Earthworms, spiders and bees as indicators of habitat quality and management in a low-input farming region – a whole farm approach

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Abstract

The benefits of low input farming on biodiversity and ecosystem services are already well-established, however most of these studies focus only on the focal field scales. We aimed to study whether these benefits exist at the whole farm scale, to find the main environmental driving effects on biodiversity at the whole farm scale in farms of different grassland grazing intensity, applying three well-known species diversity indicator groups of different ecological traits.

Edaphic (earthworms), epigeic (spiders) and flying (bees) taxa were sampled in each identified habitat type within eighteen low-input farms in Central Hungary, 2010. The number of habitat types, the number of grassland plots, the cumulative area of grasslands and habitat type had an effect on the species richness and abundance of spiders, while grassland grazing intensity influenced the species richness of bees. Both bees and spiders were sensitive to vegetation and weather conditions, resulting in more bees on flower-rich farms and those having higher temperature; and more spiders on farms with more heterogeneous vegetation structure and in low-wind areas. Relatively few earthworms were found in the whole study, and their abundance was not influenced by any of the farm composition and management variables.

We conclude that local field management (grazing intensity of grassland patches) can have a farm scale effect, detectable on species diversity indicators that have high dispersal ability and strong connection to grasslands as important foraging sites (bees). However, other farmland biota (spiders) is also strongly determined by farmland composition and habitat diversity, therefore the maintenance of a mosaic within-farm habitat structure is strongly recommended. The application of earthworms as farmland composition or management indicators is strongly restricted because of their special needs of soil conditions.

Keywords: extensive farming; farmland biodiversity; grazing intensity; invertebrates;
1. Introduction

Farmland habitats, including arable fields and grasslands are the dominant land use types all over Europe, and are very important for several open landscape-related species. The management of these habitats directly effects biodiversity at field and landscape scales (Donald et al., 2001; Stoate et al., 2009). Intensive agricultural management, especially the use of inorganic fertilisers and pesticides as well as increased land use intensity resulted in landscape homogenisation, and caused declining population trends of several plant, invertebrate and vertebrate taxa (Benton et al., 2003; Geiger et al., 2011). In the last decades, an emerging demand to halt the loss of farmland biodiversity and ecosystem degradation resulted in increased implementation of “low input farming systems”, among them organic farming and subsidised agri-environment schemes in the EU (Kleijn and Sutherland, 2003; Kleijn et al., 2011).

The benefits of low input farming systems were addressed in several former studies (Hole et al., 2005; Knop et al., 2006), but their overall effectiveness are mixed (Kleijn et al., 2006). One reason for this could be that there are no generally accepted indicators. Several studies include popular and easy-to-study taxa, like birds or plants, and simple descriptors as species richness and/or abundance data (Chamberlain et al., 1999; Gabriel et al., 2005; Verhulst et al., 2004). Additionally, studies usually compared a focal field under low input management with a nearby, conventionally managed field (Bengtsson et al., 2005; Hole et al., 2005; Kleijn et al., 2006, 2011; Pacini et al., 2003), thus on a restricted spatial scale, although landscape scale effects may interact with local scale management (Batáry et al., 2011).

However, landscape scale is rather vaguely defined, and not operative in a socio-economic context (Gabriel et al., 2010). Whole farm scale is appropriate to assess larger spatial scale effects, and is the real scale for management decisions.

In the present study, we applied a “whole farm approach”, sampling all kind of major habitat types to assess the main drivers of biodiversity in a low input farming system,
including 1) the effects of habitat composition within the farm, 2) effects at the whole farm scale of grazing intensity in grassland patches, 3) effects of local vegetation composition and structure and 4) the influence of selected weather conditions. This approach enabled us to investigate the importance on farm-level biodiversity of habitats that are not directly managed by farmers but are influenced by farming practices (linear habitat features, forest patches and wetlands). Such habitats are often neglected in studies that usually focus on the effects of management procedures on cultivated fields, yet they are important for most taxa living in agricultural landscapes (Hendrickx et al., 2007; Hof and Bright, 2010; Sunderland and Samu, 2000). Considering management effects, we focused on grassland grazing intensity, as this is probably the most important habitat for agricultural biodiversity (Duelli and Orbist, 2003) and was the dominant land use type within the study region. Vegetation structure and species composition usually has strong influence on arthropods, while the activity of most animal taxa might be fundamentally affected by weather conditions (Schmidt and Tscharntke, 2005a; Willmer et al., 2004).

Most of the published studies on farmland biodiversity were conducted in Western and Northern European countries, and there is much less knowledge from Central and Eastern Europe (CEE) on the relationship of agricultural practices and farmland biodiversity (Báldi and Batáry, 2011; Tryjanowski et al., 2011). CEE countries have different economic and agricultural history, with different biogeographical and climatic conditions. These differences highlight the urgent need for research evidence in the CEE countries because the applied conservation strategies based on knowledge of farmland ecology in Western Europe cannot simply be adopted in the CEE region (Báldi and Batáry, 2011; Hartel et al., 2010).

To assess farm composition and grassland management effects within the studied low-input systems, proper species diversity indicators are needed, which are relatively easy to monitor, provide relevant information on environmental conditions and environmental changes, are generic at wider scale and provide useful and easily understandable information.
for stakeholders. As a first step, three animal taxa were chosen to represent the endogeic
macroinvertebrate fauna, and we examined the farming effects on these selected groups,
representing both below- and above-ground biodiversity. These groups also provide important
ecosystem services. Earthworms have an essential role in the productivity of organic and low-
input farming systems through recycling and composting soil nutrients, enhancing soil fertility
and enhancing decomposition processes (Jouquet et al., 2006). Both physical (e.g. ploughing,
trampling) and chemical (fertiliser and pesticide use) agricultural practices affect soil
conditions and earthworm assemblages. Therefore they are suggested to be suitable indicators
of soil structure, tillage practice and grassland management (Chan, 2001). Spiders have an
important role in biological control as natural enemies of invertebrate pests in agro-
ecosystems (Marc et al., 1999; Riechert and Lockley, 1984; Schmidt et al., 2003). Spiders are
broadly distributed in agricultural and semi-natural habitats (Schmidt and Tscharntke, 2005b)
and are sensitive to arable crop (Batáry et al., 2008b; Samu, 2003) and grassland (Batáry et a.,
2008a,b) management and weather conditions (Schmidt and Tscharntke, 2005a), making them
widely used environmental indicators. Wild bees are the most important pollinators of arable
crops and wild plant species, especially in Europe (Biesmejer et al., 2006; Klein et al., 2007).
They are highly sensitive to the presence of flowering plants as foraging resources (Ebeling et
al., 2008; Fruend et al., 2010), require several special conditions for nesting, such as bare soil,
dead wood or plant stems (O’Ttoole and Raw, 1991), and therefore show usually direct
response to habitat management and landscape compositional effects (Holzschuh et al., 2007;
Kovács-Hostyánszki et al., 2011; Steffan-Dewenter et al., 2002).

We hypothesized that (1) farmland composition has an effect on the species richness
and abundance of all the selected below- and above-ground indicator taxa, showing higher
values in the more natural habitats (grasslands, wetlands) than in the managed patches (crops).
However, species richness and abundance of the different invertebrate groups can be
determined by the presence and size of different habitat types within a farm; (2) they will show various response to the intensity of grassland management at the whole farm scale due to their different life history and mobility, predicting stronger effect on flying organisms (bees) compared to ground-dwelling arthropods (spiders); (3) local factors such as vegetation structure will mostly influence the species richness and abundance of spiders, while bees are better predictors in changes of plant species richness; (4) the above effects will be modulated by local weather conditions through influence on activity and therefore the applicability of the selected species diversity indicators.

2. Material and methods

2.1. Study sites

The study was conducted in 2010 in the Homokhátság (“Sand Ridge”), an alluvial plain covered with Aeolian, sand-based low fertility solonchak-solonetz plains in the Kiskunság region, Central-Hungary (Appendix). The region contains a mosaic of slightly undulating, semi-fixed sandhillocks and flat areas of fixed sand, is extensively managed in general. Due to the poor conditions and low economic power of the local land-holders; the major difference between low-input and organic farms is only certification; the management was rather similar on all farms (see Appendix). The major habitats of the region are unimproved semi-natural grasslands and arable fields. Agro-chemicals are not applied on the grasslands, stocking rates are very low (0.15-1.75 LU/ha grassland). Zero or low inputs of fertilisers (15-50 t/4 year solid cattle manure or 20-30 kg N/ha/year inorganic fertiliser) and one or two pesticide applications are usual on the arable fields. We selected 18 low-input farms; that contained a mosaic of fields under agricultural management and adjacent, non-managed landscape elements that might be affected by farming practices. All habitats at each farm were mapped and classified according to a European scale standard habitat mapping procedure developed in the BioHab project (Bunce et al., 2008), based on a generic system of habitat definition, the
General Habitat Categories (GHC). Areal, linear and point habitat features were characterized with respect to their ecological quality, farming and soil properties (see details in Bunce et al., 2008 and the BioBio project website, http://www.biobio-indicator.org/deliverables/D22.pdf). On each mapped farm, one plot from each previously identified habitat category, but a maximum of 15 different habitat types were randomly selected (152 plots in total).

2.2. Zoological sampling

2.2.1. Earthworms

Three soil samples of 30 cm×30 cm×20 cm deep were taken in each of the sampling plots in May, 2010. The three samples were located 20 m from the edge of the plot and 10 m apart from each other. We extracted earthworms first by using an expellant solution; after this, the samples were hand-sorted to find all remaining earthworms. The expellant was prepared by allyl-isothiocyanate (AITC) diluted with ethanol 70% to give a 5 g/l solution, shortly before going into the field to prevent loss of irritating activity. This was diluted with water to reach a concentration of 0.1 g/l in the field prior to application. Metal frames (30×30 cm) were installed at each sampling locations in depth of approximately 1-2 cm to prevent the solution from running off. We cleaned the sampling site from vegetation or leaves and poured two doses per sampling site of 2 l of AITC solution at 5 min intervals. Emerging specimens were washed with cold water. After 10 min, the soil was dug up from the metal frame to a depth of 20 cm. This extracted soil was put on a white plastic sheet and hand sorted for 20 minutes. Earthworms were cleaned in cold water and kept in 70% ethanol solution. In the laboratory, each individual was identified to species level.

2.2.2. Bees

Bees were sampled three times during May, June and August, taking one sample per plot on each of the three sampling dates. Each plot was surveyed by walking along 100 m long and 2
meter wide transect over 15 min. All individual bees seen within the transect were caught with
an insect net, transferred into a killing jar with ethyl acetate, and identified in the laboratory.
Easily identifiable bumble bee species and domestic honey bees, were recorded and released
was carried out on dry and warm days with minimal wind, between 09.00 and 18.00 o'clock,
which covers the daily maximum activity regime of the flying insects. During each sampling
session, vegetation height and cover of flowering plants (in 1-5 scale) were estimated and the
flowering plant species were recorded along a transect.

2.2.3. Spiders
Spiders were caught with a D-VAC sampler, also three times in May, June and August within
a period of 10 days to avoid the effect of seasonal succession of spider species (following the
approach described by Schmidt et al., 2005). A 50 cm long, tapering gauze bag (mesh < 0.5
mm) was inserted into the 11 cm diameter intake nozzle to intercept the spiders. On each of
three sampling dates, five suction samples were taken in each of the selected habitat plots,
located 20 m from the border and 10 m from each other. In linear elements, the samples were
taken along a line in the middle of the habitat and 10 m apart. Each suction sample was taken
for 30 seconds within a sample tube with 35.7 cm internal diameter and 40 cm height pre-
installed on the target vegetation. The five suction samples were kept separate. Sampling was
carried out during dry, warm weather, between 09.00 and 18.00. Specimens were identified to
the species level, if possible (Heimer and Nentwig, 1991; Loksa, 1969, 1972; Nentwig et al.,
2012). Vegetation height was recorded during each of the three sampling times as average
minimum and maximum vegetation height on the site.

2.3. Data analysis
Due to the extremely rainy weather in May 2010 and the consequent constrained sampling,
data only from the second and third sampling occasions were analysed in the case of bees and spiders. In the case of earthworms, we have had 489 zero samples from the 660 soil samples, and we pooled the samples at plot level for further analyses.

To get species accumulation curves and measure the habitat use of bees and spiders, and the effectiveness of the sampling, we conducted rarefaction analyses. The species richness of bees and spiders was estimated in each habitat type with the Chao estimator (Chao 1987) using the vegan package (Oksanen et al., 2011) in R programme. The standard deviations were generated from 10,000 reshufflings of the sample order.

General linear mixed-effect models were used to study the relationship between the assumed explanatory variables and the abundance and species richness of earthworms, bees and spiders (GLMM, Bolker et al., 2009). We added a nested spatial random effect to account for the spatial structure among the sampling plots: 1. farm - farm, where the sample was taken; 2. plot - identification code of the sampling plots (eight plots per farm were sampled).

In the case of earthworms, only farm was applied as random factor. We did not consider the samples from the same farm as independent ones because of the potential ownership effects, even though they were true spatial replicates. Most of the cases the farm denoted a spatial unit as well (in four cases few fields were spatially apart from the rest of the farm). Plot and farm were considered nested variables for random effect terms in the analyses. In order to avoid the heterogeneity in variance caused by the different sampling intensity (i.e. different number of samples per habitat types per farm), the log-transformed sample number was added to the linear predictor as a known coefficient (1). In the models the response variables were log(x+1) transformed to fulfil the normality requirement for the model residuals. We used the following explanatory variables in the evaluated models:

1. farm model: habitat (factor with eight levels: canal, forest, crop, grassland, linear habitat, shrubland, trees, wetland), number of habitat types per farm (numerical), total area of the farm (ha), arable area (ha), grassland area (ha), number of arable fields (within a farm), number of
grassland fields (within a farm);

2. management model: grazing type (factor with four levels: cattle, cattle-sheep, horse-cattle, horse-cattle-sheep), total number of grazing animals (per farm), LU (livestock unit/farm area), LU/grassland (livestock unit/grassland area of the farm, ha);

3. environmental model: cloud (cover, based on a 1-5 scale), wind (Beaufort scale), temperature (C°), minimum vegetation height (cm), maximum vegetation height (cm), flower cover (1-5 scale), number of flowering species (per field).

Environmental variables were measured on the field during the sampling periods; data on farm attributes were reported by the owner in a questionnaire.

The differences among the levels of the tested factors (habitat, grazing type) were evaluated by multiple comparisons (with Tukey computed contrast matrices for several multiple comparisons procedures) after a single argument ANOVA for the tested model. The model estimates were obtained using a maximum likelihood method and diagnostics included the Akaike Information Criterion and the model residuals. We estimated the model parameters by using the nlme (Pinheiro et al. 2011) and gplots packages (Warnes, 2011) for graphical outputs in R 2.14.0 (R Development Core Team, 2011).

3. Results

3.1. Species richness

Only seven earthworm species were collected, thus we did not apply the rarefied species richness curves for earthworms. For bees, the value was not stable for any of the habitat types, but it rose continuously as the number of samples increased (Fig. 1). For spiders, the values were stable for grassland at 100 samples (46.94 species ± 1.3 S.D.), as well as for linear elements and “woodlands”. The species richness estimations were approximately stable for grassland at 85 and 100 samples, respectively (43.91 ± 0.29 species, and 46.94 ± 0.22 species, respectively, Fig. 2).
3.2. Earthworms

We collected 551 individuals of seven species in total, with 93% of the individuals belonging to three *Aporrectodes* species (*A. caliginosa*, *A. georginii*, *A. rosea*). Other species were represented by only a few individuals. Consequently, we analysed only the abundance of earthworms, which was not influenced by any of the studied habitat or environmental variables (Table 1).

3.3. Bees

Although the 1135 individuals belonged to 85 bee species, most of the collected bees were honeybees (*Apis mellifera* L.). The species richness and abundance of bees did not show any significant response to the explanatory variables included in the farm model (Table 1). The value of livestock unit in grasslands had a significant, positive effect on bee species richness ($t_{11} = 2.34, p=0.03$; Table 1, Fig. 3). According to the environmental model, cloud cover had a negative effect on the abundance of bees ($t_{126} = -2.38, p=0.01$), while the air temperature had a slight positive effect on species richness and abundance; post-hoc comparisons revealed that it was not significant (species richness: $t_{126} = 0.42, p=0.66$; abundance: $t_{126} = 0.27, p=0.78$; Table 1). Flower cover had positive effect on bee abundance ($t_{126} = 10.23, p<0.001$) (Fig. 4). The flower cover ($t_{126} = 7.86, p<0.001$) and the number of flowering species seemed to be the most important environmental variables influencing bee species richness (Table 1, Fig. 4).

3.4. Spiders

In total of 4222 individuals of 199 spider species were collected. The abundance and species richness of spiders increased by the number of habitat types per farm ($t_{11,634}=2.39, p=0.035$; $t_{11,634}=2.03, p=0.067$ respectively). Both species richness ($t_{119} = -2.80, p=0.005$) and the abundance ($t_{119} = -2.48, p=0.01$) of spiders were lower in the crop fields than in the other
habitat types (Table 1, Fig. 5). The area of grassland had a negative effect on the species richness ($t_{12}=-4.65, p<0.001$) and abundance ($t_{12}=-5.27, p<0.001$), while the species richness ($t_{12}=2.61, p=0.02$) and abundance ($t_{12}=2.47, p=0.02$) of spiders were higher in farms with more grassland patches (Table 1). Patterns of spider species richness and abundance were better explained by the environmental model than either the farm or the management models (Table 1). Wind intensity negatively influenced both species richness ($t_{508}=-4.89, p<0.001$) and abundance of spiders ($t_{508}=-5.00, p<0.001$). The minimum and maximum vegetation height had a positive impact on spiders’ species richness ($t_{508}=2.74, p=0.006$ and $t_{508}=2.38, p=0.01$ respectively) and abundance ($t_{508}=3.14, p=0.001$ and $t_{508}=2.81, p=0.005$) (Fig. 6).

4. Discussion

4.1. Farm composition effects

The rarefied species richness revealed that the spiders were numerous in the grasslands, linear habitats and tree groups, in descending order. However, reliable estimation of species richness required >80 samples. The high number of spider species in the linear elements and tree groups highlighted the importance of these marginal habitats as sources for spill-over to croplands where they contribute to biological control (Rand et al., 2006). We found similar trends for bees, but the estimations were unstable. This phenomenon could be explained by the high mobility of bees, which may reduce their beta diversity (Marini et al., 2011).

Habitat type and farmland composition had an effect on the species richness and abundance of spiders, while the species richness and abundance of earthworms and bees were not affected by the presence, area or number of the various habitat types. Earthworms form the greatest biomass of soil fauna in temperate grasslands; in these communities the number of earthworm species ranges usually 1-15 species, but they contain mostly only 3-6 species (Edwards and Bohlen, 1996). The low number of species and individuals found in our study (most of the individuals belonged only to three species, Aporrectodea rosea Savigny, 1826,
Aporrectodea caliginosa Savigny, 1826, Aporrectodea georgii Michaelsen, 1890) and the lack of difference among different habitat types can be explained by the frequent occurrences of sandy soils that provides inappropriate habitat for burrowing earthworms due to the lack of texture (Bardgett, 2005; Edwards and Bohlen, 1996; van Diepeningen et al., 2006). Further, rainy weather during the sampling resulted in extremely high soil moisture even in the normally dry habitats, when most terrestrial earthworm species are expected to emigrate from the flooded soil (Edwards and Bohlen, 1996).

Bees did not show any significant difference among the habitat types and were not influenced by the area or number of grassland and arable field patches on the farm. Semi-natural habitats are usually the main drivers of bee diversity in an agricultural landscape, due to the considerable flower resources they provide (Sjödin et al., 2008; Steffan-Dewenter et al., 2002). However, the loss of semi-natural grasslands does not necessarily cause a decline in species richness or abundance of wild bees at the farm level (Carré et al., 2009). The available habitats, especially nesting and foraging resources influence the number of species and individuals, and the species composition of bee communities, but habitat compositional change within the farm may not necessarily cause change in the total abundance or species richness (Carré et al., 2009). The lack of habitat effect on bee species richness and abundance suggests that at the farm scale, low-input farms in Hungary offer appropriate foraging resources (flowers) and nesting conditions even when the proportion of grasslands is lower.

The species richness and abundance of spiders were the lowest in the crop fields, and were enhanced by the number of grassland fields in the farm, but decreased by the increase in total grassland area. We suggest that as the number of grassland patches increase, so does habitat heterogeneity at the farm level, which contributes to the increase of spider richness and abundance (Batáry et al., 2008a; Benton et al., 2003). Arable fields are preferred less by spiders than perennial grasslands (Ratschker and Roth, 2000; Schmidt and Tscharntke, 2005), possibly due to the negative effects of management (e.g. fertilizer and pesticide use) and the
less heterogeneous vegetation structure (Batáry et al., 2008b). The complexity of landscapes including perennial non-crop habitats is key to preserve or restore high levels of spider diversity (Schmidt et al., 2005).

4.2. Management effects

Grassland management had no effect on the species richness and abundance of earthworms at the farm scale. The generally unfavourable soil and weather conditions overwrote the effects of management. Grazing intensity had a positive effect on the species richness of bees at farm level. Grazing on the grasslands could have important role in the maintenance of high flower diversity, preventing the dominance of few perennial species and/or succession into shrublands (Bakker, 1998; Hansson and Fogelfors, 2000). In the more intensively grazed grasslands the increased diversity and amount of flowers provides more foraging resources for bees, explaining their higher species richness on these farms (Sjödin et al., 2008; Batáry et al., 2010). Nevertheless, it should be noted that grazing intensity in our study sites (see methods) was still much lower than several Western-European countries, where grazing has significant negative effect on pollinators (Sárospataki et al., 2009; Batáry et al., 2010).

We found no direct effect of grazing intensity on spiders. As only high grazing intensity affects spiders, especially the number of vegetation-dwelling species due to the changes in the vegetation structure (Batáry et al., 2008a,b; Dennis et al., 2001; Horváth et al., 2009). Our results show that even under 1.75 LU/ ha grazing intensity, grasslands provide valuable habitats for species rich spider assemblages. It is also likely that in our low-input farms, the potential negative effects of grazing are buffered by the presence of semi-natural habitats and landscape heterogeneity at the farm scale (Benton et al., 2003; Schmidt and Tscharntke, 2005).

4.3. Vegetation structure and weather effects
Bees and spiders were both influenced by vegetation structure and weather conditions. For bees, flower resources were the most important driving factors; this is more important than habitat type or management (Bardgett, 2005; van Diepeningen et al., 2006). The species richness of flowering plants enhanced bee species richness, while flower cover had a positive effect on both their species richness and abundance (Ebeling et al., 2008; Holzschuh et al., 2007; Sárospataki et al., 2009). Bee species differ in their floral requirements, and a higher number of flowering plant species increases nectar and pollen resource heterogeneity, which enhances attractiveness for many pollinators and increases their species richness (Potts et al., 2003).

We found a strong relationship between vegetation structure and spider assemblages. Both the minimum and maximum vegetation height increased both species richness and abundance. Vegetation as the most important local habitat characteristic influencing spiders is well documented (Batáry et al., 2008a; Dennis et al., 2001; Gibson et al., 1992). Web-building spiders demand higher stems at different heights to construct their nets, whereas hunting species are associated with patches of low vegetation so that they can see and pursue their prey. Therefore, a more complex vegetation structure supports more spiders, both species and individuals (Dennis et al., 2001).

Cloud cover had a negative effect on bee abundance, while air temperature had a slight positive effect on bee species richness and abundance. Thermal constraints limit the foraging activity of bees, defining a microclimatic range of each species within which foraging flight can be sustained (Corbet et al., 1993), which explains the enhanced number of bees under conditions of lower cloud cover and the consequent higher temperatures (Stone and Willmer, 1989). Higher cloud cover and wind had negative effects on spider species richness and abundance. Wind prevents spiders from successfully foraging and destroys spider webs, which decreases their activity and forces them to hide in the lower levels of vegetation or in the litter layer, decreasing the possibility of their capture even by suction.
5. Conclusion

Low-input Eastern European farmlands are traditional, extensive management systems, characterized by rich biodiversity. The study of eighteen Hungarian farms showed that heterogeneous habitat composition and moderate grazing (1.75 LU/ha) intensity in grasslands have considerable importance to maintain the richness of spider and bee assemblages at the farm scale. We conclude that the farm scale effect of local field management, i.e. grazing intensity of grasslands is more detectable on species diversity indicators of higher dispersal ability and strong connection to grasslands. However, because of the strong connection between flower resources and their pollinator bees, bees were related to only a few, more flower-rich habitat types, such as grasslands and linear habitat elements, while spiders were more sensitive to habitat diversity and within-farm habitat types, which made spiders better indicators of farm compositional effects. The distribution of earthworms was strongly restricted by soil and humidity; therefore we suggest their applicability as farmland management and composition indicators only at spatially restricted scales, in the case of appropriate soil conditions. Weather conditions, such as temperature and cloud cover for bees or cloud cover and wind for spiders, have significant influence on activity of these taxa. This should be taken into account during their application as environmental indicators.

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Table 1. Results of general linear mixed-effect models relating farm, management and environmental variables to log-transformed abundance and species richness of earthworms (abundance only), bees and spiders. Significances are marked in bold.

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<th>Earthworms</th>
<th>Bees</th>
<th>Spiders</th>
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<td>log(abundance)</td>
<td>log(abundance)</td>
<td>log(species richness)</td>
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<td>F (d.f.)</td>
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<td>0.83 (7,128)</td>
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<tr>
<td>No. grassland plots</td>
<td>0.336 (1,11)</td>
<td>0.57</td>
<td>0.9 (1,12)</td>
</tr>
<tr>
<td>sd (random effect's residuals)</td>
<td>0.46</td>
<td>0.99</td>
<td>0.53</td>
</tr>
</tbody>
</table>

|                      | Management model | Management model | Management model |
|                      | Grazing type     | Total no. grazing animals | LU |
|                      | 1.027 (3,10) | 0.421 | 0.003 (1,10) | 0.957 | 0.07 (1,10) | 0.796 |
|                      | 2.12 (3,11) | 0.15 | 3.09 (1,11) | 0.1  | 0.006 (1,11) | 0.93 | 0.006 (1,11) | 0.93 |
|                      | 0.29 (1,11) | 0.59 | 0.38 (1,11) | 0.35 | 5.49 (1,11) | 0.003 | +6.8 (1,11) | 0.02 |
|                      | 0.542 (1,10) | 0.478 | 0.93 (1,11) | 0.35 | 5.49 (1,11) | 0.003 | + |
|                      | 0.46 | 0.99 | 0.53 | 0.74 | 0.53 |

|                      | Environment model | Environment model | Environment model |
|                      | Cloud cover (1-5 scale) | Wind (Beaufort scale) | Temperature (°C) |
|                      | 9.18 (1,111) | 0.003 | 2.23 (1,111) | 0.13 | 3.65 (1,508) | 0.05 | 5.85 (1,509) | 0.01 |
|                      | 2.43 (1,111) | 0.12 | 1.67 (1,111) | 0.19 | 30.08 (1,508) | <0.001 | -28.68 (1,509) | <0.001 |
|                      | 2.11 (16,111) | 0.01 | +2.14 (16,111) | 0.01 | + |
|                      | 0.11 (1,111) | 0.73 | 0.42 (1,111) | 0.51 | 33.97 (1,508) | <0.001 | +24.93 (1,509) | <0.001 |
|                      | 0.44 (1,111) | 0.5 | 1.43 (1,111) | 0.23 | 8.37 (1,508) | 0.004 | +6.19 (1,509) | 0.01 |
|                      | 165.5 (1,111) | <0.001 | +113.3 (1,111) | <0.001 | + |
|                      | 0.81 (1,111) | 0.36 | 8.18 (1,111) | 0.005 | + |
|                      | 0.72 | 0.42 | 0.56 | 0.79 |
Figure legends

Fig. 1: The species richness estimation for bees according to Chao estimators (with 95% confidence intervals) based on the habitat types on 18 low-input farms in Central Hungary.

Fig. 2: The species richness estimation for spiders according to Chao estimators (with 95% confidence intervals) based on the habitat types on 18 low-input farms in Central Hungary.

Fig. 3: The relationship between grazing intensity (livestock unit/ha grassland) and species richness of bees on 18 low-input farms in Central Hungary. The smoothed line was fitted by local polynomial regression techniques (lowess; alpha was set to one to fit closely linear regression).

Fig. 4: Relationship between the most influential environmental variables and the abundance (A) and species richness (B) of bees on 18 low-input farms in Central Hungary. The smoothed line was fitted by local polynomial regression techniques (lowess; alpha was set to one to fit closely linear regression).

Fig. 5: Distribution of abundance (A) and species richness (B) of spiders according to the studied habitat types.

Fig. 6: Relationship between the spiders’ abundance and species richness and the most influential environmental variables such as wind (A and B respectively) and minimum vegetation height (C and D respectively). The smoothed line was fitted by local
polynomial regression techniques (lowess; alpha was set to one to fit closely linear regression).
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