

Diversity of small terrestrial mammals under different organic farming managements in Mediterranean and Continental agriculture ecosystems

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With climate changes, soil-pollution and degradation, organic farming is communicated much more often. That is why more research about impact of organic farming has been appearing and developing. Aim of our research was to detect if there is any impact of organic farming on small terrestrial mammals such as has been found in other soil, plant and fauna. Nine localities, at which organic agriculture was practised, were studied and two localities were used as control samples. The research sites were located in the west of Slovakia and in Eastern Iberian Peninsula. They represent a typical Continental and Mediterranean areas. Forty-six individuals of seven species (*Apodemus sylvaticus*, *Mus musculus*, *Mus spicilegus*, *Mus spretus*, *Rattus* sp., *Crocidura russula*, *Crocidura suaveolens*) were recorded. The highest abundance was recorded at hedgerows in biodynamic vineyards and the most species at an ecotone of biodynamic vineyard and forest. At cultivated sites, we documented the highest number of species at biodynamic vineyard and biologically managed vineyard. The observed species show affiliation to different types of habitat which indicates the need of landscape heterogeneity to maintain diversity. The results signify the obligation to pay more attention to different types of organic farming, identify particular benefits and embrace the most suitable of them.

Keywords: small terrestrial mammals, organic farming, abundance, species richness

1 Introduction

Overcoming of ongoing climate change consequences requires transformation in landscape management and especially in farming and food production. Because of its many benefits (Bengtsson et al., 2005; Hole et al., 2005; Sandhu et al., 2010) organic farming could be one of the solutions, and that is why it has been recently subject of study more often. Organic farming supports the increase of diversity (Rosati et al., 2020; Brussaard et al., 2007). Diversity and its services help adapt to climate change by providing many opportunities for active carbon sequestration and emission reduction (Pierzynski & Brajendra, 2017; Daba & Dejene, 2018; Wolka et al., 2021). Obiora and Madukwe (2011) discussed importance of changing agriculture for mitigation of the climate changes and mostly the steps that should be taken to achieve improvement. They highly emphasise

sustainable agriculture, meaning e.g. better land and water management, integrated pest management or crop rotations characteristic for organic farming. The use of catch crops, mulches and cover crops contribute to reduce the soil losses, increase infiltration, avoid surface runoff and promote a diverse ecosystem in agriculture land (Keesstra et al., 2019; Cerdà et al., 2020; Guadie et al., 2020; López-Vicente et al., 2020; Rodrigo-Comino et al., 2020). Diacono et al. (2016) have made an important overview of beneficial practices that include hydraulic arrangement by a kind of ridge-furrow system, cash crop rotations, agro-ecological service crops (ASC) introduction, ASC termination techniques and organic fertilisation covered in organic farming. Their results, supporting the assumption as well, suggest that the applied agro-ecological principles help to sustain yield even with ongoing climate changes. Adding native habitats to semi-arid agrarian setting partially helped

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not only to protect less common species but also limited crop damage in orchard (Sullivan and Sullivan, 2018). On conventional farms, the widespread use of pesticides and herbicides reduce the soil and plant diversity (Oehl et al., 2004; Han et al., 2020; Aldebron et al., 2020) and induce degraded soils that yield high soil and water losses (Rodrigo-Comino et al., 2018; Novara et al., 2019).

The main purpose was to study the effect of organic farming in various management intensities within the two regions: Mediterranean in Eastern Iberian Peninsula and Continental in Slovakia. To investigate the impact of organic farming, small terrestrial mammals had been selected as indicator organisms. The applied concept is not completely new as already Gomez et al. (2017) used the same group for evaluating changes in agricultural ecosystems. The benefit of engagement of micromammals stands for its composition of different trophic levels – insectivores, herbivores and omnivores as well as relatively short life cycles of small terrestrial mammals. In addition, the organisms are very agile what indicates reliable and almost immediate reflection of changes and biotope conditions in the communities. The use of small mammals as biological and landscape change indicators has been used in other disciplines such as archaeology or paleontology (Khenzykhenova, 1996; Marco et al., 2019; Rick et al., 2013) where they are used as tracers of the climate and landscape change. Further, small mammals provide possible contributions in agricultural lands, as biological control of weed (Fisher et al., 2018) or serve as base for protection of apex predators.

Effects of organic farming on communities of small mammals are not studied widely and often. Only a few conducted studies including small terrestrial mammals were developed in Argentina (Coda et al., 2015), Denmark (Jensen et al., 2011) or Germany (Fisher et al., 2011). There are also some studies focused on small mammal biodiversity in orchards, for example by Chaiyarat et al. (2020) from Thailand, Balčiauskas et al. (2019) in Lithuania, Sullivan & Sullivan (2018) in Canada or Riojas-López et al. (2018) in Mexico. All of the studies were focused on differences in diversity between conventional and organic farming, possibly nearby natural habitats, though none of them surveyed disparity in different forms of organic farming. Although fauna belong to the key parameters used for understanding the impact of the land use and management on the ecosystem functioning and services (Sannigrahi et al., 2019), it is little discussed (Walmsley & Cerdà, 2017).

Investigation of the differences in number of species and abundance at various types of organically managed agricultural lands and ascertain where to lead ensuing

research, is the focus of the study. Farmland in Spain and Slovakia was analysed. Both of the countries have long agricultural history, agriculture has been crucial in the development of the societies, and the current landscape is the result of the agriculture expansion and management. The research took place in two contrasted ecosystems to shed light on the impact of climate, and because of the high importance and diversity of agriculture in Europe, where central Europe and the Mediterranean are the two largest agriculture ecosystems. Many types of organic as well as conventional farming can be found in both locations and its production is remarkable in Europe. The preliminary research includes different types of orchard and vineyards to obtain an overview of the impact of different types of organic farming. The main intensification and expansion of agriculture in Slovakia was the consequence of the socialist regime. However, Slovak viticulture has history over 2,500 years (Kalesný, 1972). Even though it was abandoned during previous regime, it has been recovering in past years. Nowadays, the studied localities are part of the recovering vineyard areas of viticulture after the abandonment. The viticulture is re-expanding again probably due to demand for local products and partially due to people leaning towards unconventional living and farming. In addition, growth of new markets such as China promotes creating of large-scale vineyard. Thus, there is a high potential in expanding of the vineyard area and consecutive impact on biodiversity, considering conventional large-scale as well as biological farming.

2 Material and methods

2.1 Studied localities and site selection

Number of localities (11) used for agricultural purposes were examined during the research, eight localities in Spain and three localities in Slovakia (Figure 1). In line with previous detailed fieldwork recognition and interviews with growers, nine patches of organically managed vineyards and orchards were chosen. Four orchard localities in Canals, Spain were established – young persimmon orchard (38° 58' 26.0" N 0° 34' 59.7" W) with abundant diverse vegetation undergrowth, old persimmon orchard (38° 58' 23.8" N 0° 35' 06.7" W) with low grass undergrowth, conventional persimmon (38° 58' 25.7" N 0° 35' 01.0" W) and orange orchard (38° 58' 25.4" N 0° 35' 02.0" W) with no undergrowth. In Slovakia, two localities of organic vineyard were studied – organic vineyard in Svätý Jur (48° 15' 02.7" N 17° 12' 02.0" E) that was left unmown and organic garden vineyard in Vinosady (48° 18' 22.2" N 17° 17' 07.6" E) that was tilled regularly. Also biodynamic vineyard in Moixent, Spain (38° 49' 21.9" N 0° 48' 20.2" W), that was tilled at the time of the research, with adjacent vineyard hedgerow

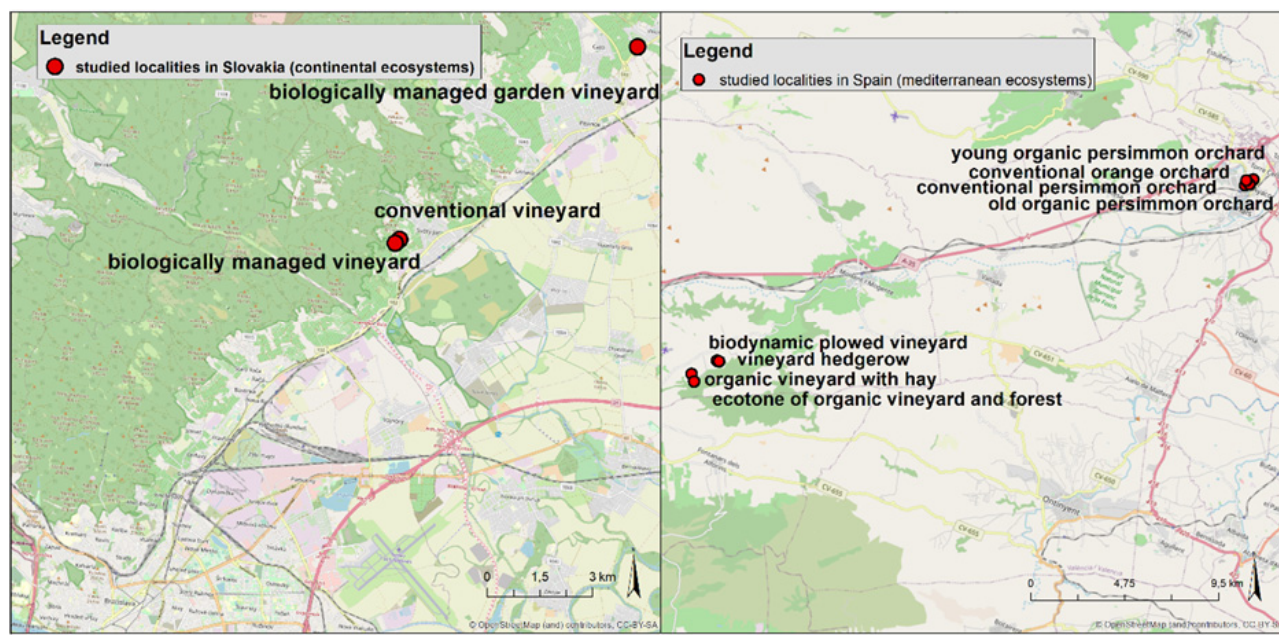


Figure 1 Location of the study sites in Slovakia (left) and Eastern Iberian Peninsula (right)

(38° 49' 22.0" N 0° 48' 19.8" W) were included to the small terrestrial mammal analysis.

The locality of conventional small-scale vineyard in Slovakia (48° 15' 04.0" N 17° 12' 05.9" E) and ecotone of organic vineyard and forest near Celler del Roure (Moixent) (38° 48' 36.3" N 0° 48' 46.8" W) were used as control samples. In Slovakia, to determine species possibly living at conventionally vineyards and in Spain, to determine the species living in semi-natural habitats, and if the adjacent organic vineyard with hay (38° 48' 43.6" N 0° 48' 58.2) is used as living space.

2.2 Data collection

The research was conducted in Spain and Slovakia with the sampling method capture-mark-recapture using wooden "Chmela" type live traps. The traps were exposed for two nights, as the aim of the project was to provide insight to small mammal communities at biologically managed agricultural sites. At every locality, a line consisted of 14 to 25 traps was laid with 5 meter distance between. Dimensions of the sites limited the number of traps, as some of the sites were small-scale lands. The traps were checked twice a day – after sunrise and after sunset to investigate night and day activity of the species and ensure the trapped animals survive. Larvae of *Tenebrio molitor* and oat flakes were provided as the feed. Altogether, several trapping actions were carried out; on 4.–7. 8. 2018 at biologically managed garden vineyard, biologically managed vineyard and conventional vineyard in Slovakia, on 13.–15. 10. 2019 at young organic persimmon orchard, old organic persimmon orchard, conventional persimmon orchard

and conventional orange orchard in Spain and on 18.–20. 10. 2019 at vineyard hedgerow, organic vineyard with hay, ecotone of organic vineyard and forest and biodynamic tilled vineyard.

2.3 Statistical analysis

Considering the character of the obtained data (relatively low abundance and species richness), multidimensional scaling (NMDs) was used to visualize relationships between the species and localities. The analysis was done in using the software Statistica 12 (StatSoft, Inc., 2013). The recorded species with similar functions in ecosystems were combined to one group (*Crocidura russula* and *Crocidura suaveolens* – *Crocidura* sp. as well as *Mus* sp.) for the purpose of visualisation of the links between the organisms and the localities.

3 Results and discussion

Throughout the exploratory research, 48 individuals of small terrestrial mammals belonging to seven species were documented (*Apodemus sylvaticus*, *Mus musculus*, *Mus spicilegus*, *Mus spretus*, *Rattus* sp., *Crocidura russula*, *Crocidura suaveolens*). The most species (three) were indicated at the ecotone of the organic vineyard and the forest. However, mentioned locality served only as a control locality to see what species occur in the close vicinity of the vineyards. At the adjacent locality – organic vineyard with hay, only one individual of *Mus* sp. was present, the most probably *Mus spretus*. The most individuals were registered in the hedgerow at biodynamic ploughed vineyard. Despite the high abundance, all individuals belonged to the same species.

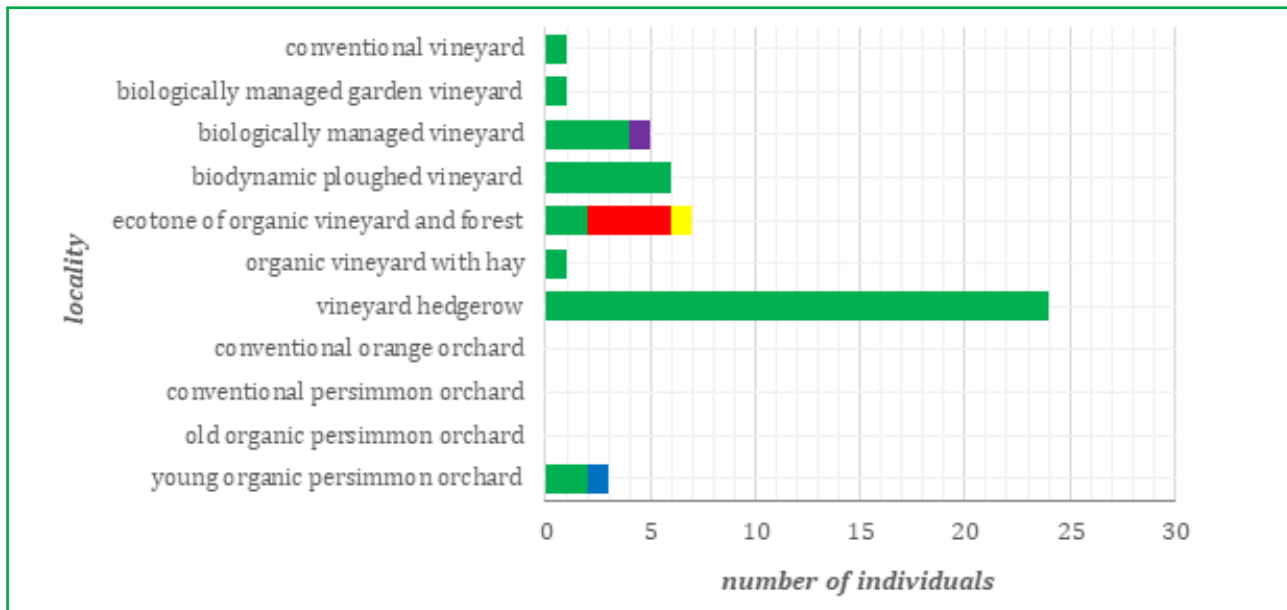


Figure 2 Numbers of trapped individuals at the studied localities

At three localities, no small terrestrial mammals were noted (old organic persimmon orchard, conventional persimmon orchard, conventional persimmon orchard) and at the same number of localities, only one species was noticed (Figure 2).

At the studied regions, three different species of the genus *Mus* Clerck, 1757 that are difficult to distinguish between without genetic research or precise morphology measurements (Gerasimov et al., 1990; Csanády et al., 2018), can be found. *Mus spretus* Lataste, 1883 occurring only in Spain and *Mus spicilegus* Petényi, 1882 occurring only in Slovakia, range mostly in the wild. *Mus musculus* Linnaeus, 1758 occurs in both countries (Slovakia as well as Spain), however, its occurrence is tightly tied with human activities and dwelling. For ensuing analysis,

occurrence data about both of the species were united to the one category (*Mus* sp.) because of their similar roles in ecosystems.

As every individual was marked at its first trapping, the movement between the localities as well as affinity to the studied localities was feasible to be monitored. Affinity represents how suitable is the habitat and if the species or an individual is able to abide there. The highest number of re-traps was reported at vineyard hedgerow where the abundance was the highest as well. At the locality, the results indicate the long-term residence of the individuals at the locality. However, the highest number of ratio of re-traps was recorded at young organic persimmon orchard (Table 1). At the localities with low rates, the noticed animals were probably migrating through and

Table 1 Number of re-trapped individuals

Locality	Number of re-trapped individuals	Number of individuals
Young organic persimmon orchard	3	3
Old organic persimmon orchard	0	0
Conventional persimmon orchard	0	0
Conventional orange orchard	0	0
Vineyard hedgerow	11	24
Organic vineyard with hay	0	1
Ecotone of organic vineyard and forest	2	7
Biodynamic ploughed vineyard	1	6
Biologically managed vineyard	1	5
Biologically managed garden vineyard	0	1
Conventional vineyard	0	1

not using the biotope as permanent habitat. Number of re-trapped animals might be higher at hedgerow because of a high trap concurrence at the locality.

The results of the NMDs analysis are displayed in the Figure 3. Except the young organic persimmon orchard (S1), ecotone of organic vineyard and forest (S7) and biologically managed vineyard (S9), the distance of the studied localities is short, which represents statistically significant similarity. The character of the localities in Spain and Slovakia remains indistinguishable since their positions were not divided into separate clusters. There is no strong dependency of the observed species. The test displays the strongest association formed between *Mus* sp. and the vineyard localities as well as between *A. sylvaticus* and orchards. The relation of *Crocidura* sp. was proven to be the closest with the localities S7 and S9. The most distant is the location of *Rattus* sp. proving the weak affinity for the studied localities.

Total number of captured species was relatively low. Gomez et al. (2018) documented 321 individuals in organic farms. However, they assessed only field borders, not actual arable farmland which is always characterised by lower abundance. The phenomenon might be caused by the short trapping actions (only two days). Nonetheless, the high numbers of re-trappings at the selected localities indicate accurate representation of the state of the localities at the time, being the main objective of the study.

Three detected species, *A. sylvaticus*, *Mus* sp. and *Rattus* sp. occur in Slovakia as well as in Spain. Conforming to the position in the Figure 1, *Mus* sp. is not a discriminating species towards a type of locality. Two species of the genus *Crocidura* sp. at the studied localities represent the same functional traits in both countries (*C. suaveolens* in Slovakia and *C. russula* in Spain). The occurrence conditioned by sufficient amount of invertebrates for feeding makes them beneficial indicators. The hypothesis, that pesticide and herbicide treatments might influence also higher trophic levels, is supported by the fact that insectivores were observed only at organic farmlands and the results of NMDs analysis. Rollan et al. (2019) also recorded positive impact of organic farming on insectivorous birds, which might be the same case – there is sufficient number of invertebrates to feed on for bird and insectivores. Yin et al. (2020) confirm that invertebrate diversity and functionality (in particular Collembola) are strongly influenced by land use.

The low species richness is consequence of particularly inhospitable habitat for small mammals with none or insufficient vegetation that serves as shelter and often as food as well. Gomez et al. (2018) identified vegetation volume as the most significant for occurrence of small

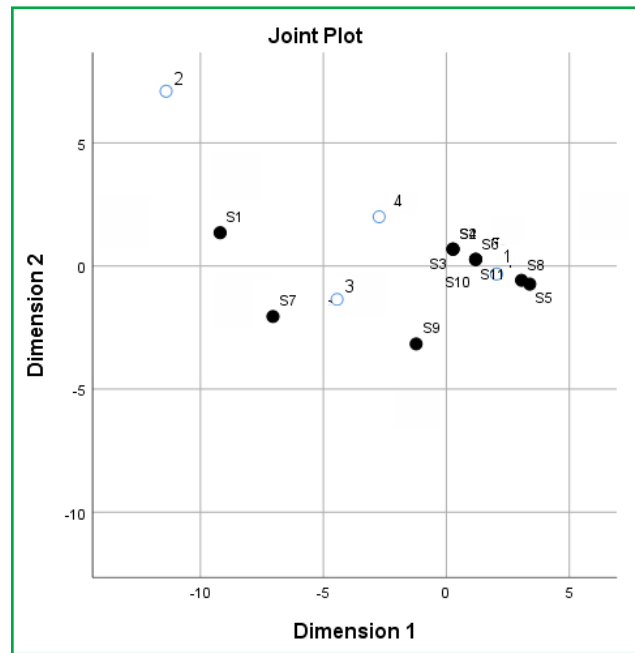


Figure 3 Graph illustrating relationships between recorded small mammal species and studied localities.

1 – *Mus* sp., 2 – *Rattus* sp., 3 – *Crocidura* sp., 4 – *Apodemus sylvaticus*; S1 – young organic persimmon orchard, S2 – old organic persimmon orchard, S3 – conventional persimmon orchard, S4 – conventional orange orchard, S5 – vineyard hedgerow, S6 – organic vineyard with hay, S7 – ecotone of organic vineyard and forest, S8 – biodynamic ploughed vineyard, S9 – biologically managed vineyard, S10 – biologically managed garden vineyard, S11 – conventional vineyard

mammals. Most of the studied cultivated localities are tilled yet still being organic farming (except the localities biologically managed vineyard and young persimmon orchard and partially old organic persimmon orchard). Only *Mus* sp. and *A. sylvaticus* show affiliation to agricultural land regardless of management type, which does not maintain diversity. However, conservation tillage has been slowly introduced to farming all over the world and it has been supporting biodiversity maintenance (Holland, 2004). In addition, any of the small mammal species were registered at the localities with missing or low occurrence of vegetation (old organic persimmon orchard, conventional persimmon orchard, conventional persimmon orchard). The obtained results concur with the concept, since the untilled localities of our research show the highest number of species.

Bates and Harris (2009) proved that there is no difference in diversity of small mammals in hedgerows at organic or conventional farms. Number and size of non-crop areas appear to be more important overall. The hedgerow from Bates and Harris's research (2009) attracted mostly species *Apodemus sylvaticus* (wood mouse), *Clethrionomys glareolus* (bank vole) and *Sorex araneus*

(common shrew). At the studied hedgerow, only one species (*Mus* sp.) was recorded. *A. sylvaticus* occurred at the nearby ecotone of vineyard and forests, however, it was not noticed at the hedgerow (other two species do not occur in the studied area). Contrarily, Sullivan et al. (2012) determined the highest species richness and diversity at hedgerows, but not the abundance. The achieved results of the research are an example how abundant hedgerows can be with small mammals but still missing species diversity. Increase of species richness could be obtained by connecting the hedgerow to the neighbouring natural forest habitats.

During the research, the studied orchards did not demonstrate high diversity nor high abundance (only two species of small terrestrial mammals were recorded, represented by low numbers) and according to our results only *A. sylvaticus* associate with these type of localities. However, at macadamia monoculture orchard, although number of species was lower than at other studied localities (coffee under Khasia pine plantation and forest khasia pine plantation mixed with native species), diversity was the highest (Chaiyarat et al., 2020). Exceptionally, Mexican nopal orchards were source of high diversity as well as abundance (Riojas-López et al., 2018). The divergence might be cause by distinct climate, character of the crop and agrarian land that is more similar to native habitats and provide suitable residence for the organisms. As reported by previous studies, at orchards, different species of voles were often the most abundant species (Balčiauskas et al., 2019), possibly causing also crop damages by trunk bark gnawing (Suchomel et al., 2019; Bertolino et al., 2015). This phenomenon occurs especially at apple farms (Suchomel et al., 2019; Sullivan & Sullivan, 2018), which were not included in the studies as they are not characteristic crop for the studied region of Valencia. With missing distribution of the species in Valencia commune, occurrence of the species was not recorded at the studied localities and no other species has replaced the role, thus no extensive damage was recorded.

According to findings of Coda et al. (2015), management does not influence species richness yet has a positive impact on abundance. Our results show, there are more species as well as higher abundance at organic localities in the same area (as well as west of Slovakia or Valencia commune, Spain) than at conventional farmlands with possibility of occurrence of the same species. The diagram (Figure 3) shows that there is no significant difference between managements but the species are drawn to a specific type of habitat. The results correspond to studies from Thailand (Chaiyarat et al., 2020), where pine plantation mixed with native species showed the highest number of species and habitat with natural

elements provides suitable biotope. In addition, organic farming can minimize negative impact of voles in arable land by decreasing crop damage (Fisher et al., 2018). For example, Schlotelburg et al. (2019) findings proved that self-service traps, which help reduce numbers of voles at arable land, are visited with higher probability at sites with characteristics of organic farming. On the contrary, Bruggisser et al. (2010) claim that at organic vineyards, there is no positive effects on biodiversity nor abundance (studying plants, grasshoppers and spiders). Using fluctuating asymmetry (FA) and body condition of animals Coda et al. (2016) confirmed higher levels of FA and feeble body mass of specialist species, Pampean grassland mouse, at conventional farmland but no impact on generalist species, corn mouse and small vesper mouse. Finally, Balčiauskas et al. (2019) did not indicate any species of small mammals at most intensively cultivated fruit farms. In consonance with Fisher et al. (2011) and Serafini et al. (2019), organic farming improves abundance and biodiversity mainly in simple landscape and heterogeneity introduces clear benefits in conventionally managed farmlands, since it provides refuges for different organisms, including small mammals. There are studies with different statements, which leads to the conclusion that more research is needed to be done to recognize the suitable managements and practices.

4 Conclusions

Higher biodiversity is unquestionably connected with heterogeneity of landscape (Šálek et al., 2018) yet it is often reduced by farming rapidly (Benton et al., 2003). Our research contributes with similar results – higher species richness and numbers of individuals in non-crop localities but no strong differences between organic and conventional farming. Nonetheless, alternative farming includes more non-crop area than conventional agriculture, which brings the higher abundance and diversity (landscape, fauna and flora). The affiliation of the observed species to different types of habitats contributes to the knowledge of positive impact of landscape heterogeneity on diversity. However, in future research, suitable types and practices of organic farming are needed to be identified and subsequently applied into various managements.

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