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Plant diversity in a changing agricultural landscape mosaic in Southern Transylvania (Romania)

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ABSTRACT

Traditional agricultural landscapes represent mosaics of land use covers that often support high species diversity. Many Eastern European countries contain large areas of High Nature Value (HNV) farmland. However, these landscapes are likely to change under current EU regulations and global market pressure, with potentially negative consequences for biodiversity. The conservation value of Romania's grasslands is widely recognized, but the potential conservation value of other parts of the landscape mosaic has not been assessed to date. For this reason, we sought to assess patterns of plant diversity across the entire landscape mosaic. We sampled vascular plants at 139 sites (comprising 8 plots of 1 m^2/ha) in forest (n = 23), grassland (n = 57) and within the arable mosaic (n = 59). To examine potential differences in species richness and composition between these land cover types, we used analysis of variance and detrended correspondence analysis. We also modeled total species richness, richness of HNV indicator plants and richness of arable weeds in response to variables representing topography as well as structural and configurational heterogeneity. Species composition differed strongly between grassland, the arable mosaic and forests. Richness was highest in grasslands, but surprisingly, the arable mosaic and grassland contributed similarly to the cumulative number of recorded species. Models of species richness revealed a wide range of responses of plant groups to topographical conditions and to structural and configurational heterogeneity, which often differed between land use types. Plants were affected by conditions measured at both local (1 ha) and landscape (50 ha) scales. Noting the substantial, and hitherto under-recognised, contribution of the agricultural mosaic to regional-scale plant diversity, we recommend consideration of the entire landscape mosaic in future conservation schemes.

1. Introduction

Many agricultural landscapes around the world are characterized by a mosaic of land covers (Forman, 1995). With their various patches of land-use types and structures, mosaic landscapes often host a wide range of species (Bennett et al., 2006). However, unprecedented changes in agricultural mosaic landscapes are causing major biodiversity loss worldwide (Tscharntke et al., 2005). Moreover, patterns of species richness and distribution in agricultural landscapes are affected by processes operating at multiple spatial scales, including both local and landscape-level variables (Vandvik and Birks, 2002; Rundlöf et al., 2010; Costanza et al., 2011). Hence, effective management of biodiversity in agricultural landscapes requires an assessment of the drivers of species diversity across multiple spatial scales.

In many Eastern European countries, such as Romania, traditional practices have created small-scale mosaic landscapes. For example, 72% of farms in Romania are smaller than 1 ha (Fundatia Adept, 2012), and individual fields are typically smaller than that. However, Romania's farmland has been undergoing drastic changes since the collapse of communism in 1990 (Kuemmerle et al., 2008) and accession to the European Union (EU) in 2007. Ongoing land use changes comprise both intensification of land use in some areas, and land abandonment in others

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(Government of Romania, 2010; Dahlström et al., 2013; Mikulcak et al., 2013). At present, 20% of Romanian farmland is considered to be High Nature Value (HNV) farmland, and 10% is protected under the EU Birds and Habitats Directives (Natura 2000) (European Environment Agency, 2010). Despite official recognition of the ecological values of large areas of farmland, the future of Romania's agricultural landscapes and their biodiversity is uncertain.

Some of Romania's most notable mosaic landscapes occur in the region of Southern Transylvania. A large part of Transylvania was recently designated one of the largest continuous (lowland) Natura 2000 sites in Europe (i.e., Târnavelor Plateau), partly in recognition of its outstanding grassland diversity (Jones et al., 2010; Akeroyd and Page, 2011). The region's biodiversity includes various taxa that are rare or endangered in other parts of Europe, such as the yellow-bellied toad (*Bombina variegata*) (Hartel and von Wehrden, 2013), *Maculinea* butterflies (Vodă et al., 2010) and several rare species of woodpeckers (Dorresteijn et al., 2013). Moreover, Transylvanian dry grasslands hold the world record for vascular plant species richness at the scales of 0.1 m^2 and 10 m^2 (Wilson et al., 2012). However, land use change is likely in Transylvania, and would pose major threats to its biodiversity. Modifications of land use will most likely consist of increasing cropland area, increasing the use of agrochemicals, structural homogenization, and conversion of traditional hay meadows to pastures, thus mirroring the patterns already apparent in Western Europe (McLaughlin and Mineau, 1995; Benton et al., 2003; Billeter et al., 2008; Ernoult and Alard, 2011).

In this study, we focus on vascular plants and their distribution throughout the entire landscape mosaic in Southern Transylvania. Plants respond relatively slowly to environmental changes (Helm et al., 2006), but in agricultural landscapes, specialized species are highly prone to rapid decline (Davies et al., 2004; Clavel et al., 2010). Plant communities in agricultural landscapes are at risk of homogenization in composition because of nutrient inputs, which many species, and especially grassland specialists, are sensitive to. For Transylvania, a specific set of sensitive grassland specialists has been proposed to indicate High Nature Value (HNV) grassland (Akeroyd and Bădărău, 2012). Furthermore, arable weeds are of particular interest. Many such weeds have persisted in Transylvania to date, but are under worldwide decline, and may react quickly to changes in the environment, both at local and landscape scales (Gabriel et al., 2005; Armengot et al., 2012; Storkey et al., 2012).

We sought to understand the responses of vascular plant diversity to key landscape features. To that end, we used a snapshot natural experiment (Diamond, 1986; Lindenmayer et al., 2008) that spanned a wide range of environmental conditions with respect to heterogeneity and woody vegetation cover across local and landscape scales. We sampled vegetation and environmental conditions throughout the landscape mosaic and asked: (i) how current land use was associated with vascular plant diversity and species composition; and (ii) how landscape structure was related to total richness, richness of HNV indicator plants and richness of arable weeds.

2. Methods

2.1. Study area

Our study area covered approximately 7000 km^2 in the lowlands of Southern Transylvania, Romania. The area consists of undulating terrain with altitudes from 300 to 700 m above sea level, and its climate is subcontinental-temperate. The area comprises a mosaic of land use types, including arable fields (40% according to CORINE land cover), secondary grasslands and ancient dry steppe-like grasslands (30%) and deciduous forests (30%) (Dengler et al., 2012). The natural vegetation consists of oak-hornbeam forests (*Quercus petraea*–*Carpinus betulus*; Bohn et al., 2004).

2.2. Site selection

We followed the notion of a natural experiment (Diamond, 1986), with randomized site selection in pre-defined strata at two levels: (i) village catchments and (ii) survey sites within village catchments. We delineated the study area into village catchments using a cost-distance algorithm that allocated each pixel to the village with the lowest travel cost to this pixel (slope-penalized distance, implemented in ArcGIS 10.1). We randomly selected a subset of 30 village catchments within three different strata cross-combined by a gradient of terrain ruggedness (low, medium, high; defined by quantiles) and protection status according to EU Birds and Habitats Directives (Site of Community Importance (SCI), Special Protection Area (SPA) and unprotected; Table S1). Within each village catchment, we assigned land to three different land use types using the CORINE land cover map, namely forest, grassland or arable land. By "arable land", we refer to the mosaic of arable land in its entirety, including semi-natural vegetation occurring within the mosaic, such as field margins, road verges, hedges and old fields. Throughout grassland and arable land (collectively termed "farmland"), we identified gradients of heterogeneity and woody vegetation cover. We quantified heterogeneity as the standard deviation of panchromatic SPOT 5 data (© CNES 2007, Distribution Spot Image SA) within a 1 ha moving window. We calculated the percentage of woody vegetation within a 1 ha moving window by supervised classifications of the panchromatic channels of SPOT 5, using a support vector machine algorithm (Knorn et al., 2009). We used the upper, middle and lower thirds of these gradients to randomly select cross-replicated circular 1 ha survey sites – 59 within arable land and 57 within grassland (Table S2). An additional 23 sites (also measuring 1 ha) were randomly selected in forest without further stratification.

2.3. Vegetation surveys

We conducted vegetation surveys between 26 May and 26 August, 2012. We sampled eight plots measuring 1 m × 1 m within each site, placed at a random distance from the center, and distributed every 45°. We alternated between random distances >40 m and <40 m from the center to cover the inner and the outer 0.5 ha of the site equally. In each plot, we identified vascular plants to species level and recorded their percent cover.

2.4. Environmental parameters

We considered variables that were potentially related to plant species richness within circles of 1 ha (henceforth: local level) and circles of 50 ha (henceforth: landscape level) around a given site. At the local level, we considered heterogeneity, altitude, woody vegetation cover, a heat index (after Parker (1991): cos (slope aspect − 225) × tan (slope angle)), a terrain wetness index (after Fischer et al., 2010), and land cover type. At the landscape level, we considered terrain ruggedness, woody vegetation cover, edge density to account for configurational heterogeneity (Fahrig et al., 2011), and a Simpson index of heterogeneity to account for compositional heterogeneity. Variables were calculated using ArcGIS 10.1 and FragStats 4.1, and are described in more detail in Table 1.

2.5. Statistical analyses

The analyses consisted of three steps. First, we compared the means of alpha and beta richness (sensu Tuomisto, 2010) between the different types of land use and different levels of protection status. Second, we investigated patterns in community