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Changes in management practices over time explain most variation in vegetation of field margins in Brittany, France

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ABSTRACT

Studies of the effects of modern agriculture on biodiversity have generally lacked a historical perspective. Field margins have considerable ecological significance in agriculture-dominated landscapes, but are affected by interaction with management practices in the margin and on adjoining land. This study investigated the time period over which changes in management practices best explains the occurrence of 40 plant species now commonly found in 311 field margins of Zone Atelier Armorique, Brittany, France. Five management practices were surveyed every year since 1995. Species occurrence was recorded in 2007, 2011 and 2013 and related by means of GLMMs to management practices over time, up to a maximum of 12 years, i.e., scores of field margins on the two first axes of correspondence analysis (CA) performed on management practices. Model selection using AIC criteria allowed us to identify the time period over which to consider management practices that best explain plant patterns. For one third of the common 40 plant species recorded, the time period over which to consider management practices was greater than one year. The rest of the species showed inconsistent patterns with high level of variability between 2007, 2011 and 2013. The time period tended to be longer for species with vegetative reproduction and for zoochorous species. Our results show that the long-term simultaneous monitoring of both vegetation and management practices is important to understand some ecological patterns that would be missed either in short-term studies or for studies that exclude management information. Our findings contribute to long-term strategies for management and conservation of field margins diversity by highlighting that different plant groups require management on particular timescales.

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1. Introduction

Field boundaries such as hedgerows have a range of purposes in agricultural landscapes, including agricultural, environmental, wildlife and cultural functions (Baudry et al., 2000). These perennial non-crop habitats bordering fields are important for maintaining biodiversity and associated ecosystem services (Kleijn and Verbeek 2000; Olson and Wäckers 2007). 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). By the provision of nectar and pollen-producing plants, habitat sheltering and overwintering, high level of floral diversity in field boundaries can enhance beneficial arthropods such as pollinators and natural enemies of crop pests (Schweiger et al., 2005), and the services they provide.

The networks of field boundaries have evolved with agriculture (Marshall and Moonen 2002). During the mid-20th century, agricultural intensification, field enlargement and mechanization led to a drastic loss of field boundaries. Deckers et al. (2005) reported that the hedgerow network more than halved between 1900 and 1992 in Flanders, Belgium, for example. More recently, the increasing recognition of the ecological and amenity functions of hedgerows has led to initiatives for their conservation and restoration, e.g., through planting programs (Croxton et al., 2004). Although efforts to conserve these semi-natural habitats are increasing, their management regimes and their impact on biodiversity are poorly known (Gove et al., 2007).

Field boundaries are often managed by farmers for whom one of the primary maintenance objectives is weed control. Consequently, herbicide use at the base of the hedge or on a ditch bank is common (Kleijn and Verbeek 2000). As the limit of fields, field boundaries are often subject to disturbance from adjacent farming operations, such as ploughing, herbicides drift, mowing or

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chopping regimes (Kleijn and Verbeek 2000). Other activities dedicated to the management of the woody part of the boundary, such as trimming, coppicing, pollarding of the tree and shrub layer are also common. Some or all these factors result in a high level of disturbance, a potential nutrient enrichment due to fertilizer misplacement and agrochemical drift, which may alter the plant community structure and composition of boundaries (Deckers et al., 2004). The idea that the history and evolution of field management may strongly affect current flora richness, abundance and biomass in focal field is common (e.g., Bohan et al., 2011; Potts et al., 2010). Yet the long-term consequences of management actions on field margins are rarely investigated. Long-term monitoring will thus be crucial to addressing the full extent of changes caused by management practices in field margins and to understand how present patterns of vegetation came about. We believe that this knowledge will be key to forecasting future change in community structure and ecosystem function, to deliver wise management and restoration decisions.

The relationship between the past use of fields and their current suitability for plant species has been well documented in grasslands (Gustavsson et al., 2007; Newton et al., 2012). In contrast, crop fields and field margins have been poorly investigated (but see Alignier et al., 2013). Studies have focused on individual sites, changes in biodiversity between two points in time and are often limited to compare two management regimes (i.e., grazing versus non grazing) (Zhou et al., 2011).

This paper examines over the long-term (19 years), the effects of margin management on the distribution of 40 common plant species found in 311 field margins of the Zone Atelier Armorique, Brittany, France. Our first objective was to determine what time period has to be considered when studying the effect of management on vegetation. We hypothesize that knowledge of management practices over several years will improve the explanatory power of plant presence/absence models. Indeed, plant species such as weeds may exhibit long-lived seedbanks and unfavorable environmental conditions one year would not impede their emergence the following year (Buhler et al., 1997). A recent study has demonstrated that weed richness and biomass can successfully be predicted by the crop rotation of focal fields (Bohan et al., 2011). Such results suggest that accounting for past land management may help predict the distribution of weed species but the time scale to be considered remains to be identified. Second, we hypothesize that the time period of management effect will be not independent of the life history attributes and ecological strategies of plant species. Previous studies showed that recurrent herbicide use leads to a shift in the weed seed bank in favor of more species less susceptible to herbicides applications or which avoided the selection pressure through late germinations (Fried et al., 2009). In abandoned grasslands, long-lived plants, often with clonal propagation were selected (Lindborg 2007), whereas heavier grazing would disadvantage species less able to colonize gaps or more competitive species (Bullock et al., 2001).

2. Material and methods

2.1. Study area

The study was conducted in northern Brittany, south of Mont-Saint Michel Bay, 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 close to 600 mm of annual precipitation. The study area is located in a 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).

In Brittany, as in other "bocage" regions of western Europe, the evolution of agriculture since the 1950s has been accompanied by a general decrease in the density of hedgerows, accentuated by land consolidation programs (Thenail 2002). Permanent grasslands associated with extensive livestock production gave way to maize, cereal and sown grasslands. The agricultural census data indicate an increase in farm size and a decline in human labor availability.

2.2. Vegetation sampling and life history traits

We sampled 311 field margins across three margin networks (henceforth "sites", with areas from 500 to 700 ha). These sites 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 crops. As the three sites are within 5–10 km from one another, they have a common plant species pool (Le Coeur et al., 1997).

A field margin was defined as one side of the field boundary. So, within a boundary, two field margins were distinguished for vegetation sampling (Fig. A.1). Field margins may differ in their structure (presence or not of a ditch, a tree layer) and width. Vegetation was sampled in 25 m long quadrats (one quadrat per margin) placed in the middle of the field margin or stream bank to avoid edge effects from connection with other field margins.

Presence–absence of 40 plant species of the herb layer vegetation was recorded. The 40 plant species were selected because they were common, readily identifiable and represent a large range of characteristics: in taxonomy, morphology and life history (Table A.1). Vegetation surveys were conducted in 2007, 2011 and 2013, exclusively between May 15 and August 15. Nomenclature of vascular plants is according to the *Flora Europaea* (Tutin et al., 1993).

Plant species were characterized for ten life history traits and ecological strategies. The traits selected were intended to capture characteristics known to be important in species responses to disturbance. We compiled information from literature on general life form, Raunkier life form, life span, seed dispersal type, ability of vegetative reproduction, Ellenberg values for light, pH, soil nutrient, seedbank longevity and Grime strategies (for data sources, traits categories, and species values/assignments, see Table A.1). All variables were qualitative and nominal except for the integer Ellenberg values.

2.3. Management practices monitoring

Information about management practices of the herb layer of field margins was gathered continuously for 19 years by irregular observations (one to twelve observations *per* year) between 1995 and 2002, then each trimester between 2003 and 2013. For consistency, management data was transformed to presence–absence *per* year. We focused on five management practices which can co-occur in a same year: grazing, chopping, mowing, herbicide spraying, and ploughing. Grazing, by interfering with competition in plant species, is likely to influence the composition of plant assemblages. Mowing is done with a mower or a brush cutter backpack and the hay is usually removed. Chopping consists in complete destruction of aerial plant biomass and leaves residues on the field margin, contributing to nutrient enrichment. Herbicide spraying may create gaps in the herb layer that can be used by species with efficient dispersal for colonization and transitory establishment. In the absence of ditches, ploughing may be used on the field margin, intentionally or not. Ploughing, by soil disturbance, may facilitate colonization by incoming seeds or stolons.

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