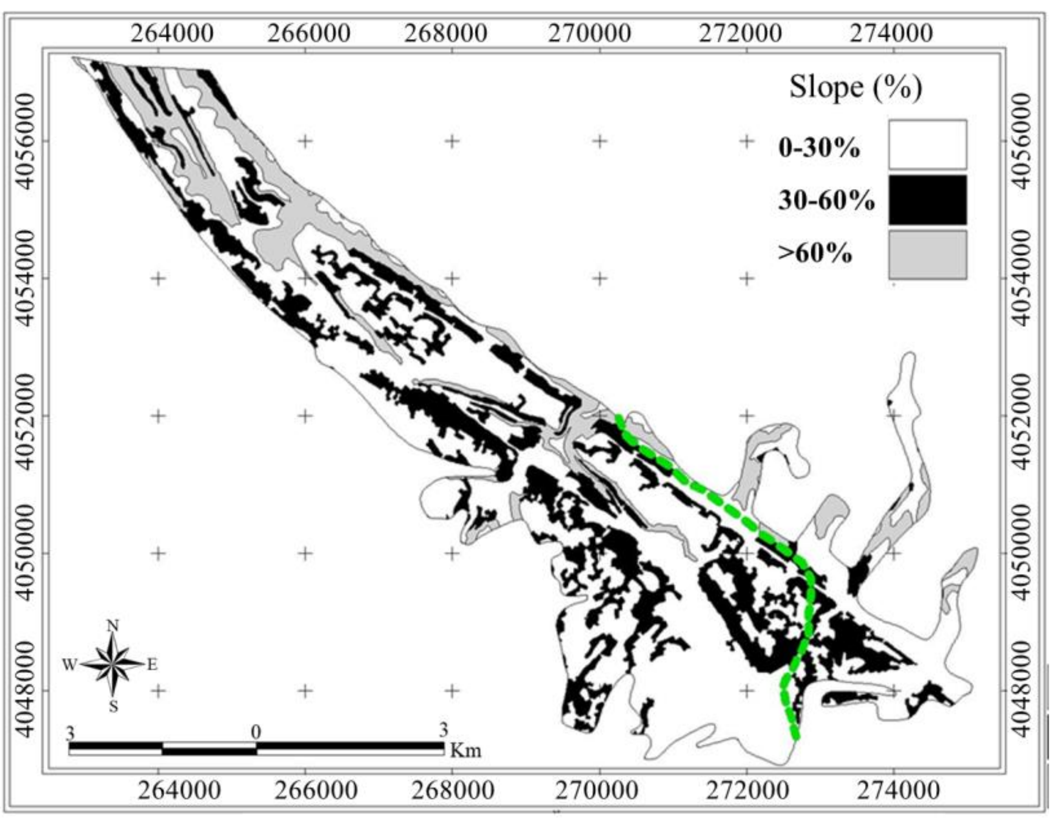

Figure 4. The slope map

Finally, the three maps were merged, and a map of landform units was obtained. The landform map includes aspect, elevation, and slope, respectively. For example, a unit with code 213 has an east, 540-800 meters and >60% (Table 2).

Table 2. The properties of the landform map

Landform map		
Aspect	Elevation	Slope
Flat =0	500-800(m) =1	0-30% =1
North =1	800-1184(m) =2	30-60% =2
East =2		>60% =3
South =3		
West =4		
For example: code 213= East, 540-800(m) and >60%		

It should be noted that no polygons with code 123 were found. Also, non-directional regions, i.e. with zero aspect code, were not considered from the census and counting list. In Total 23 work units were considered to do a survey (Fig. 5).

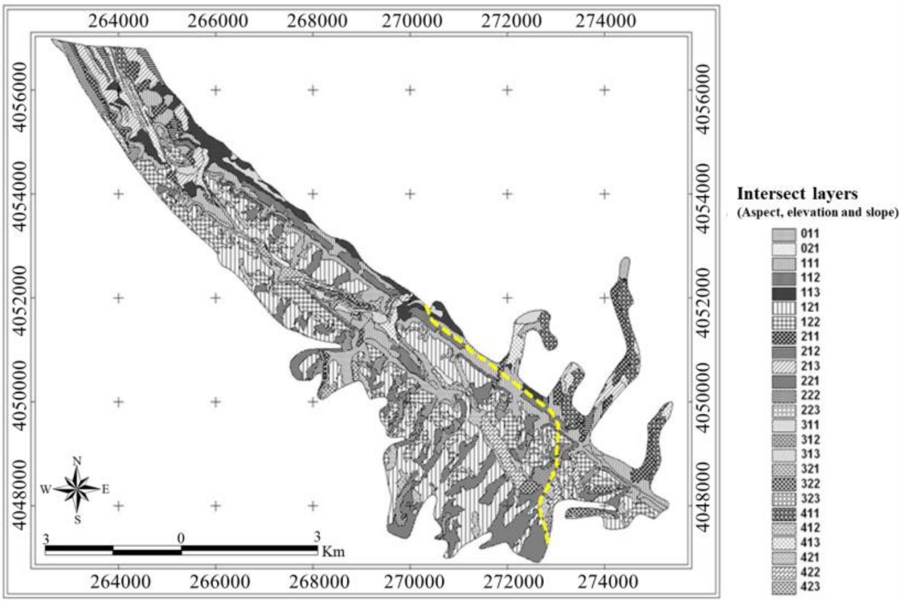

Figure 5. The intersect map of aspect, elevation, and slope

After preparing the landform map, units with similar topographic characteristics, soil and forest pasture cover density in the two enclosed and non-enclosed regions were determined and GPS distribution points on the map were prepared (Fig. 6). In these 23 GPS points in both enclosed and non-enclosed regions, sample plots with variable regions that had at least 15 trees were selected (Khanalizadeh *et al*., 2020). In plots with a region of 1 square meter, rodent nests under the canopy of 15 trees were identified and counted (Madden *et al*., 2019). The data obtained from the count including normality and homogeneity test were checked using the Bartlet homogeneity test and Anderson Darling normal test (Kluxen & Hothorn, 2020). Then they were analyzed in a factorial experiment with a completely randomized design in SAS software. Also, the correlation between rodent nest number and topography was calculated (Yuan *et al*., 2018).

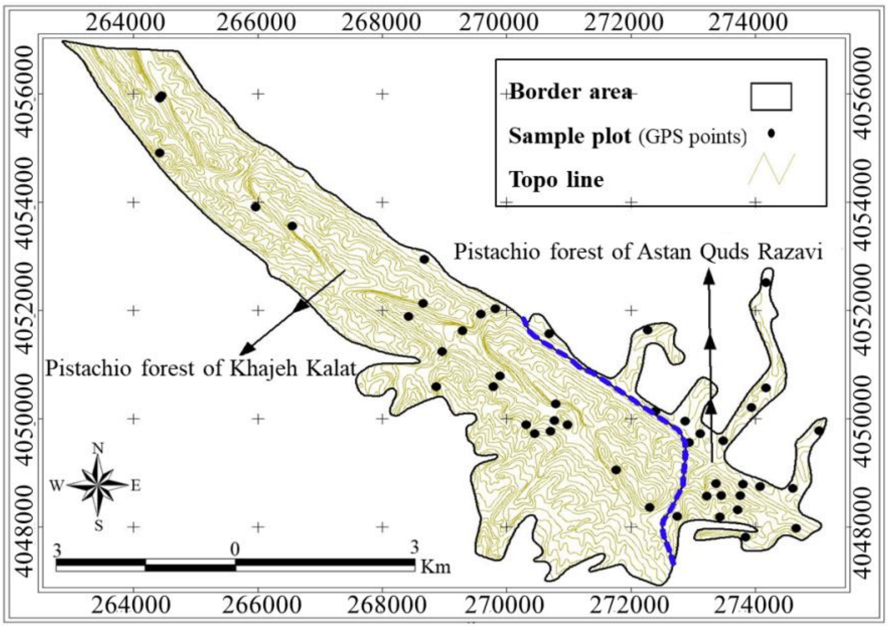

Figure 6. GPS distribution points (Sample plot)

Results

Analysis of variance of rodent nest in two enclosed and non-enclosed regions

The analysis of variance table of variable rodent nests in two enclosed and non-enclosed regions shows that the effect of aspect, height, slope, region (enclosed and non-enclosed), (aspect × height), (aspect × slope), (region × aspect), (height × slope), (direction × height× region) (region × aspect × slope) and (region × aspect × slope) are significant (Table 3).

Table 3. Analysis of variance of a variable number of rodent nests in a factorial experiment, (Region, Aspect, Elevation, and Slope)

Source of changes	Degrees of freedom	SS	MS	F test
Aspect	3	1.96	0.65	6.91 **
Elevation	1	0.67	0.67	7.10 **
Slope	2	0.75	0.37	4.01 **
Region	1	8.88	8.88	93.92 **
Aspect * Elevation	3	1.76	0.58	6.20 **
Aspect * Slope	6	3.69	0.61	6.51 **
Region * Aspect	3	3.63	2.21	23.36 **
Elevation * Slope	2	6.63	0.05	0.54ns
Elevation * Region	1	0.2	0.2	2.11ns
Slope * Region	2	0.76	0.38	4.06 **
Aspect * Elevation * Slope	6	2.33	0.38	4.10 **
Aspect * Elevation * Region	3	2.41	0.8	8.40 **
Region * Aspect * Slope	6	5.75	0.92	9.82 **
Region * Elevation * Slope	2	0.15	0.07	0.84ns
Region * Aspect * Elevation * Slope	6	4.43	0.73	7.80 **
Error	672	63.6	0.094	
Total	719	103.95		

SS= Sum of Squares, MS=Mean Square ** Significant at 1%, * Significant at the 5%, and ns: not significant

Due to the significance of these factors, the comparison of the mean of these factors is shown separately in Figures 7-10. Comparison of the mean number of rodent nests in the two regions showed that the enclosed Region is significantly different from the non-enclosed regions (Fig. 7).

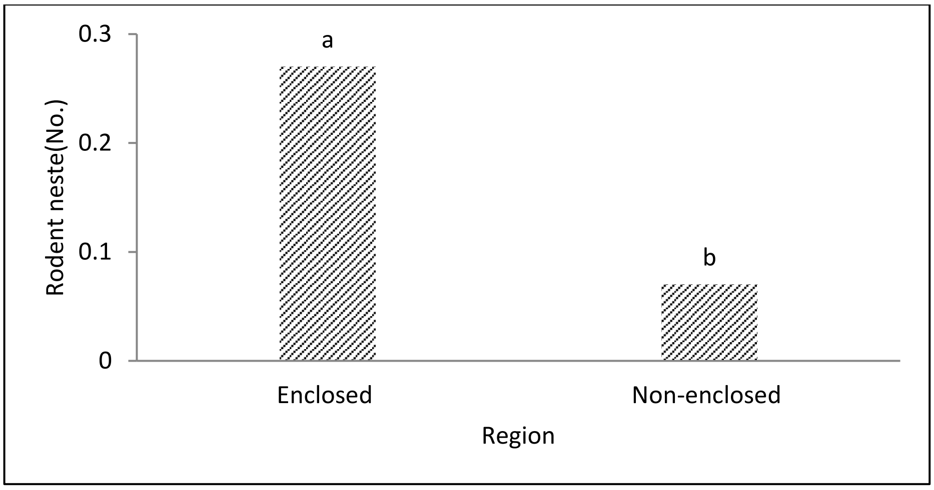

Figure 7. Comparison of mean number of rodent nests in two Region s with Tukey test (P <0.05)

Comparison of the mean number of rodent nests in the two altitude classes shows that the number of rodent nests in these two altitude classes is significantly different so that the number of rodent nests at high altitudes is higher than low altitudes (Fig. 8).

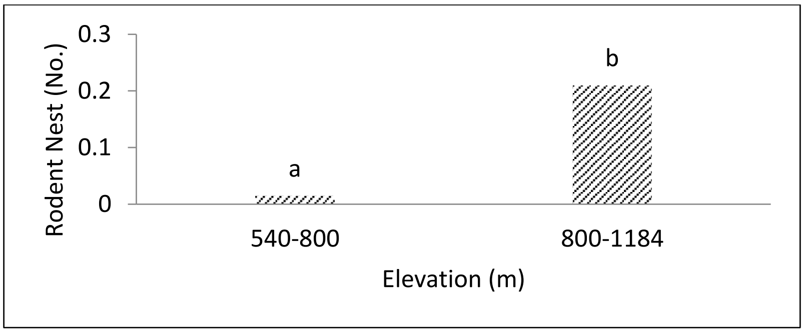

Figure 8. Comparison of the mean number of rodent nests in two elevation classes with Tukey test (P <0.05)

Comparison of the mean number of rodent nests in three slope classes (30%-0%), (60%-30%), and (60%-30%) shows that these three slope classes do not differ in terms of the number of nests. But, class 1 and class 3 were significantly different from each other (Fig. 9).

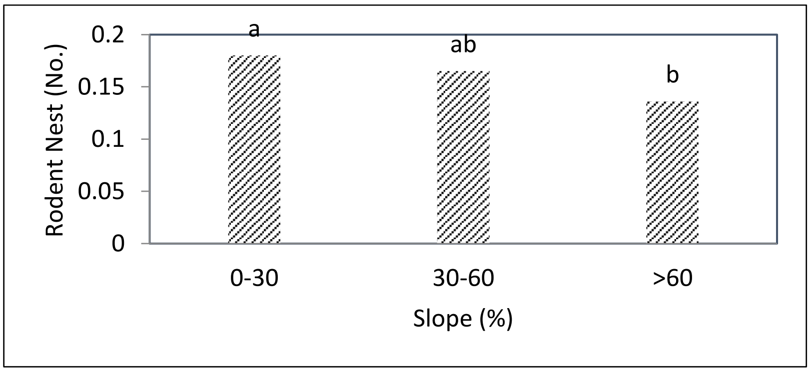

Figure 9. Comparison of the mean number of rodent nests in three slope classes with Tukey test (P <0.05)

Comparison of the mean number of rodent nests in the four aspect classes shows that the north, east and west aspects have significant differences. Subsequently, the north and south aspects do have not a significant relationship (Fig. 10).

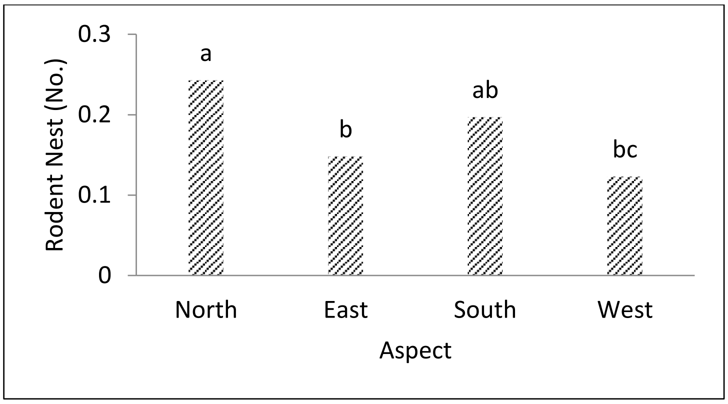

Figure 10. Comparison of the average number of rodent nests in four aspect classes with Tukey test (P <0.05)

Therefore, the correlation between the number of rodent nests and topography shows that the south direction has a high correlation concerning other topographic factors (Table 4).

Table 4. Simple regression coefficient between rodent nest and topography (Aspect, Elevation, and slope)

Variable	Rodent Nest	R2
Aspect	North	0.41
	East	0.13
	South	0.73
	West	0.03
Elevation	500-800 (m)	0.27
	800-1184 (m)	0.3
Slope	0-30%	0.41
	30-60%	0.44
	>60%	0.24

Discussion

In this study, it was found that the number of rodent nests in the enclosed region is more than in the non-enclosed region. Also at higher altitudes, low slopes, and north direction, the number of nests is more. As mentioned, mammalian rodents are herbivores and it is natural for their spread to be affected by factors affecting the growth and density of vegetation. In the restricted region, which is managed under the supervision of the Natural Resources Department, the measures taken to protect the region and prevent the entry of exploiters will naturally increase the number of rodent nests. In poorer vegetation, lack of protection against predators, access to food for small mammals is more difficult and dangerous. One of the most effective factors in the distribution of these small mammals, which have high activity and metabolism, is rainfall. Because the climate of the region is arid according to the Domarton classification, precipitation is a limiting factor and directly and indirectly affects the distribution of rodents (Dantas *et al*., 2021). It can be said that with increasing altitude, rainfall increases, and the production and density of vegetation increases. The same conditions exist in the heights of the study area, which has led to the reproduction of rodents (Sharaby *et al*., 2020). According to Ghorbani *et al*. (2021); Kluxen & Hothorn (2020); Madden *et al*. (2019) the results are in line with the findings of the mentioned researchers. Fluctuations in the density of different species of rodents in one place are usually not simultaneous, and this is related to the specialized reactions of the species to the events of life. On the other hand, because reproduction is one of the most costly activities in female mammals, caloric intake, especially for small mammals such as rodents, plays a major role in reproduction. Rodent nest distribution is also related to the soil characteristics of the region, and rodents prefer deeper, more fertile soils with a lighter texture and better drainage so that they can dig in easily and rain does not flood their nests (Sharaby *et al*., 2020). The slope factor is related to soil depth. As the slope increases, the soil depth decreases, so the number of rodent nests is higher on lower slopes that have deeper soil (Li *et al*., 2018). Slope also has an effective role in runoff, infiltration, flood intensity, erodibility, and sedimentation which are not ineffective in rodent release. The north and south aspect are more suitable for rodents due to their moisture and shading and better soil for nesting, and therefore the number of nests in the north and south aspects is higher than in another aspect.

Conclusion

Therefore, it can be acknowledged that with the change in the topographic characteristics of the region (elevation, slope, and aspect), vegetation changes, and with the change of vegetation, the distribution of animal communities, especially herbivores, changes. Of course, other factors also affect rodent distribution, including social interactions and ecological relationships between species, competition, hunting, and human activities.

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