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Modelling farming system dynamics in High Nature Value Farmland under policy change

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ABSTRACT

Understanding the factors driving changes in farm management is needed for designing policies and subsidy schemes to protect High Nature Value Farmland (HNVF). We describe farming system dynamics in HNVF of southern Portugal, between 2000–2002 and 2008–2010, encompassing a period of major policy transformations introduced by the reform of the Common Agricultural Policy (CAP) of the European Union in 2003. We also assess how farming system dynamics was modulated by structural, biophysical and policy factors constraining agricultural options. Farming systems changed in about 40% of the farmed area during the period of study. Overall, there was a marked transition from arable systems to either specialized livestock or permanent crop systems, involving major declines in the traditional system of dry cereal rotations and sheep grazing. Transitions were influenced by farm size, soil quality and coverage by open oak woodlands, while there was little effect of agri-environment schemes and legal regulations specifically targeted to support the traditional farming system. Despite these changes, agricultural intensity remained essentially stable, though there was a marked decline in land-use heterogeneity with likely negative impacts on biodiversity. Observed changes agree with *ex-ante* impact assessments of the CAP reform in Iberian cereal steppes, which suggested that decoupling of payments from production could promote shifts from the traditional cereal–fallow–sheep system towards specialized livestock grazing systems. Effectively protecting HNFV may thus require a better integration of horizontal policies and agri-environment schemes.

1. Introduction

In Europe, the concept of High Nature Value Farmland (HNVF) was developed to typify and help safeguarding agricultural systems with biodiversity value (Baldock et al., 1993; Hoogeveen et al., 2004), because many wild species of conservation concern are dependent on habitats created or maintained by low-intensity farming (Kleijn et al., 2009; Bugalho et al., 2011; Doxa et al., 2012). Despite its importance, HNFV has been declining due to rural depopulation, agricultural abandonment and afforestation in marginal farming areas, coupled with intensification in the most productive areas (Stoate et al., 2009). It is generally agreed that agri-environment schemes (AES) and other funding mechanisms implemented under the Common Agricultural Policy (CAP) of the European Union (EU) could contribute for ameliorating these trends. However, the design of effective policies is hindered by a limited understanding of how policies affect farmer decisions, and how these in turn shape farmland landscapes and their value for biodiversity (Baldock et al., 1993; Mattison and Norris, 2005; Beaufoy et al., 2012).

Major modifications to EU agricultural policies were introduced by the CAP reform of 2003. The main innovation of this reform was the Single Farm Payment and the associated decoupling of payments from production, whereby farmers were no longer required to maintain production for receiving CAP payments, but had to keep land in good environmental and agricultural conditions (Renwick et al., 2008; Brady et al., 2009). *Ex ante* conjectures of the consequences of this change for HNVF were contrasting, with some foreseeing positive outcomes because farmers would no longer be forced into intensive farming (BirdLifeInternational, 2003), whereas others anticipated negative effects because decoupling could promote abandonment of low-income farming areas of conservation value (Oñate et al., 2007; Tranter et al., 2007). These processes were thought to be conditional on other CAP mechanisms such as AES, which could support otherwise economically unsustainable farming (Brady et al., 2009). At present, however,

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there is little information on how agricultural management of HNVF varied during this period of major policy change, and how this variation was affected by AES, farm characteristics and biophysical constraints.

The farming system framework may provide a relatively simple and practical approach to evaluate agricultural changes in HNVF, because it concentrates on groups of farms with similar typology, thereby avoiding the need to detail the multiple idiosyncrasies of a large number of individual farms (Paracchini and Britz, 2010; Darnhofer and Gibbon, 2012). Farms included in the same farming system type have similar resource bases, enterprise patterns, livelihoods and household restrictions, and so they are expected to show similar responses to policy, market and biophysical drivers (Dixon et al., 2001; Ferraton and Touzard, 2009). Furthermore, information on potential biodiversity impacts can be gained by analysing changes in farming systems, because they are associated with specific agricultural practices and land-use patterns to which biodiversity components respond (Calvo-Iglesias et al., 2009; Carmona et al., 2010; Bamière et al., 2011).

This study used farming systems to examine agricultural changes on cereal-steppes of the Iberian Peninsula, during a period (2000–2010) encompassing the CAP reform of 2003. This HNVF type corresponds to extensively farmed, mixed rotational systems of winter cereals, fodder crops and grazed fallow land and pastures, covering over 4.5 million ha in dry areas with low forest cover (Suárez et al., 1997). Cereal-steppes are critical for the conservation of a range of open farmland birds of European conservation concern (Suárez et al., 1997; Bota et al., 2005). The specific objectives of the study were to: (i) quantitatively define a farming system typology based on spatially explicit farm-level data; (ii) estimating farming system dynamics in the period 2000–2010; (iii) modelling farming system dynamics in relation to structural, biophysical and policy constraints to agricultural management; and (iv) evaluating the consequences of farming system dynamics in terms of agricultural intensification and land-use heterogeneity, which are known to influence biodiversity patterns and trends (Benton et al., 2003; Donald et al., 2006). Results were then used to explore the consequences of farming system dynamics for biodiversity conservation in Iberian cereal-steppes, and to discuss potential applications of the farming system concept to improve agri-environment schemes and other agricultural policies.

2. Methods

The study was conducted in lowland agricultural landscapes of southern Portugal, within about 210,000 ha (Appendix 1). The climate is Mediterranean, with hot dry summers and cold and moderately rainy winters. Despite its relative homogeneity, the study area shows a north-south gradient of decreasing soil quality and reduced availability of irrigation water, which is reflected in the presence of more intensive crops in the north (e.g. irrigated annual crops and olive groves) and a more extensive land-use to the south, dominated for decades by the traditional cereal–fallow–sheep farming system (Bacharel and Pinto-Correia, 1999; Delgado and Moreira, 2000). The study area encompassed the Special Protection Area (SPA) of Castro Verde, designated under EU Directive 92/43/EEC. This is the most important area in Portugal for the conservation of open farmland birds, including globally threatened species such as lesser kestrel *Falco naumanni*, great bustard *Otis tarda*, and little bustard *Tetrax tetrax* (Pinto et al., 2005; Reino et al., 2010; Moreira et al., 2012). Since 1995, following the CAP reform of 1992, most of the SPA has benefited from an agri-environment scheme (AES) specifically targeted at the conservation of open farmland birds through the maintenance of the traditional farming system (Marta-Pedroso et al., 2007). Farms within most of the SPA are thus entitled to AES payments, subject to production commitments that have changed over the years but that generally included maintaining a traditional cereal–fallow rotation, keeping livestock grazing densities below specified thresholds, growing specified crops benefiting steppe birds and keeping watering spots for wildlife. At the same time, these farms were affected by some legal constraints associated with the SPA status, such as restrictions on the plantation of permanent crops or farmland afforestation.

2.1. Farm characterization

Farms ($n = 2800$) were characterized using variables reflecting the dominant agricultural land uses and the stocking rates (Table 1). Dry cereals included mainly wheat and barley. Other annual crops were generally irrigated arable crops (e.g. sunflower, chickpea). Fallows included arable land that was not seeded for one or more seasons, and which was usually grazed by sheep or cattle. Pastures included all fodder crops and pastures (excluding grazed fallows), either permanent or temporary, natural or sown. Permanent crops were mostly olive groves. Livestock density was based on Livestock Units (LU), aggregating animals from different species (cattle and sheep) and ages using standard conversion factors (Appendix 2). Variables were extracted from a spatially explicit database maintained by the Portuguese Ministry of Agriculture, which is based on farmer declarations when applying for CAP payments, and is verified on a random basis by Ministry officers. A farm was assumed to correspond to all the parcels owned by a farmer, though sometimes it did not represent a continuous block of land. Variables for each farm were obtained for each year and then averaged for each of two time periods, corresponding to the start (2000–2002) and end of the study (2008–2010), thereby eliminating short term variations in agricultural land uses due for instance to crop rotation. Farms were excluded from analysis if they were not represented in the data sets in at least one year in each of both study periods, and if most of its land was outside the study area in a given year.

Farms were also characterized in terms of structural, biophysical and policy variables reflecting significant constraints to management options (Table 1). Soil quality was estimated from a digital map of soil capacity for agriculture (SROA/CNROA, 2012). Oak woodland cover was estimated by extracting the area occupied by open cork oak *Quercus suber* and holm oak *Q. rotundifolia* woodlands (locally called "montado") from a digital land cover map (IGP, 2012), and it was used because cutting these oaks is strongly restricted by Portuguese law, constraining the range of farmer management possibilities. The location of the farm inside the SPA of Castro Verde was included because it is associated with legal restrictions to some land-use changes. The adherence of the farmer to AES specifically targeted at open farmland birds was used because it supports the traditional cereal–fallow–sheep system.

2.2. Data analysis

Farming system typology was determined by non-hierarchical clustering of the whole dataset, considering both time periods together and the seven agricultural variables (Table 1), using the partition around medoids (PAM) clustering algorithm (Kaufman and Rousseeuw, 1990). In PAM, representative elements of each cluster (medoids) correspond to real observations, rather than centroids or averages. So, a medoid is a representative farm in a cluster, whose average dissimilarity to all the other farms in the same cluster is minimal. Silhouette plots were used to help assess the ideal number of categories to be considered (Rousseeuw, 1987). PAM was implemented with the 'cluster' package (Maechler et al., 2012) for R (R Development Core Team, 2011). Based on the results of PAM, each farm in each time period was assigned to a farming system, and the total area occupied by each farming system in each period