



Original article

Is plant temporal beta diversity of field margins related to changes in management practices?

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ABSTRACT

Field margins have considerable ecological significance in agriculture-dominated landscapes by supporting biodiversity and associated services. However, agricultural changes during mid-20th century led to their drastic loss with a serious threat for biodiversity. Using time-series data, we aimed to get better insights into processes underlying plant patterns of field margins through time by i) quantifying plant temporal beta diversity components, ii) assessing whether the observed changes in plant communities can be related to changes in management practices applied to field margins. During the springs of 1994, 1998 and 2001, we surveyed plant communities and management practices of the same 116 field margins in three contrasted landscapes. We estimated temporal beta diversity in plant communities and partitioned it into its two dissimilarity resultant components, accounting for replacement of species (i.e. turnover) and for the nested gain or loss of species (i.e. nestedness). We then tested whether the observed changes in plant communities between 1994 and 1998 and, between 1998 and 2001 were related to changes in management practices using linear models. Plant communities of field margins exhibited strong temporal beta diversity dominated by turnover. Temporal turnover in plant communities was partly related to changes in management practices, i.e., a decrease of grazing concomitant to an increase of herbicide spraying. However, relationships were not consistent between all landscape contexts nor time period, suggesting that other unmeasured deterministic or stochastic processes could be driving the observed plant patterns. Taken together, our results suggest that maintaining a wide diversity of field margins with contrasted management contribute to maintaining plant diversity at a landscape scale. They underline the value of investigating plant temporal diversity patterns using time-series data and thus, the need to develop long-term studies making it possible to understand ecological processes shaping plant communities in agricultural landscapes.

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1. Introduction

Field margins, as non-crop habitats, are generally considered to be of great importance for maintaining biodiversity and associated services in agricultural landscapes (Baudry et al., 2000). Field boundaries can benefit crop growth by serving as windbreak (Forman and Baudry, 1984), and by reducing soil erosion, floods and pesticide drift (Marshall and Moonen, 2002). Field boundary vegetation can also provide resources and refugia for farmland wildlife (Meek et al., 2002). Since the 1950s, the agricultural

intensification with more artificial inputs, has presented a serious threat to the biodiversity of agricultural landscapes through the drastic loss and degradation of field margins (Deckers et al., 2005).

As the boundary of fields, field margins are often subject to drift from adjacent farming operations, such as ploughing, fertilizing, herbicide drift, mowing and grazing regimes (Kleijn and Verbeek, 2000). Some or all these factors result in a high level of disturbance, a potential soil nutrient enrichment, with consequences on plant assemblage structure and composition of field margins (de Snoo and van der Poll, 1999; Marshall and Moonen, 2002). In addition, these local management practices may have been affected by agricultural trends such as the increase in land-use intensity (Billetter et al., 2008). Hence, understanding how the plant diversity of field margins evolves and responds to agricultural changes is needed to provide baseline information for biodiversity

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conservation and deliver wise management decisions (Croxtton et al., 2004).

Many studies have analyzed spatial variation in plant species richness and composition of field margins in relation to management practices (e.g. Le Coeur et al., 1997; Moonen and Marshall, 2001). A recent study (Alignier and Baudry, 2015) has shown that the examination of past management practices opens new avenues by which the present patterns of field margin vegetation can be understood. Although the study of temporal variations in local communities represents a necessary complement to that of spatial variations and because of the difficulty in obtaining temporal data, there is no study, to our knowledge, that have explicitly addressed the effects of temporal changes in management practices on variations in plant diversity of field margins.

One way to consider and measure the implication of human activity and land-use change for biodiversity is to partition diversity. Diversity partitioning has been increasingly applied to examine diversity within hierarchical systems (e.g. Wagner et al., 2000; Golodets et al., 2011). Diversity components include alpha diversity (the average number of species in a sample of homogeneous habitat), gamma diversity (the total number of species of the habitat type for a given study site) and beta diversity, which is a measure of the heterogeneity in community composition. Assessment of beta diversity is a useful approach as it preserves species identities (through species composition). It bears the potential to unveil patterns of assemblage variation that would be independent of species richness (Baselga and Leprieur, 2015). In addition, beta diversity provides a link that connects diversity measures across scales, between local (i.e. alpha diversity) and large scale (i.e. gamma diversity) (Anderson et al., 2011).

Recently, temporal beta diversity has been proposed to examine how species composition within a community fixed in space changes over time (La Sorte et al., 2014; Shimadzu et al., 2015). As for spatial beta diversity, temporal beta diversity can be partitioned into two additive components reflecting two different phenomena: (i) the replacement of species (temporal turnover) and (ii) the gain or loss of species (nestedness–resultant dissimilarity) through time (Baselga et al., 2015). Of the two, only the gain or loss of species causes richness difference. When the gain or loss of species occurs in a more or less ordered manner, community pattern become nested (Atmar and Patterson, 1993). Nestedness refers to the extent to which species of a smaller assemblage are a subset of a larger assemblage.

From the point of view of species assembly, temporal changes in species composition (i.e. temporal beta diversity) result from deterministic changes in species distributions in relation with environmental changes through niche filtering. For example, agricultural intensification through management practices and land use changes, have lead to a decline in farmland species richness (Flohre et al., 2011). However, changes in species distributions might also result from the stochastic influence of environmental fluctuation (e.g. climatic conditions), demography, non-equilibrium conditions (e.g. non-saturated habitats in which local populations can disperse or disappear) and species dispersal (Tognetti et al., 2010). Both phenomena, turnover and nestedness, can either reflect such stochastic or deterministic processes. But, turnover and nestedness patterns are drastically different in their biological consequences (species loss vs. species replacement). For this reason, even if two landscapes had the same beta diversity value, it would be misleading to consider them to be equivalent if one had high turnover and low nestedness, while the second had low turnover and high nestedness (Baselga, 2010). We believe that such a beta diversity partitioning approach provides better insights into processes that underlie variations and shape ecological communities across time.

In this work, we investigated temporal changes in plant communities of field margins following a beta diversity partitioning approach. We focused on the temporal beta diversity of plant communities in 116 resurveyed field margins at three dates (1994, 1998 and 2001). We hypothesized that plant community assembly of field margins is driven by a sequence of field margin-scale disturbances and stresses that may be interpreted as assembly filters (Kleijn and Verbeek, 2000). Indeed, under a community assembly framework, management practices may be viewed as filters that negatively affect the establishment, growth and reproduction of plant species and therefore reduce the size of the species pool. Plant species that possess traits making them susceptible to a given filter or set of filters are less likely to be present in the community following the application of that filter (Booth and Swanton, 2002). With agricultural intensification, we expect that management practices filter plant assembly through time and thus, nested patterns should be observed. We also expect biotic homogenization i.e. process referring to an increase in the taxonomic similarity between communities through time (Rooney et al., 2007), due to selective management practices. Specifically, we aimed to get better insights into processes underlying plant patterns of field margins across time by i) quantifying plant temporal beta diversity components, ii) assessing whether the observed changes in plant temporal beta diversity can be related to changes in management practices applied to field margins. We considered three contrasting landscape contexts. The rationale here was that landscapes with distinct evolutionary trajectories can lead to contrasted relationships between temporal beta diversity and management practice changes.

2. Material and methods

2.1. Study area

The study was conducted in northern Brittany, France (48°36'N, 1°32'W). This area called “Zone Atelier Armorique” is a Long Term Ecological Research (LTER) site and part of the French “Zones Ateliers” networks. The climate is temperate oceanic with mild and humid winters. The annual average rainfall is close to 600 mm, the annual average temperature is 12 °C. The study area is located in a bocage region where the dominant agriculture is mixed dairy farming, with annual crops (mostly winter cereals and maize), and temporary and permanent grasslands being bordered by hedgerows and interspersed by woodlands. The hedgerows are rows of oak (*Quercus robur*) or chestnut (*Castanea sativa*), in general, planted on an earthen bank 0.5–0.8 m high (Burel et al., 1998).

2.2. Field margin selection

We sampled 116 field margins across three contrasted landscapes (50 in landscape A, 36 in landscape B and 30 in landscape C). The three landscapes (~600 ha each) were defined from mapping surveys using a combination of the grain size of the field mosaic, the density of hedgerow network, and the relative abundance of grassland versus crop. The three landscapes were 5–10 km distant from each other. In landscape A, the hedgerow network had the highest density, landscape B was intermediate and landscape C was a more open landscape with a low density of hedgerows (Le Coeur et al., 2002). The area of fodder production (maize for silage and grassland) averaged 80% in landscape A, 71% in landscape B and 63% in landscape C (Le Coeur et al., 1997). Between 1952 and 1982, landscape A lost 54% of its hedgerows against 81% for landscape C. Much greater removals occurred during the subsequent decade, especially in landscape C following a large reallocation operation (Morant, 1994). Permanent grasslands associated with extensive

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