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Arable weed decline in Northeast Spain: Does organic farming recover functional biodiversity?

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ABSTRACT

The comparison of the frequency, richness and weed cover of total species and functional groups of weeds, including those of interest for birds, pollinators and other invertebrates, and the subset of segetal and rare species from the 1950s to the present, has allowed to detect the consequences of the agricultural intensification in Catalonia (NE Spain) at regional and field scales. We analyzed field plots of conventionally managed cereal fields of the periods 1953–88 and 1996–99 while cereal fields assessed in the period 2005–07 were organic and conventionally managed. Our results indicate a remarkable reduction in weed frequency (58%), species richness (47%) and total weed cover (69%) from the 1953–1988 to 2005–2007 periods. The diminishing species richness was observed in species that are important for birds, pollinators and other invertebrates, but the most drastic decline was observed in the segetal and rare species subsets (75% and 87%, respectively). In current organic crops, the frequency, richness and total weed cover per relevé are significantly higher than in conventional crops, especially for those groups of species that are interesting for fauna and for segetal (more than twice) and rare species (4-fold). Nevertheless, the increase in arable weeds by current organic management is still insufficient to recover the highest plant biodiversity values that were observed before the widespread agricultural intensification in Catalonia.

1. Introduction

A decline of species richness and abundance of arable weeds in the last decades in relation to agricultural intensification has occurred at regional and field scales (Andreasen et al., 1996; Hyvönen et al., 2003; Baessler and Klotz, 2006; Meyer et al., 2013; Storkey et al., 2012; Richner et al., 2015). The high application rates of chemical herbicides and fertilizers, use of commercial seeds and the monoculture of species or varieties, or the transformation of marginal arable land into grasslands or forests are the main factors that have reduced weed diversity in arable fields (Robinson and Sutherland, 2002; Roschewitz et al., 2005; Hyvönen, 2007; José-María and Sans, 2011). Moreover, the accumulative effects of these high-intensive farming practices are the main drivers that have led to the decrease or disappearance of the segetal flora (a subset of the arable weeds that thrive almost exclusively in cereal fields and that are characteristic species of arable crops) in different European countries (Andreasen et al., 1996; Sutcliffe and Kay, 2000; Baessler and Klotz, 2006; Fuchs and Saacke, 2006; Fried et al., 2009; José-María et al., 2010; Meyer et al., 2013). A meta-study on arable species in Central Europe showed a reduction of species per field of 20–50% for the period between 1950 and 1990 (Albrecht and Bachthaler, 1990), and recently Richner et al. (2015) remarked that changes in agricultural practices have dramatically altered the arable flora of Europe since the Second World War.

The role of weeds is manifold. From an agronomic point of view, they represent a major problem for farmers because of the yield losses that are associated with their presence. Moreover, the decrease in weed diversity has dramatically affected the associated food web and, in turn, the provision of agronomic ecosystem services such as biological pest control and pollination (Robinson and Sutherland, 2002; Marshall et al., 2003). In addition, arable flora provide food and shelter for a wide variety of farmland fauna. Thus, agricultural intensification may reduce functional weeds such as interesting flora for several groups of fauna, including birds (Campbell and Cooke, 1997; Wilson et al., 1999; Marshall et al., 2001, 2003), pollinators (Biesmeijer et al., 2006; Kremen et al., 2002; Potts et al., 2010; Henriksen and Langer, 2013) and other invertebrates such as phytophagous insects and plant pests (Marshall et al., 2001, 2003).

Organic farming has been addressed as an environmental-friendly set of practices that can counter the negative effects of

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agricultural intensification and the decline of biodiversity in agricultural landscapes (Rahmann, 2011). Some comparative studies among organic and conventionally managed systems have shown that weed biodiversity is enhanced in the former (Hole et al., 2005; Roschewitz et al., 2005; Armengot et al., 2012; Gibson et al., 2007; Kleijn et al., 2009). It is also widely acknowledged that less intensive farming practices such as those used in organic farming systems tend to benefit the richness and diversity of segetal flora (Van Elsen, 2000; Fuchs and Saacke, 2006; Romero et al., 2008; José-María et al., 2010) as well as the occurrence of rare arable weeds (Romero et al., 2008). Furthermore, the biodiversity of birds and invertebrates (Hyvönen, 2007), particularly insect pollinators (Holzschuh et al., 2007, 2008), have also benefited from organic farming systems.

The present paper analyses the weed diversity in dry cereal winter crops in Catalonia (Spain) from 458 floristic phytosociological relevés (field plots) surveyed between 1953 and 2007. We have also compared data from organic and conventional cereal field plots that were surveyed during the period 2005–2007 to ascertain to what extent organic farming may recover the current biodiversity decline that is related to agricultural intensification. Changes in the assemblages of weed communities considering segetal and rare species and the functional role of weed species, assessed as the proportion of important weeds for birds, pollinators and phytophagous insects, were also evaluated.

We addressed the following questions: (1) Has weed diversity been reduced in cereal crops of Catalonia throughout the last five decades by agricultural intensification, including the segetal and rare flora and the interesting weeds for birds, insect pollinators and other invertebrates? (2) If this weed diversity depletion has occurred, to what extent has organic farming influenced the recovery of plant biodiversity in current cereal crops and especially in segetal and rare species and in the aforementioned weed functional biodiversity groups?

2. Material and methods

2.1. Data sources and plant surveys

We analysed 458 floristic field plots (Braun-Blanquet method) of non-irrigated cereal crops in central Catalonia (NE Iberian Peninsula) from 1953 to 2007. Most of the field plots (439) were carried out by the authors in different survey periods: 51, 84 and 294 sampled plots in 1983–1988, 1996–1999 and 2005–2007, respectively. In the latest survey 218 and 76 field plots were performed in conventional and in organically managed cereal crops, respectively; differences in the number of samples were related to the lower availability of organic farms in the studied area.

As we did not resampled the same field in the following periods to first period (1953–1988) in any case, we understand that this sampling design is resampling of localities or parts of the territory. Some locations were resampled in the posterior periods to 1953–1988 within an area comprising approximately 5×5 km, in some cases a 10×10 km area depending on the presence of arable land.

All of the field plots were carried out from May to June (before crop harvest) primarily in commercial crops of winter barley

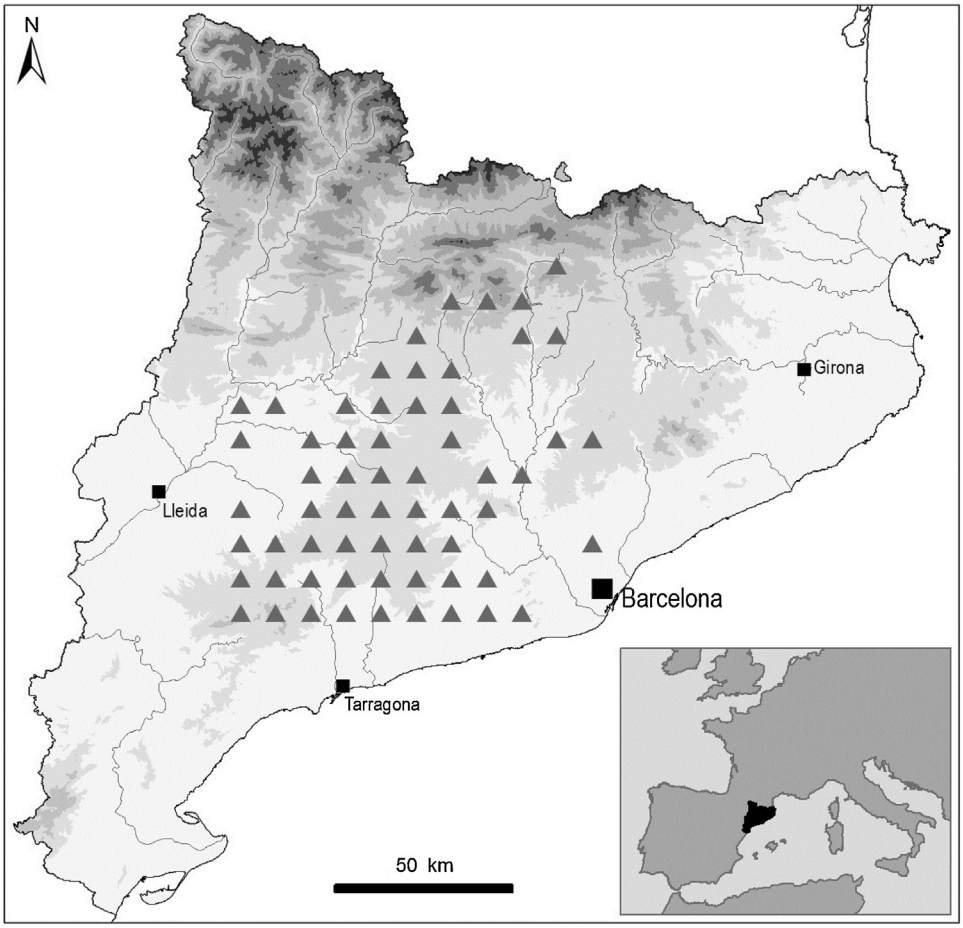

Fig. 1. The surveyed area in Central Catalonia (NE Iberian Peninsula) in the 1953–88, 1996–99 and 2005–07 periods. Symbols indicate the 10×10 km UTM grid areas in which field plots were performed.