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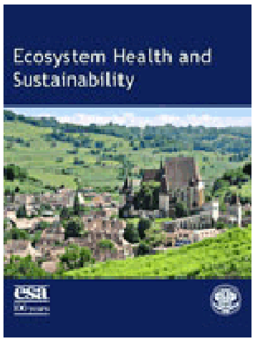

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Functional diversity and trait composition of butterfly and bird communities in farmlands of Central Romania

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Abstract. Cultural landscapes all over the world harbor species communities that are taxonomically and functionally diverse. In Eastern Europe, but also in many other regions of the world, the conservation of this farmland biodiversity is threatened by land use intensification and abandonment. In order to counteract the negative effects of land use change in such landscapes, a thorough understanding of the functional relationships between species and their environment is crucial. In this study, we investigated the relationship of functional traits of butterfly and bird communities and environmental conditions in 120 sites in traditional farmlands of southern Transylvania, Romania. First, we compared taxonomic diversity (i.e., Shannon diversity) with functional diversity (i.e., functional dispersion), and second, we linked species traits to environmental variables by performing RLQ analyses. Functional traits indicating reproduction, movement, and feeding behavior related with environmental variables describing heterogeneity, amount of woody vegetation, and topography at three different spatial scales. We found positive relationships between taxonomic and functional diversity, as well as strong linkages between species traits and environmental conditions for both groups. Specifically, butterfly composition was most strongly influenced by land use type and life-history strategies. Bird composition was most strongly related to the amount of woody vegetation and nesting and foraging strategies. We conclude that maintaining the typical features of traditional farming landscapes, especially a small-scale heterogeneity in arable land and gradients of woody vegetation cover, would be desirable in order to sustain a high functional diversity in southern Transylvania in the future.

Key words: *agricultural intensification; bird communities; butterfly communities; farmland heterogeneity; land abandonment; low-intensive agriculture; RLQ analysis; Transylvania, Romania.*

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Introduction

Cultural landscapes all over Europe are important strongholds of farmland biodiversity. Centuries of low-intensity farming have created landscapes characterized by a mosaic of different land cover types, by relatively large amounts of natural and seminatural vegetation, and by the abundance of structural elements such as hedgerows, walls, or side strips, leading to highly heterogeneous landscapes (Plieninger and Bieling 2012). These landscapes, today often recognized as high nature value farmland areas (Beaufoy et al. 1994) or biocultural refugia (Barthel et al. 2013), are of crucial importance for biodiversity conservation as well as the preservation of traditional management practices and knowledge.

Eastern Europe contains many farming landscapes that are managed at low intensities by applying traditional land practices. Often, these cultural landscapes sustain species communities that are exceptionally rich, as has been shown for birds (Tryjanowski et al. 2011, Loos et al. 2015), butterflies (Schmitt and Rakosy

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2007, Loos et al. 2014*a*), and plants (Wilson et al. 2012, Loos et al. 2015). Furthermore, these landscape often show a high abundance of species that are relevant for conservation, such as rare amphibians (Hartel and von Wehrden 2013) or woodpeckers (Dorresteijn et al. 2013).

Ongoing land use changes in many of these cultural landscapes threaten both the maintenance of traditional land use practices as well as related farmland biodiversity (Skórka et al. 2007, Dahlström et al. 2008, Van Dyck et al. 2009). Agricultural intensification is one of the key processes triggering a transformation of management practices and, consequently, an alteration of the whole landscape. The change toward intensified land use is often characterized by increased use of agrochemicals and machinery. Furthermore, increased field sizes and the elimination of structural elements and natural and seminatural vegetation in intensive agriculture lead to landscape homogenization (Benton et al. 2003, Tscharntke et al. 2005). As a consequence, agricultural intensification induces deterioration of ecosystem functioning, increased fragmentation, and loss of species habitats (Stoate et al. 2001, Tscharntke et al. 2005). Besides agricultural intensification, farmland abandonment is another key aspect of land use change, especially in Eastern Europe, also having negative effects on farmland biodiversity (Stoate et al. 2009). Overall, the socio-political changes in Eastern Europe, including the breakdown of communism, the introduction of market-based economies and, for many countries, accession to the European Union, had clear effects on farming and land use patterns (Griffiths et al. 2013, Prishchepov et al. 2013). However, knowledge on the impacts of this transition on biodiversity is still sparse (Sutcliffe et al. 2015).

In order to safeguard biodiversity in these remaining refugia and to enable sustainable management of these landscapes, it is necessary to understand current diversity patterns and to obtain baseline data for future studies. Functional diversity, for example, is an important aspect of biodiversity and has been linked to ecosystem functioning (Diaz and Cabido 2001), productivity (Hector et al. 1999), and stability of ecosystems (Peterson et al. 1998). Further, the functional composition of species has been shown to be tightly linked to land use and land use change (Castro et al. 2010). A thorough knowledge of the functional responses to land use changes can serve as an indicator of biodiversity loss and to inform conservation management (Vandewalle et al. 2010).

Here, we present a study on patterns of functional diversity and functional composition in a traditional farming landscape in southern Transylvania (Romania). Specifically, we collected data on butterfly and bird species abundance and composition in arable and pasture sites and investigated the linkages between environmental conditions and species traits. This case study adds to a mechanistic understanding of farmland biodiversity in Eastern Europe and aims to inform biodiversity conservation in the future.

Methods

Study area and study design

The study area covered 7441 km^2 in southern Transylvania, Romania. Within this landscape, we selected 30 villages using a stratified random selection along a gradient of terrain ruggedness (high, medium, low) and covering different protection levels within the Natura 2000 network (site of community importance, special protection area, and no protection; $n = 10$ each; Loos et al. 2014*a*). For each village, we selected four survey sites of 1 ha each within the main farming land cover types: arable land and pasture (EEA 2006). Site selection followed a stratified random design based on the gradients of woody vegetation cover and heterogeneity within each land cover type (Loos et al. 2014*a*). In total, 120 sites, of which 60 each were located in arable land and grassland, were selected and subsequently surveyed for bird and butterfly presence throughout spring and summer 2012. The surveys were temporally replicated with three repeats for birds and four repeats for butterflies, respectively (Loos et al. 2014*b*). Of all species observed, we selected species that occurred in more than one study site. Thus, we used 88 butterfly species and 35 bird species.

Environmental variables

We selected environmental variables at three different spatial scales (local, context, and landscape) because both butterflies and birds have been shown to respond to environmental conditions at these scales (Loos et al. 2014*a*, Dorresteijn 2015) and because these scales are also highly relevant for conservation management in the study area. The local scale describes the conditions within a given sampling site (1 ha), which approximately corresponds to the home range of many passerines (Cramp 2000), but also to the size of an average farming unit in our study area. The context scale describes the conditions in a circle of 50 ha around a given site (i.e., radius of 400 m), an area that has been shown to influence trait composition of birds and butterflies elsewhere (Barbaro and Van Halder 2009) and that would be relevant for collective management by farmers in a given village. Finally, the landscape scale describes conditions within the village (2046 ± 1123 ha; mean ± SD) in which a given site is located. This scale represents ecological effects over larger distances (Öckinger et al. 2012) as well as the possible effects of village-wide management. Within each of the scales, we calculated variables describing amounts of woody vegetation, heterogeneity, and topography. These were selected because they are relevant drivers of species composition

Table 1. Environmental variables that were used in the study.

Variable (abbreviation), by scale	Description
Local	
Woody vegetation cover (woody.1ha)	percent woody vegetation cover derived from a supervised classification of the panchromatic channels of SPOT 5 data (CNES 2007)
Heterogeneity (het.1ha)	heterogeneity indicated as the reflectance of land surfaces with a resolution of 2.5 × 2.5 m pixels reflectance measured using the monochromatic channel of SPOT 5 satellite data
Terrain wetness index (TWI.1ha)	measure of soil wetness, calculated as a function of slope and topographic position, based on the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model Version 2 (GDEM V2)
Context	
Woody vegetation cover (woody.50ha)	percent woody vegetation cover derived from a supervised classification of the panchromatic channels of SPOT 5 data
Land cover diversity (SD.50ha)	Simpson's diversity index of land cover, based on raster of all land-use types derived from corine land cover digital map (EEA 2006) and calculated using FRAGSTATS 4.2 (McGarigal et al. 2012)
Terrain ruggedness (rugg.50ha)	terrain ruggedness calculated as the standard deviation of altitude (ASTER GDEM)
Landscape	
Woody vegetation cover (woody.catch)	percent cover of forest derived from corine land cover digital map (EEA 2006)
Land cover diversity (SD.catch)	Simpson's diversity index of land cover, based on a raster of all land-use types derived from corine land cover digital map (EEA 2006) and calculated using FRAGSTATS 4.2 (McGarigal et al. 2012)
Terrain ruggedness (rugg.catch)	terrain ruggedness calculated as the standard deviation of the altitude (ASTER GDEM)

(Loos et al. 2014*a*, Dorresteijn 2015) and because they are likely to be modified through land use change (Benton et al. 2003). For a detailed description of all environmental variables see Table 1.

Functional traits

We selected two different sets of functional traits (sensu Violle et al. 2007) for birds and butterflies, which were selected to cover a wide range of different life-history characteristics and which were likely to be sensitive to land use changes in agricultural landscapes (Henle et al. 2004, Butler et al. 2007, Barbaro and Van Halder 2009). For butterflies, we selected 10 functional traits (see Table 2 for a more detailed description): wing length, egg potential, generations, development times of eggs, larva, and pupa, lifetime of the imago, reproductive strategy, diet, and mobility. Trait data for butterflies were obtained from Bink (1992) and Tshikolovets (2003). For birds, we selected four functional traits (see Table 2):

Table 2. Species functional traits that were used in the study.

Functional trait (abbreviation), by taxon	Description
Butterflies	
Wing length (Winglength)	mean wing length (mm)
Egg potential (Eggs_pot)	maximal potential number of eggs laid
Generations	number of generations per year
Egg development time (Eggdevtime)	mean number of days as egg
Larva development time (Larvdevtime)	mean number of days as larvae
Pupa development time (Pupdevtime)	mean number of days as pupa
Imago lifetime (Imagotime)	mean number of days as imago
Reproductive strategy (Strat)	strategy type; either *r* (Strat.r) or *K* (Strat.K)
Diet (D)	degree of specialization on larvae host plants: monophagous (D.m; only one host plant), oligophagous (D.o; host plants within one genus), polyphagous (D.p; host plants in several families)
Mobility	eight levels of mobility ranging from 1 (low mobility) to 8 (high mobility)
Birds	
Nest location (N)	specialization in nesting location: tree cavity (N.tree_cavity), open nest in tree (N.tree_open), open nest in shrubs (N.shrub), open nest on the ground (N.ground)
Diet (D)	dietary specialization; granivore (D.granivore), insectivore (D.insectivore), omnivore (D.omnivore)
Foraging technique (F)	four levels of foraging techniques: generalist gleaner F.general), canopy gleaner (F.canopy), understory gleaner (F.understory), ground gleaner (F.ground)
Body mass (BM)	four body mass groups: BM.1: $\leq$ 14 g; BM.2: 15–24 g; BM.3: 25–49 g; BM.4 $\geq$ 50 g)

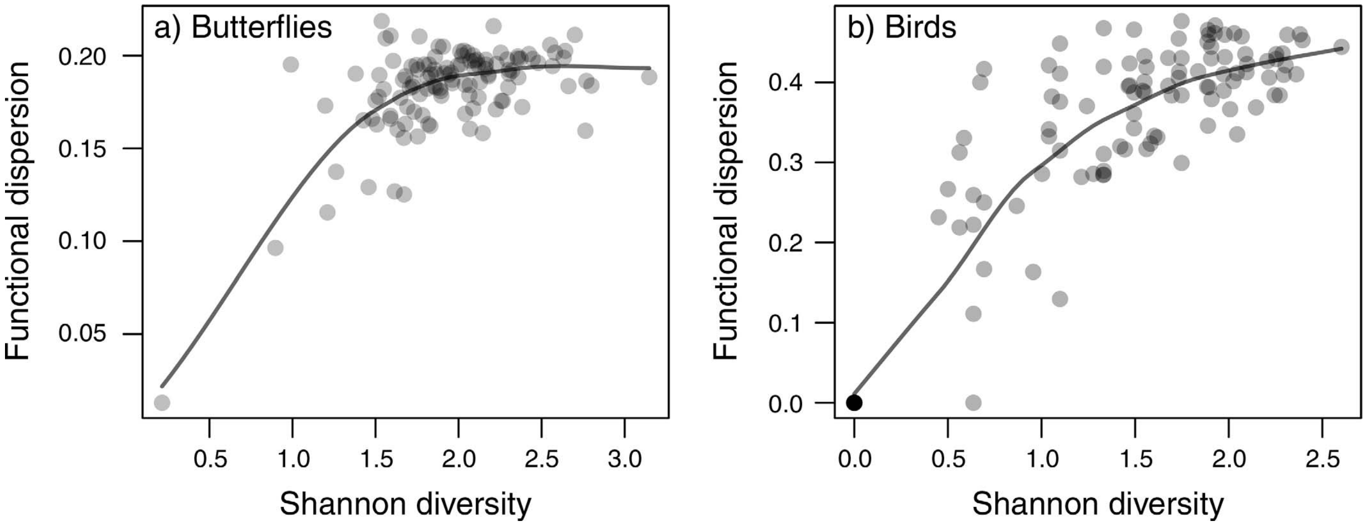

Fig. 1. Comparison between Shannon diversity (i.e., taxonomic diversity) and functional dispersion (i.e., functional diversity) per site for (a) butterflies and (b) birds. Polynomial loess-smoother functions were fitted to visualize trends in the data. Overplotting of points is indicated by darker shades of gray.

nest location, diet, foraging technique, and body mass. These traits were derived from the Birds of the Western Palearctic (Cramp 2000) but adapted to Romania (Linţia 1954, 1955, Ciochia 1992).

Data analysis

First, we calculated taxonomic and functional diversity both for butterflies and birds in a given site. Taxonomic diversity was calculated as the Shannon index and functional diversity was calculated as the functional dispersion index (Laliberte and Legendre 2010). Diversity indices were calculated separately for butterflies and birds based on abundance data and compared to each other using Spearman's rank correlation.

Second, we applied a three-table ordination method (RLQ analysis) to analyze the links between environmental variables and functional traits (Doledec et al. 1996). An RLQ analysis is an ordination approach that maximizes the covariance between sites and species on the basis of environmental variables of the sites and the species' traits. We conducted RLQ analyses separately for butterfly and bird data accounting for the influence of environmental variables from different spatial scales (see Table 3). RLQ was based on separate ordinations on environmental variables (*R*; Hill-Smith principal components analysis), species abundance (*L*; correspondence analysis), and species traits (*Q*; Hill-Smith principal components analysis).

All statistical analyses were performed within the R environment (R Core Team 2014), using functions from the vegan package (Oksanen et al. 2014), the FD package (Laliberté et al. 2014), and the ade4 package (Dray and Dufour 2007).

Results

Functional diversity

Functional dispersion was positively related to Shannon diversity both for butterflies (Spearman's $\rho = 0.4$) and birds (Spearman's $\rho = 0.73$). Remarkably, functional diversity of butterflies showed an increase with increasing taxonomic diversity only at lower values of taxonomic diversity and leveled off at higher values (Fig. 1a). Functional diversity of birds increased over the whole range of taxonomic diversity (Fig. 1b).

Functional composition

Butterfly trait composition was related to environmental conditions in the RLQ analyses with a projected inertia of 69% on the first and 25% on the second axis. The first axis described a gradient from sites that are situated in arable land, have high local heterogeneity, and are flat (left-hand side of the ordination plot; Fig. 2a) to pasture sites with a rugged topography (right-hand side of the ordination plot; Fig. 2a). This gradient related to a trait gradient from mobile species that are *r*-strategists and have many generations to species that are *K*-strategists and have a long larval development time (Fig. 2b). The second axis described a gradient in woody vegetation on which monophagous diet loaded most strongly (Fig. 2a, b).

Bird trait composition related to environmental variables in the RLQ analysis with a projected inertia of 82% on the first and 10% on the second axis. In contrast to butterflies, the amount of woody vegetation on all scales was the strongest environmental gradient and decreased from left to right in the ordination plot (Fig. 3a). The corresponding gradient in trait composi-

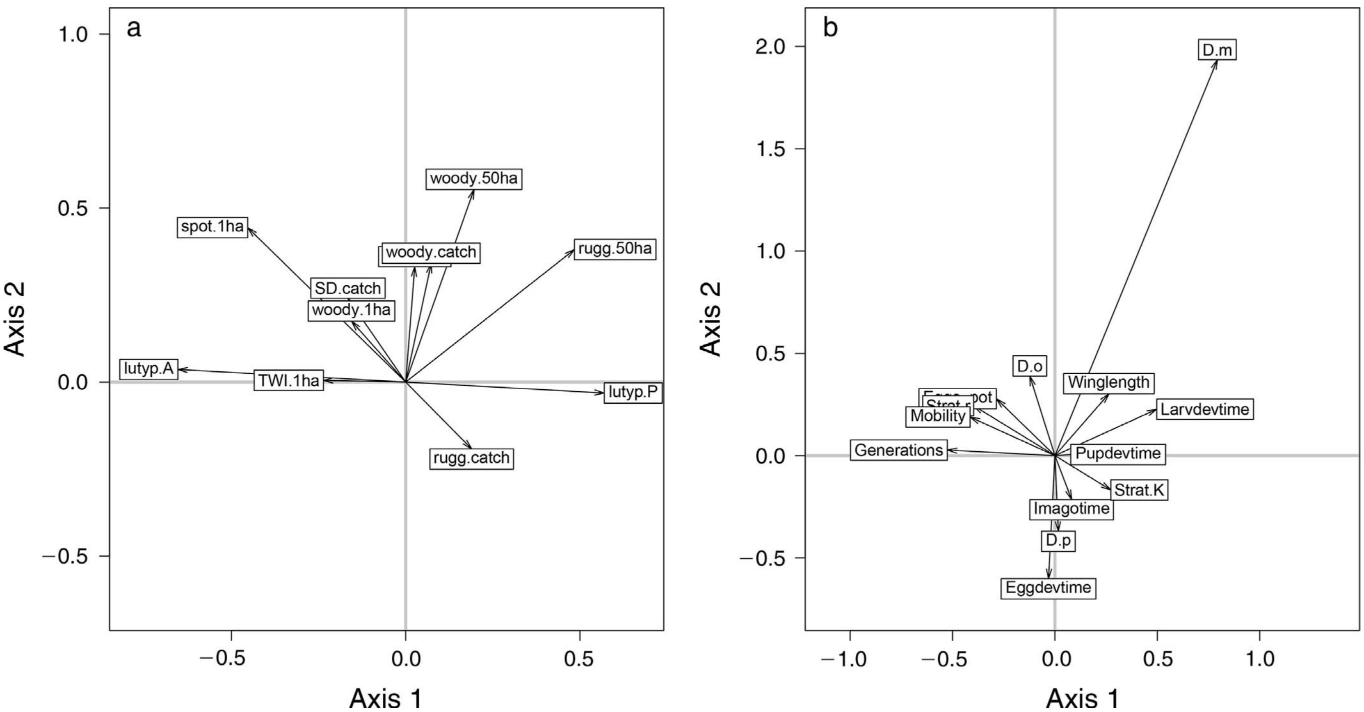

Fig. 2. Results from the RLQ analysis of the butterfly data. The ordination plots show the scores of (a) environmental variables and (b) functional traits on the first two axes (for abbreviations, see Tables 1 and 2). RLQ, which maximizes the covariance between sites and species, involved separate ordinations on environmental variables (*R*; Hill-Smith principal components analysis), species abundance (*L*; correspondence analysis), and species traits (*Q*; Hill-Smith principal components analysis).

tion ranged from large or small species that nest and forage in trees to species of intermediate size that nest and forage on the ground (Fig. 3b). The second environmental axis described a gradient from arable sites and local variables being important to pasture sites and context variables being important (Fig. 3a). Granivorous species and generalist gleaners tended to occur more frequently in pasture sites and omnivorous species that feed in the understory occurred more frequently in arable sites (Fig. 3a, b).

Discussion

Land use intensification has decreased functional diversity of different taxa worldwide, including birds, mammals, and plants (Flynn et al. 2009, Laliberte et al. 2010). Similarly, butterfly communities have been shown to become functionally more homogenous with increasing farming intensities in Germany and Finland (Ekroos et al. 2010, Börschig et al. 2013). Land abandonment, despite bringing a de facto decrease in land use intensity, showed a similar homogenizing effect on bird communities in Spain (Clavero and Brotons 2010). While land use change, especially in Eastern Europe, is an important and ongoing process (Fuchs et al. 2013), its impact on diversity and functioning of species communities cannot be foreseen yet (Sutcliffe et al. 2015). Our study presents patterns of functional diversity and composition in a traditional farming landscape in central Romania that is currently subject to such land use changes but has not (yet) been affected by large-scale agricultural intensification (Schmitt and Rakosy 2007, Hanspach et al. 2014). Thus, our study provides important baseline data and contributes to improving our understanding of biodiversity patterns in cultural landscapes in a mechanistic way.

Functional diversity

In this study, we found a positive relationship between functional and taxonomic diversity, which was particularly strong for birds. This finding is in line with theoretical expectations as well as empirical findings that functional diversity should increase with species richness (Diaz and Cabido 2001, Devictor et al. 2010). This indicates that land use intensification might not only lead to species loss (Loos et al. 2014*a*, Dorresteijn 2015) but also to a functional simplification of species communities. A similar loss in functional diversity has been described for bird, mammal, and plant communities in farmlands of North and South America (Flynn et al. 2009). Notably, the relationship between taxonomic and functional diversity was less strong for butterflies, indicating that functional diversity is already saturated at moderate levels of taxonomic diversity. A similar quadratic relationship was found by Cumming and Child (2009) for birds in South Africa. Possibly, in our

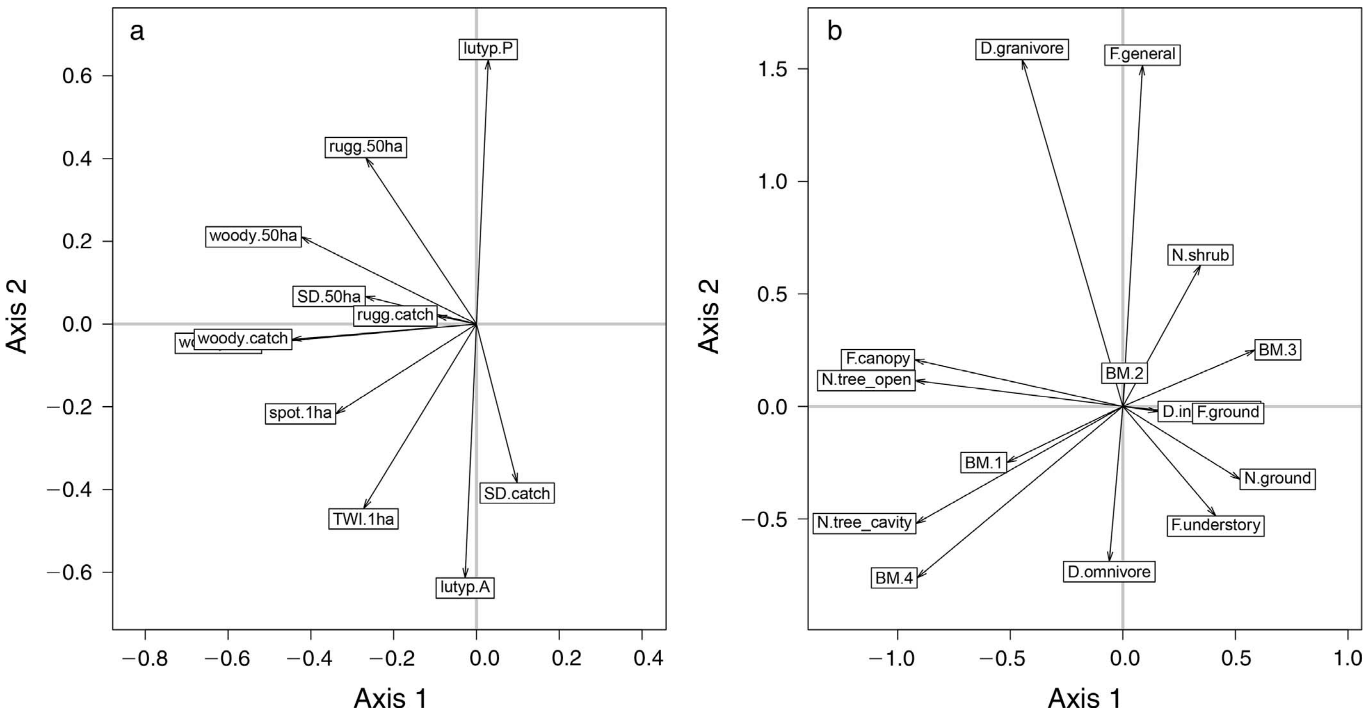

Fig. 3. Results from the RLQ analysis of the bird data. The ordination plots show the scores of (a) the environmental variables and (b) the functional traits on the first two axes (for abbreviations see Tables 1 and 2).

case study this pattern is due to the fact that farming intensities are still relatively low compared to many Western European countries (Dorresteijn et al. 2015) and can thus sustain a relatively high functional diversity. This is also supported by a study from northern Spain that found a particularly high functional diversity of birds in farmlands (Clavero and Brotons 2010).

Functional composition

Trait composition of butterflies related to the main land cover types, which reflected the different reproduction strategies of butterfly species, with *r*-strategists preferably occurring in arable land and *K*-strategists in pastures. This pattern of species with short lifespan and fast reproduction with many offspring has analogously linked to systems with high disturbance (e.g., through farming practices) for plants (Lavorel et al. 1997). Likewise, ground beetles in Scotland showed a strong response to management intensity, with smaller-sized species being more abundant in farmland sites with high levels of disturbance (Ribera et al. 2001). Remarkably, we found that species and trait composition of butterflies in arable land correlated consistently with environmental variables at small scales, indicating the importance of fine-scaled heterogeneity for species composition. The loss of local heterogeneity in arable land would likely lead to a loss of species with certain traits, such as oligophagy, high mobility, *r*-strategy, and a high egg potential. However, these traits are usually considered to be characteristic for generalist species and they are seen to be favored by a homogenization of agricultural landscape (Ekroos et al. 2010). This contradiction may be explained by the overall heterogeneity in southern Transylvanian landscapes, which is not comparable to the gradient of homogenization in the highly intensified agricultural landscapes of Western Europe (Van Dyck et al. 2009). Another environmental variable representing heterogeneity and fine-scale structure of the landscape is woody vegetation cover, which correlated with monophagous diet of specialized butterfly species. Thus, a loss of structural diversity in the landscape by, for example, a reduction of woody vegetation is likely to result in the loss of specialized butterflies (Öckinger et al. 2012, Ohwaki et al. 2014).

Bird species composition in our study was most strongly influenced by a gradient of woody vegetation that correlated with body size, nesting location, and feeding preferences. This result complements previous findings that species richness of birds is strongly driven by the amount of woody vegetation at the local scale (Dorresteijn 2015). It also confirms findings by Barbaro and Van Halder (2009), who reported that large- and small-bodied birds were positively related to woody vegetation in a mosaic landscape in southwestern France. Similar to Barbaro and Van Halder (2009), we found that the amount of woody vegetation at all scales was important to structuring species and trait composition of bird communities. In contrast to the results for butterflies, we found only a very weak relationship with

Table 3. Results of the RLQ analyses for butterflies and birds.

Variable	Butterflies		Birds	
	Axis 1	Axis 2	Axis 1	Axis 2
Correlation *L*	0.22	0.15	0.40	0.22
Projected inertia (%)	69.2	25.4	81.9	9.7
Variance retained *R* (%)	78.1	87.7	95.3	95.2
Variance retained *Q* (%)	82.8	85.9	72.1	61.6

Note: RLQ was based on separate ordinations on environmental variables (*R*; Hill-Smith principal components analysis), species abundance (*L*; correspondence analysis), and species traits (*Q*; Hill-Smith principal components analysis).

land use type on bird communities. Our findings demonstrate that homogenization through intensification of the agricultural landscape may result in the loss of functional traits related to small or large body size, and ecological mechanisms linked to the presence of woody vegetation, such as foraging in the understory.

Conclusions

This study provides a mechanistic understanding of the response of species to environmental conditions in a traditional farming landscape in Eastern Europe. Since many traditional farming landscapes are threatened by either agricultural intensification or land abandonment, efficient conservation strategies are required to halt biodiversity decline. In order to preserve Transylvania's high taxonomic and functional diversity, it is crucial to maintain the typical landscape characteristics, such as small-scale mosaics of different land use types and intensities, as well as gradients of woody vegetation throughout the region. These findings are highly relevant for similar farming systems in Eastern Europe as well.

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