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A stronger influence of past rather than present landscape structure on present plant species richness of road-field boundaries

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ABSTRACT

Road verges provide a refuge for numerous plant species, especially in agroecosystems characterized for decades by a general decline in semi-natural habitats and edge density. Beyond the influence of present landscape structure on the local structure and composition of plant communities, past landscape structure could also have a substantial effect. Indeed, a temporal delay could especially be hypothesized between periods of landscape changes and biological responses of plant communities. We surveyed plant communities of three adjacent elements of 190 road-field boundaries in Central-Western France: the berm, the embankment and the field margin. We compared the effects of past (1980) and present (2011) surrounding agricultural landscape structure on the plant species richness of each element and on the Sørensen taxonomic compositional dissimilarity index between pairs of elements using linear models and a model averaging procedure. We characterized the landscape structure at both time periods within three circular buffers of 250, 500 and 1000 m radius around the centre of each sampled road-field boundary. In each buffer, we calculated the proportion of grasslands, the proportion of woodlands and the edge density. Despite a weak explanatory power of the landscape structure, species richness of each road-field element was better explained by past than present landscape structure. Species richness of berms, the element of the road-field boundary having the highest proportion of perennial species, was also the most influenced by past landscape structure. As an example, species richness of berms increased with the proportion of woodlands and the edge density when considering a buffer of 500 m radius. In contrast, compositional dissimilarity between pair of elements was neither affected by past nor present landscape structure. Our results suggest that the taxonomic diversity of plant communities of road-field boundaries have a time-lagged response to landscape changes, emphasising that currently implemented management programs represent high stakes for biodiversity conservation in future decades.

1. Introduction

With the rapid growth of human population during the last century, associated with industrialization and urbanization, road networks have largely expanded over urban and rural areas. Roads have major direct and indirect ecological impacts on biodiversity, including habitat destruction and isolation of populations of different taxa (Rytwinski and Fahrig, 2012; Trombulak and Frissell, 2000). However, road verges, which are permanent linear vegetation margins established along roads, may also represent refuges for various plants and animals (e.g. Auestad et al., 2011; de Redon de Colombier et al., 2015). Road verges can therefore play a major role in maintaining or even enhancing ecological processes within agroecosystems, such as pollination and pest control (Le Viol et al., 2008; Noordijk et al., 2009). These positive effects may be exacerbated in intensively managed agricultural landscapes where semi-natural habitats are rare and highly fragmented (de Redon de Colombier et al., 2015). In these landscapes, road verges are usually adjacent to arable fields, therefore also potentially favoring the dispersal of some competitive generalist weed species from road verges to field margins (Chaudron et al., 2016a), causing a serious concern to farmers. In this context, understanding the factors that shape species assemblages of road-field boundaries appears crucial to implement effective management programs for biodiversity conservation purposes.

Numerous studies have focused on the management practices made

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locally by employees of technical services that drive road-field plant assemblages (Auestad et al., 2011; Chaudron et al., 2016b; Humbert et al., 2012; Persson, 1995). While the influence of changes in management practices on plant assemblages is well recognized (e.g. Kahmen et al., 2002; Köhler et al., 2005), factors driving these assemblages at larger scales are less known. Landscape composition (the relative proportions of the different land-covers within an area) and landscape configuration (the spatial arrangements of these different land-covers; Lausch et al., 2015) surrounding road-field boundaries are likely to influence the pool of propagules able to colonize local plant assemblages. For instance, a high proportion of semi-natural habitats in the surrounding landscape frequently favors a higher local species richness in the focal habitat, either grassland or arable field (Concepción et al., 2012; Öster et al., 2007; Petit et al., 2013; Reitalu et al., 2009; Solé-Senan et al., 2014). However, not all studies highlight this relationship (Aavik and Liira, 2010; Armengot et al., 2011; Petit et al., 2016). This can be due to the relative effects of management practices and landscape structure on plant communities of linear elements in agricultural landscape, as well as their potential interactions (see Aavik and Liira, 2010; Le Coeur et al., 1997; Marshall, 2009).

In a context of dispersal limitation and long-term persistence of species via seed bank or as long-lived perennials, several authors have also suggested that past rather than present landscape structure could strongly affect present local plant community structure and composition (Lindborg and Eriksson, 2004; Piqueray et al., 2011). In particular, response of plant assemblages to environmental changes would often be slower than environmental changes themselves (Kuussaari et al., 2009). However, until now conclusions about time-lagged response of plant communities of agroecosystems are contrasted and context-dependent. For instance, in Sweden, Lindborg and Eriksson (2004) showed no influence of the present grassland connectivity level on plant species richness of grasslands while a positive effect of past connectivity level was shown. This effect was also highlighted on plant communities of calcareous grasslands in Belgium (Piqueray et al., 2011), while other studies found weak or no effect of past landscape structure on present plant species richness (Cousins et al., 2007; Öster et al., 2007). Furthermore, it has been suggested that the impact of past landscape structure could be species dependent, with a more rapid response to landscape changes for short-lived species than for long-lived species, the latter having hypothetically a more marked time-lagged response (Johansson et al., 2011; Lindborg, 2007).

All previously mentioned studies have focused on environmentally homogeneous perennial habitats characterized by slow environmental changes, especially permanent grasslands, while only a few have considered more intensively disturbed habitats such as road verges and arable fields (Baessler and Klotz, 2006; Cousins, 2006).

Therefore, our study aims to compare the influence of the past and the present landscape structure on diversity and composition of plant communities of road-field boundaries in an intensive agricultural area.

First, we assessed whether plant communities of three elements of road-field boundaries, i.e. the berm, the embankment and the field margin, show a time-lagged response to changes in landscape structure and are better related to the past than to the present landscape structure. Based on previously mentioned studies (Johansson et al., 2011; Lindborg, 2007), we hypothesized that road-field elements with the highest proportion of perennial species, i.e. berm and embankment, should show the strongest time-lagged response to the landscape structure. Moreover, we hypothesized that the species richness should be promoted by a higher proportion of semi-natural habitats in the surrounding area (Öster et al., 2007; Reitalu et al., 2009; Solé-Senan et al., 2014), due to higher colonization rate by other perennials from neighboring grasslands and woodlands, as previously suggested by Cousins (2006).

Some studies have also shown that local species richness is generally higher in fine-grained landscapes characterized by a large number of small arable fields, and therefore higher density of field margins should be able to contain various plant species (Fahrig et al., 2015; Gaba et al., 2010; Medeiros et al., 2016). These linear edges can represent favorable habitats and corridors for some species potentially able to colonize road-field boundaries.

In this context, we also hypothesized that the compositional dissimilarity between plant communities of road-field elements should be higher when the proportion of semi-natural habitats and density of edges increase, due to an expected higher flow of propagules from the surrounding area, more likely firstly colonizing berms and embankments.

Finally, given that responses of local communities to landscape structure have been shown to be scale-dependent (McGarigal et al., 2016), to investigate landscape effects on plant communities, we also studied which scale(s) is (are) relevant to explain the species richness and the taxonomic composition of road-field boundaries.

2. Materials and methods

2.1. Study sites

The study was conducted in Central-western France, south-east Indre-et-Loire department (Fig. 1a), which is characterized by clay-limestone soil, leached siliceous soil, cambisols and lightly leached cambisols (Chambre d'Agriculture d'Indre et Loire, 1986). In our study area, for more than three decades, agricultural intensification has led to strong changes in landscape structure, including a substantial increase in cropland area and in arable field size, leading to the decline of grassland area and perennial linear elements (Xiao et al., 2015, see Appendix A for details). In 2014, i.e. the year of the study, land covers were mainly composed of arable crops (64%), woodlands (17%) and permanent and temporary grasslands (10%). Mean temperature was 5.5 °C in December 2013 and 20.4 °C in July 2014, and annual precipitation in 2014 was 656 mm (Infoclimat, database).

2.2. Vegetation survey

A total of 190 road verges were surveyed, located adjacent to arable fields sown with winter cereals that represent the dominant crop production in the area (around 35% of the agricultural area sown with winter wheat and 10% with winter barley). Three adjacent road-field elements were sampled in each road-field boundary, corresponding to two elements predominantly dominated by perennial species (the berm and the embankment, Fig. 1b) and one element dominated by annual arable weed species (the inner-field margin, Fig. 1b). All vascular plant species were recorded from May to July 2014 within a plot of 10 m^2 positioned in each element, resulting in a total of 570 plots sampled (190 road-field boundaries × 3 elements). Within each sampled boundary, the width and the length of the three plots were defined based on the width of the narrowest road-field element of this boundary. Among road-field boundaries, the width and the length of the three plots partly varied among the sampled boundaries (length = 24.27 ± 7.27 m, min = 20 m, max = 67 m; width: 0.44 ± 0.08 m, min = 0.15 m, max = 0.5 m), although a low variation in plot dimensions occurred among most of the boundaries, with 78% of plots having a length between 20 and 25 m. The presence-absence of each species was recorded within each plot. The nomenclature was based on the French taxonomic reference TAXREF v8.0 database (Gargominy et al., 2014).

2.3. Landscape variables

Landscape structure was characterized in 1980 and 2011, i.e. before and after the reform of the European Common Agricultural Policy implemented in 1992 that had resulted in the promotion of arable crop production to the detriment of grassland areas (Peyraud et al., 2012). Past and present landscape structure were characterized within three