Factors influencing the presence of rodents in olive agrosystems in southern Tunisia using occupancy models

Karama Ettiss [1,2*], Mohsen Chammem [1], Touhami Khorchani [1]
[1]*Laboratoire d'Elevage et de la Faune Sauvage, Institut des Régions Arides de Médenine, Médenine 4119 – Tunisia*
[2]*Institut National agronomique de Tunis – Université de Carthage, 43 Avenue Charles Nicolle, Tunis 1082– Tunisia*
**Corresponding author: Karama Et*tiss .hopefulmednino@hotmail.fr
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1 ABSTRACT
The identification of the factors associated with patch occupancy is particularly important to understand how animal species are distributed. This study investigated the habitat variables affecting the distribution of rodents in olive agrosystems and their relative impact. Thirty (30) stations for trapping rodents were identified. At each station, an area of one-hectare surface was selected and 20 snap traps were used between early November 2015 and February 2016 in olive agrosystems. The objective of this process was to collect presence/absence data and to identify major species that occupied such a landscape. Regarding site covariates potentially affecting rodent detection, Clay%, Silt %, Sand %, calcium carbonate%, Organic matter and distance from urban area were measured. A total of 68 individuals belonging to two species, namely *Psammomys obesus (*The fat sand rat) and *Meriones libycus* (The Libyan jird*)* were caught. Using a likelihood-based approach, it was found that rodents avoided loamy soils with high $CaC0_3$ rate and preferred landscapes with important distance from the urban area. These findings may be useful by state and farmers for planning decisions to preserve agriculture.

2 INTRODUCTION
The southern Tunisia is subjected to the continuous expansion of agricultural lands. Huge areas, including marginal one, are used for cultivation. The agriculture is focusing on the cereal cultivation, market gardening and olive production. On the other hand, the conversion of natural ecosystems into agricultural land leads to deep changes in the environmental components. Southern Tunisia hosts a multitude of small mammals, among which the rodent group is the most diverse and can be part of agricultural land. However, many rodent species are often considered a significant problem for agricultural ecosystems as they can cause damage to the land and crops. Thus, rodent pest management is necessary for the sustainability of agricultural and environmental resources. For this purpose, certain issues such as the rodent species composition and the occupancy factors affecting the rodent distributions in landscapes should be clarified. Our study focused on the species of rodent present in a sample of 30 stations from southern Tunisia. In particular, interest was in the occupancy of the main species inhabiting the olive agrosystems. Indeed, (1) occupancy could help to understand changes in species distributions (Gibbs *et al.,* 1999), and (2) it is

considered as the state variable of interest to wildlife managers assessing the impacts of management actions (Mazerolle *et al.,* 2005). Recent papers have emphasized that reliable inferences from these types of studies require estimating occupancy from the detection-non detection (presence-absence) data in a way that deals with imperfect detection (Moilanen, 2002; Gu and Swihart,2004; MacKenzie and Royale, 2005). Estimating occupancy itself can be modelled as a function of site covariates, and can therefore help to elucidate those affecting species distributions and is a decision-making tool for decision making for future management by farmers. In the literature, there are several studies that describe the factors that affect the ecology of rodents, including the soil structure that was important (Booth, 1960; Ajayi and Tewe, 1978; Yeboah and Akyeampong, 2001). On the other hand, the interest in the ecological effects of roads on ecosystems and landscapes has increased, evidenced by a number of review papers published in scientific journals and edited volumes (Trombulak and Frissell, 2002). Moreover, the effect of urbanization on the density of an animal population, was another factor that may be in favour of the density of a population (Riley *et al.,* 2006), as it can disturb animals presence (Merenlender *et al.,* 2009). Due to the lack of information on rodent species especially in the olive ecosystem, many site related covariates were taken and this study tries to clarify the relationship between occupancy of rodent species and human occurrence throughout urban area and road presence, and to confirm if organic matter and soil texture can affect their presence.

3 MATERIALS AND METHODS

3.1 Study area: The investigation was conducted over 4 months within an area of the south-eastern of Tunisia (Medenine and Tataouine) covering an area of 60973 km² (37.2% of the country) (Fig 1). The area studied was from Djerba (33°45'N, 10°47'E) and Fjaa (33º30'N, 10º38'E) in the north to Ferech (32º57'N, 10º21'E) and Bir Amir (32º34'N, 10º16'E) in the south and the elevation of the study area ranges from 424 to 1m above sea level. The climate is arid to hyper-arid-Saharan. The mean temperatures range from 10 to 12 °C in winter, 18 to 20 °C in spring, 30 °C in summer and 20 to 22 ° C in autumn. The number of rainy days is relatively low, but the intensity of the rains is very high. Over the last few decades, the south-eastern Tunisia has undergone a series of changes related to public and private interventions notably: the development of irrigated agriculture characterized by the predominance of arboriculture.

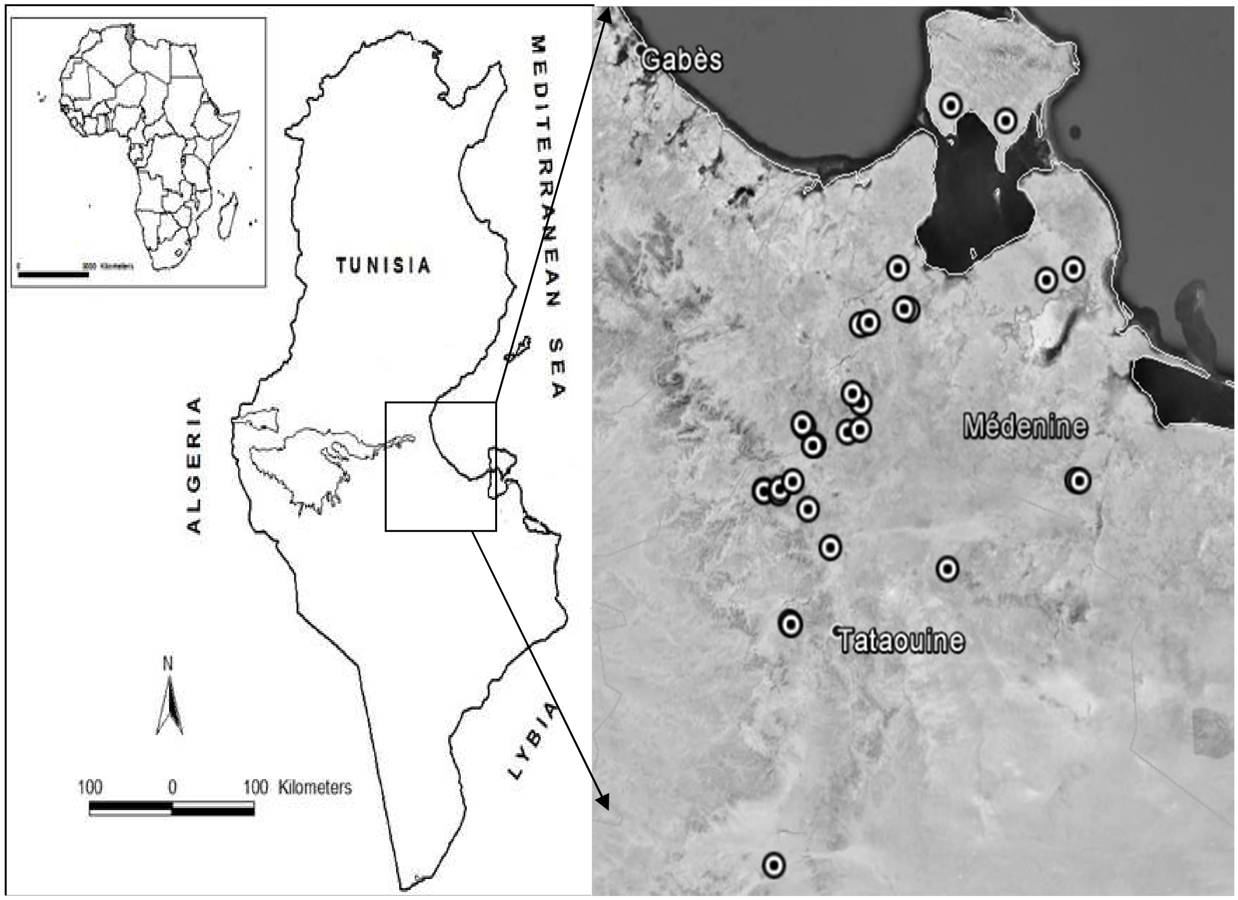

Figure 1: Locations and maps of the study areas

3.2 Data collection: Rodent populations were studied on olive (*Olea europea*) agrosystems between early November 2015 and February 2016 corresponding to the harvesting stage, and because the main interest was to identify rodents that are a threat olive fruits, we tried to focus trapping exactly in this period when the fruit became mature and the damage of this animals became clear. The difference would be observed between two olive trees, one with the presence of several burrows around the trunk and where there is absolutely no fruit on the ground and the other without burrows and where the ground is covered by fallen fruits. In particular, rodent species that damaged olive fruit were identified. Thirty stations were selected for the placement of the traps. At each station, a one hectare surface area was selected and 20 snap traps were used, giving a total of 600 trapping sites. Traps baited with biscuit dough were spaced 1–3 m apart on each station and they were placed only for two consecutive days in the burrow entrances showing signs of activity, to not disturb a lot the rodent that his presence will be useful to us in other subsequent studies concerning the quantification of the damage it causes in olive fields.

3.3 Rodent identification: To make identification of species causing damage, a sample of sand in the area was studied first to look for signs of rodent activity in particular burrows. In addition, this study looked for cuttings of grass or plant material in the field and near the burrow entrances. Snap traps are used to catch rodent species damaging the crop. At the laboratory, the specimens captured were identified based on morphological parameters and the characterization of the bristle (Incorvaia, 2004). All specimens were kept in the refrigerator for further studies. During trapping, distance from the urban area 'UA' was recorded. In each landform encountered, soil samples were taken at a depth of 0-45 cm, considered the deepest for most rodent burrows (Brabers, 2012). Soil samples were analysed in the laboratory for texture (percent of clay 'CLAY', percent of silt 'SILT' and percent of sand 'SAND', organic matter 'OM' and actif $CaCO_3$'ACTCAL'.

3.4 Data analysis: The single-season model available in the PRESENCE program was applied to estimate occupancy of rodents together and of each species identified alone. All possible occupancy models based on different combinations from the six sites covariates were executed. The models created were ranking using the Akaike Information Criterion (AIC). ΔAIC values were computed to give the difference in AIC scores between each model compared to the best model. Models with the lowest AIC were considered best supported by the data (Burnham and Anderson, 2002). Moreover, AIC was employed to calculate Akaike weights as an indication of the explanatory power of each model (Burnham and Anderson 2002; Wintle *et al.,* 2003). Finally, the average of all models was used to estimate the proportion of occupied sites and the standard error as proposed by Burnham and Anderson (2002) and Wintle *et al.,* 2003.

4 RESULTS

A total of 68 individuals of rodents were captured. *Psammomys obesus* and *Meriones libycus* were the two commonly caught rodent species. The trapping success (number of captures/number of trap nights) was 14.66 % for *Meriones libycus* and 8% for *Psammomys obesus.*

4.1 Meriones libycus* occupancy*: Twenty-five models are ranked and the best model was a combination between two covariates: distance from urban area and active $CaCO_3$ level (Table 1, Table 4). According to the data collected, the estimated naïve occupancy was 53.33%.The constant occupancy and detection model[ψ (.) p (.)] showed an occupancy of 57.67 ± 10.08% with detection probability at12.14 ± 1.99%.The model's average occupancy value was 54.5 ± 11.4% and the total weights for each covariate namely percent of clay 'CLAY', percent of silt 'SILT', percent of sand 'SAND', actif $CaCO_3$ 'ACTCAL', organic matter 'OM' and distance from urban area 'UA' were 39.25%, 34.98%, 0%, 58.47% ,30.69% and 72.36%, respectively.

Table 1: Estimated *Meriones libycus* occupancy (Ψ ±SE) and detection probability (*p*±SE)

Model	AIC	deltaAIC	AIC wgt	N	φ(±SD)	P±SE
psi (UA+ACTCAL),p(.)	287.44	0.00	0.1340	3	0.510±0.111	0.125±0.0194
psi(UA+ACTCAL+SILT),p(.)	287.71	0.27	0.1171	4	0.503±0.157	0.124±0.0196
psi(UA+ACTCAL+OM),p(.)	288.30	0.86	0.0872	4	0.530±0.140	0.125±0.0195
psi(UA),p(.)	288.32	0.88	0.0863	2	0.617±0.059	0.121±0.0196
psi(CLAY+SILT+ACTCAL),p(.)	288.93	1.49	0.0636	4	0.444±0.132	0.126±0.0194
psi(UA+CLAY),p(.)	289.11	1.67	0.0581	3	0.575±0.096	0.123±0.0196
psi(CLAY+SILT+UA),p(.)	289.17	1.73	0.0564	4	0.603±0.122	0.123±0.0196
psi(UA+ACTCAL+CLAY),p(.)	289.18	1.74	0.0561	4	0.503±0.134	0.126±0.0194
psi(UA+ACTCAL+OM+CLAY),p()	289.77	2.33	0.0418	5	0.524±0.160	0.125±0.0194
psi(ACTCAL+OM),p(.)	289.93	2.49	0.0386	3	0.528±0.134	0.122±0.0200
psi(UA+OM),p(.)	290.32	2.88	0.0317	3	0.617±0.108	0.121±0.0198
psi(UA+SILT),p(.)	290.32	2.88	0.0317	3	0.619±0.087	0.121±0.0198
psi(OM+CLAY+SILT),p(.)	290.93	3.49	0.0234	4	0.629±0.151	0.115±0.0204
psi(OM+CLAY+UA),p(.)	290.94	3.50	0.0233	4	0.592±0.134	0.123±0.0197
psi(CLAY+SILT),p(.)	290.97	3.53	0.0229	3	0.540±0.100	0.123±0.0196
psi(OM),p(.)	291.14	3.70	0.0211	2	0.607±0.081	0.120±0.0201
psi(.ACTCAL+OM+CLAY),p(.)	291.58	4.14	0.0169	4	0.528±0.160	0.122±0.0201
psi(OM+CLAY),p(.)	291.80	4.36	0.0151	3	0.587±0.128	0.120±0.0202
psi(ACTCAL+SILT),p(.)	291.96	4.52	0.0140	3	0.468±0.117	0.125±0.0195
psi(.),p(.)	292.04	4.60	0.0134	2	0.576±0.100	0.121±0.0199
psi(SILT),p(.)	292.10	4.66	0.0130	2	0.550±0.069	0.122±0.0196
psi(ACTCAL,p(.)	292.38	4.94	0.0113	2	0.454±0.089	0.125±0.0195
psi(CLAY),p(.)	292.49	5.05	0.0107	2	0.476±0.060	0.124±0.0194
psi(OM+SILT),p(.)	293.12	5.68	0.0078	3	0.510±0.134	0.125±0.0217
psi(ACTCAL+CLAY),p(.)	294.37	6.93	0.0042	3	0.510±0.135	0.125±0.0218

Table 4: Beta estimates, standard errors, and 90% confidence intervals of the covariates used in modelling *Meriones libycus* occupancy.

Covariable	β	SE	90%	
Distance /UA	0,438	0,329	-0,056	1,022
Actif $CaCO_3$	-0,066	0,037	-0,127	-0,005
Silt%	0,036	0,025	-0,005	0,077
Clay%	-0,622	0,481	-1,41	0,166
Organic matter	0,002	0,003	-0,172	0,426

***4.2 Psammomys obesus* occupancy:** Twenty-three models were ranked and the best one was simple with one variable distance from the urban area and constant detection probability (Table 2, Table 5). According to data collected, the estimated naïve occupancy was 50%.The constant occupancy and detection model showed a mean occupancy rate of 68.61 ± 15.57% and a detection probability of 6.32 ± 1.70%. The model's average occupancy value was 58.6 ± 14.1% and the total weights of each covariate namely percent of clay 'CLAY', percent of silt 'SILT', percent of sand 'SAND', active $CaCO_3$ 'ACTCAL', organic matter 'OM' and distance from urban area 'UA' were 28.66%, 20.92%, 0%, 39.1%, 51.21% and 51.5%, respectively.

Table 2: Estimated *Psammomys obesus* occupancy (Ψ ±SE) and detection probability (*p*±SE)

Model	AIC	deltaAIC	AIC wgt	N	φ(±SD)	P±SE
psi(UA),p(.)	213.83	0.00	0.1072	2	0.609±0.069	0.0693±0.0155
psi(ACTCAL+OM),p(.)	213.90	0.07	0.1036	3	0.591±0.173	0.0696±0.0166
psi(OM),p(.)	214.07	0.24	0.0951	2	0.729±0.130	0.0607±0.0154
psi(UA+ACTCAL),p(.)	214.87	1.04	0.0638	3	0.518±0.138	0.0747±0.0167
psi(UA+ACTCAL+OM),p(.)	214.89	1.06	0.0631	4	0.532±0.156	0.0730±0.0170
psi(UA+ OM),p(.)	215.24	1.41	0.0530	3	0.681±0.150	0.0650±0.0165
psi(.),p(.)	215.48	1.65	0.0470	2	0.686±0.155	0.0632±0.0170
psi(OM+ SILT),p(.)	215.56	1.73	0.0452	3	0.668±0.166	0.0647±0.0167
psi(UA+ SILT),p(.)	215.57	1.74	0.0449	3	0.571±0.122	0.0717±0.0456
psi(ACTCAL+OM+CLAY),p(.)	215.61	1.78	0.0440	4	0.594±0.168	0.0694±0.0167
psi(UA+ CLAY),p(.)	215.69	1.86	0.0423	3	0.631±0.110	0.0680±0.0158
psi(CLAY+ SILT+ UA),p(.)	216.03	2.20	0.0357	4	0.548±0.140	0.0726±0.0160
psi(OM+ CLAY),p(.)	216.06	2.23	0.0352	3	0.726±0.160	0.0608±0.0156
psi(UA+ACTCAL+CLAY),p(.)	216.13	2.30	0.0340	4	0.529±0.162	0.0742±0.0166
psi(UA+ACTCAL+ OM+CLAY),p(.)	216.51	2.68	0.0281	5	0.562±0.190	0.0730±0.0461
psi(OM+ CLAY + SILT),p(.)	216.72	2.89	0.0253	4	0.617±0.183	0.0687±0.0170
psi(CLAY),p(.)	216.81	2.98	0.0242	2	0.547±0.070	0.0711±0.0157
psi(UA+ACTCAL+ SILT),p(.)	216.86	3.03	0.0236	4	0.520±0.178	0.0745±0.0169
psi(ACTCAL),p(.)	217.22	3.39	0.0197	2	0.473±0.112	0.0750±0.0167
psi(OM+ CLAY + UA),p(.)	217.24	3.41	0.0195	4	0.683±0.177	0.0649±0.0165
psi(SILT),p(.)	217.27	3.44	0.0192	2	0.494±0.086	0.0738±0.0162
psi(CLAY+ SILT),p(.)	217.72	3.89	0.0153	3	0.491±0.109	0.0745±0.0160
psi(ACTCAL+ CLAY),p(.)	218.36	4.53	0.0111	3	0.483±0.141	0.0747±0.0166

Table 5: Beta estimates, standard errors, and 90% confidence intervals of the covariates used in modeling *Psammomys obesus* occupancy.

Covariable	β	SE	90%	
Distance / UA	0,373	0,202	0,042	0,704
Actif $CaCO_3$	-0,031	0,023	-0,069	0,007
% Silt	-0,006	0,010	-0,02	0,01
% Clay	0,24	0,37	-0,36	0,84
Organic matter	0,542	0,415	-0,138	1,222

4.3* Rodent occupancy*: Single-season occupancy models showed that the estimated naïve occupancy for both species taken together was 63, 33%.The constant occupancy and detection model calculated an occupancy rate of 64.71 ± 9.02% and a detection probability of 17.51 ± 2.02%.The top ranked from the 12 candidate models according to AIC score indicates that the occupancy probability varied with percent of CLAY, percent of SILT and UA. The model's average occupancy value was 64.7 ± 9.6% and the total weights for each covariate namely percent of 'CLAY, percent of 'SILT', percent of 'SAND', 'ACTCAL', 'OM' and 'UA' were 45.16%, 62.14%, 0%, 0%,28.16% and 91.67%, respectively. Results showed that 'UA' and the 'SILT' percent have a significant effect on rodent occupancy. In fact, the confidence interval of these covariates did not overlap zero (Table 3, Table 6).

Table 3: Estimated rodent occupancy (Ψ ±SE) and detection probability (*p*±SE)

Model	AIC	deltaAIC	AIC wgt	N	φ(±SD)	P±SE
psi(CLAY+SILT+UA),p(.)	393.47	0.00	0.3032	4	0.636±0.109	0.1764±0.0200
psi(UA),p(.)	394.62	1.15	0.1706	2	0.673±0.056	0.1755±0.0202
psi(UA+SILT),p(.)	394.80	1.33	0.1559	3	0.579±0.092	0.1761±0.0201
psi(UA+OM+CLAY+SILT),p(.)	395.07	1.60	0.1362	5	0.653±0.133	0.1763±0.0200
psi(UA+CLAY),p(.)	396.55	3.08	0.0650	3	0.681±0.088	0.1754±0.0202
psi(UA+OM),p(.)	396.59	3.12	0.0637	3	0.680±0.092	0.1755±0.0202
psi(OM+CLAY+SILT),p(.)	398.28	4.81	0.0274	4	0.625±0.127	0.1754±0.0202
psi(OM+CLAY+UA),p(.)	398.54	5.07	0.0240	4	0.684±0.123	0.1754±0.0202
psi(OM),p(.)	398.75	5.28	0.0216	2	0.650±0.079	0.1747±0.0203
psi(.),p(.)	399.69	6.22	0.0135	2	0.647±0.090	0.1751±0.0202
psi(CLAY),p(.)	400.35	6.88	0.0097	2	0.580±0.056	0.1760±0.0201
psi(OM+CLAY),p(.)	400.52	7.05	0.0089	3	0.659±0.110	0.1748±0.0203

Table 6: Beta estimates, standard errors, and 90% confidence intervals of the covariates used in modelling Rodent occupancy.

Covariable	β	SE	90%	
Distance / UA	0,949	0,555	0,039	1,859
% Silt	-0,068	0,037	-0,12	-0,008
% Clay	1,274	0,877	-0,164	2,712
Organic Matter	0,087	0,132	-0,129	0,303

5 DISCUSSION

This paper investigated the habitat characteristics and the occupancy rates of *Meriones libycus* and *Psammomys obesus* that were the only species found for olive agrosystems in southern Tunisia. The likelihood-based method showed that the presence of each species alone was related to calcium carbonate ($CaCO_3$) and to the distance from urban area, respectively. The occupancy probability of both species together is strongly affected by the distance from urban area and the SILT. The significant effect of calcium carbonate on the *Meriones libycus* occupancy is consistent with previous results reported by Adamou et al. 2009 for Meriones shawii in the cultivated fields of Algeria. Duchaufour (1995) reported that these chemical elements inhibit the absorption of certain nutrients like the phosphorus, the potassium and the iron. This phenomenon can lead to a lower fertility of the ground and therefore a nutritional deficit for *Meriones libycus*. Soil quality is indeed important to deal with plant communities and growth, and non-fertile soils are not able to sustain neither agricultural plant nor spontaneous vegetation necessary to satisfy the nutritional requirements of herbivores like rodents. Furthermore, the calcium carbonate richness could make the soil less compact and weak and thus decrease the ability of rodent to build burrows. As the aggregation property of soil particles depends on the forces exerted between constituent minerals causing the swelling of the particles, Rimmer and Greenland (1976) argued that the presence of some mineral such as the calcium carbonate could limit the particles aggregation. The other site-covariates considered in this work did not predict the occupancy rate of *Meriones libycus*. This could be explained by the fact that this species is generalist and has therefore large dispersal ability and the exibility to exploit various habitat types. According to

Niethammer (1985), generalist species such as *Jaculus jaculus*, *Meriones libycus* and *Meriones crassus* appear to be the most successful in terms of geographical distributions throughout the southern Palaearctic desert belt. Unlike *Meriones libycus, Psammomys obesus* occupancy depends only on the distance from the urban area. This species is unable to inhabit urban landscape characterized by the scarcity of food, mainly the *Chenopodiaceae* for the survival. This result is consistent with the view that rodent communities and bird communities decrease in species diversity, richness and native species representation with increasing human pressure and urban conditions (Babinska-Werka *et al.,* 1979; Melles *et al.,* 2003; Palomino and Carrascal, 2006; Regino *et al.,* 2008). A plausible explanation for such result is the effect of domestic and commensal predators on rodents in the agrosystems near the urban edges. In this regard, several previous studies indicated the impact of urban predators, especially domestic cats (Felis catus), on rodent populations (Barratt, 1997; Hall *et al.,* 2000). As rodent pests causing losses to olive, the distribution of both species, was only affected by soil properties. The occupancy analysis showed the lower preference for loamy soil of these two rodent species taken together. The importance of such parameter in rodent population ecology was underlined by several previous studies (Booth, 1960; Ajayi and Tewe, 1978; Yeboah and Akyeampong, 2001). It was reported that the soil texture is a primary factor limiting the distribution of some fossil mammals (Hardy, 1945; Miller, 1964). The two species are more likely to prefer sandy soils and to avoid silty ones (Khemiri *et al.,* 2017). Obtained results indicated that it is likely that during dry seasons silty soils become more hard and difficult to work, hence difficult to dig burrows for rodents. This is in agreement with other studies mentioned that rodents avoid digging burrows in compacted areas to reduce energy use (Lovegrove and Wissel, 1988; Romanach, 2005; Luna and Antinuchi, 2006). Generally, loamy soils are not preferred for some rodent like *Psammomys obesus* and *Meriones libycus* because they compact easily in dry regions. Loamy soils are however preferred for other species. In this respect, Jhon *et al.,* 1993, suggested that burrows of Wyoming ground squirrels (*Spermophilus elegans*) were deeper, longer, and more complex as percentage of silt increased. In addition, the volume, length, and complexity of kangaroo rat (*Dipodomys ordii*) burrows were greater in soils with higher amounts of silt. For Adamou-Djerbaouiz et al. 2009, there is no clear relation between the silt rate in the soil and the pullulation level of Meriones shawii. Overall, the present study showed that in southern Tunisia *Olea europea* agrosystems the occurrences of *Meriones libycus* and *Psammomys obesus* are affected by the soil texture and the anthropic activity. Indeed, these species seem to avoid landscapes with loamy soils rich in $CaCO_3$ and those within and near urban areas. Despite the small sample size, this study is the first step towards enhancing our understanding of rodent occupancy and abundance in crops that maintain a large surface area in arid regions. Thus, if they have to be sustainable, farming in such area under many kinds of stress need to be managed. Therefore, the management program would incorporate a variety of tools and solutions. One of the factors that require much higher priority is how to prevent rodent attack.

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