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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

Table 1
Summary statistics of variables used to characterize farms and to model farming system dynamics. UAA = Utilized Agricultural Area.

Variable	Description	Mean ± SD (Min-Max)
Agricultural variables (n = 2800 farms)		
Dry cereals	% of dry cereals in the UAA	29.1 ± 26.4 (0–100)
Fallow land	% of fallows in the UAA	9.8 ± 15.8 (0–100)
Pastures	% of forages and pastures in the UAA	41.5 ± 38.8 (0–100)
Other annual crops	% of other annual crops in the UAA	12.0 ± 19.5 (0–100)
Permanent crops	% of permanent crops in the UAA	7.6 ± 21.9 (0–100)
Livestock density	Livestock units (LU) per ha of fodder area	0.27 ± 0.44 (0–2)
Cattle ratio	% of cattle LU in total LU	14.1 ± 31.4 (0–100)
Structural, biophysical and policy variables (n = 722 farms)		
Farm size	Total UAA of the farm in the initial period. Ordinal coding: 1 (<25 ha), 2 (25–50 ha), 3 (50–150 ha), 4 (150–250 ha), 5 (>250 ha)	3.40 ± 1.34 (1–5)
Soil quality	% of soils with no or few restrictions for agricultural use in the UAA. Ordinal coding: 0 (0%), 1 (0–20%), 2 (20–40%), 3 (>40%)	1.13 ± 1.26 (0–3)
Oak woodland	% of the UAA covered with cork or holm oak woodlands. Ordinal coding: 0 (0%), 1 (0–25%), 2 (25–50%), 3 (>50%)	1.30 ± 1.14 (0–3)
Castro Verde SPA	>50% of the UAA inside or outside (1/0) the Castro Verde Special Protection Area (SPA)	0.35 ± 0.48 (0–1)
AES	Farms adhering or not (1/0) to agri-environment schemes specifically targeted at open farmland birds (i.e., within the AES area of Castro Verde and with more than 50% of the UAA joining agri-environment measures)	0.14 ± 0.35 (0–1)

was estimated and mapped. Overall dynamics in farming system cover between time periods was summarized in a transition matrix (Gergel and Turner, 2002).

A more detailed analysis of factors affecting transitions was then carried out by overlaying a 500-m grid on the study area, and registering the transition type observed at each point. To avoid pseudo-replication only one point was used per farm, and we only used farms for which information was available for both periods. Based on these criteria, we obtained a sample of 722 farms that were used to model farming system dynamics in relation to the five structural, biophysical and policy variables (Table 1) using multinomial logistic regression (Hosmer and Lemeshow, 1989). A minimum sample of 10 observations was required to include a given transition type in the model. Modelling started with all explanatory variables and a backward variable selection was then carried out using likelihood ratio tests. In all models, farming system persistence (lack of change) was used as the reference category. A threshold of $P < 0.10$ was used to identify potentially important variables, as we were more interested in understanding their explanatory role than making predictions. Model fit was assessed by comparing with a null model as an overall significance test (likelihood ratio test), and by using Nagelkerke's r^2 (Nagelkerke, 1991) and classification accuracy compared to that of a null model classifying all cases as the modal category. Models were run in SPSS for Windows 19.0.0.

Agricultural intensity and land-use heterogeneity were estimated for each farming system, based on the characteristics of the corresponding medoid farm. Intensity was estimated using an indicator of farm income per hectare (Turner and Doolittle, 1978), based on the Portuguese database of agricultural standard gross margins (Rosário, 2005). Subsidies were discounted to minimize the effects of changes in income support schemes introduced by the CAP reform of 2003. Heterogeneity was based on the diversity of agricultural land uses computed with Shannon's diversity index (Spellerberg and Fedor, 2003). Intensity and heterogeneity estimates were standardized by dividing their values by the corresponding maximum values. Intensity and heterogeneity dynamics were then estimated by computing a weighted mean of the corresponding indicators for each time period, with weights proportional to the surface occupied by each farming system.

3. Results

Overall, the UAA of the sampled farms was dominated by pastures (ca. 40%), followed by cereals (ca. 30%), other annual crops (ca. 12%) and fallows (ca. 10%) (Table 1). The average livestock density, mostly sheep, was 0.27 LU/ha of forage area. Six farming systems resulted from the cluster analysis (Table 2). Cluster 1 (Traditional; 17.2% of farms) typically comprised farms with a mosaic of dry cereals, pastures and fallow land, where livestock density was moderate and composed only by sheep. Cluster 2 (Annual Crops; 36.4% of farms) was the most common farming system, including farms with dry cereals and other annual crops occupying about 90% of the land, and with no pastures, no livestock and little fallow land. Cluster 3 (Cattle Grazing; 16.2% of farms) included farms characterized by a large dominance of pastures and little dry cereals, and with a high livestock density dominated by cattle. Cluster 4 (Sheep Grazing; 24.2% of farms) included farms with a crop pattern similar to Cattle Grazing system, but with lower livestock densities and composed strictly by sheep. Cluster 5 (Permanent Crops; 6.0% of farms) corresponded to farms entirely covered by permanent crops, most of which were very intensive olive grove plantations. Cluster 6 (Intensive Sheep; 6.0% of farms) corresponded to farms dedicated to sheep husbandry with livestock densities six times higher than those typical for the region (Tables 1 and 2), probably relying on rented pastures or stubble crops in neighbouring farms to enable the maintenance of large herds. This farming system was not considered further, because it occupied a very small area (<1%) and it was an outlier in relation to the others prevailing in the study area.

3.1. Farming system dynamics

There were marked changes in cover by different farming systems between 2000–2002 and 2008–2010 (Fig. 1). In the former period, Traditional and Cattle Grazing were the dominant farming systems, whereas Cattle and Sheep Grazing were the dominant systems in the later period. This change was caused by marked increases in the area covered by Cattle (34%) and Sheep (50%) Grazing systems, which were matched by drastic reductions in the Traditional (65%) and Annual Crop

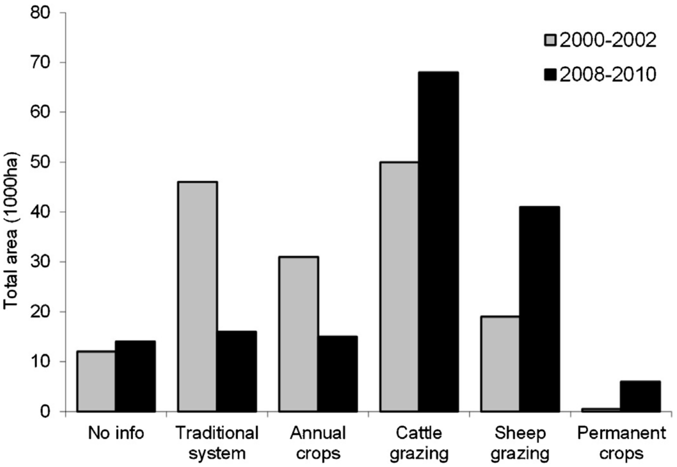

Fig. 1. Total area (×10^3 ha) occupied by farming systems identified in the study area (2000–2002 and 2008–2010).

Table 2
Characteristics of representative farms (medoids) identified for farming systems identified in the study area. n = sample size (farm/period combinations). Variable definition provided in Table 1.

Variable	Cluster 1 *Traditional* (n = 454)	Cluster 2 *Annual Crops* (n = 962)	Cluster 3 *Cattle Grazing* (n = 427)	Cluster 4 *Sheep Grazing* (n = 638)	Cluster 5 *Permanent Crops* (n = 159)	Cluster 6 Intensive Sheep (n = 160)
Dry cereals (%)	28.3	57.6	14.2	9.6	0.0	0.0
Fallow land (%)	24.9	9.5	5.9	0.4	0.0	0.0
Pastures (%)	42.4	0.0	77.2	88.1	0.0	100.0
Other annual crops (%)	4.4	31.1	0.0	0.2	0.0	0.0
Permanent crops (%)	0.0	1.8	2.6	1.7	100.0	0.0
Livestock density	0.15	0.00	0.46	0.23	0.00	1.81
Cattle ratio (%)	0.0	0.0	85.1	0.0	0.0	0.0

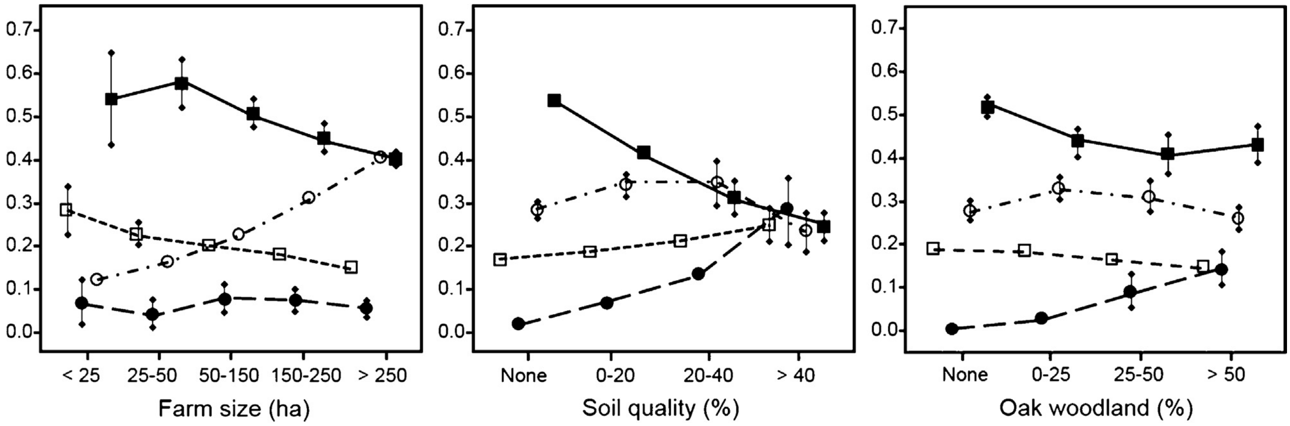

Fig. 2. Estimated transition probabilities (and 95% confidence intervals) in relation to explanatory variables for the Traditional system: persistence (white squares), and transitions to Annual Crops (black dots), Cattle Grazing (white dots) and Sheep Grazing (black squares).

(54%) systems (Fig. 1). Permanent crops were largely absent in the first period and showed the largest proportional increase.

There were transitions between nearly all farming systems, though the most important were those from Traditional to either Sheep (ca. 18,000 ha) or Cattle (ca. 16,000 ha) Grazing systems (Table 3). Other relevant transitions were those from Annual Crops to Traditional (ca. 7000 ha), Cattle Grazing (ca. 4700 ha) or Permanent Crop (ca. 4200 ha) systems. Still relevant were the transitions from Sheep to Cattle Grazing (ca. 4000 ha), and the opposite transition (ca. 4600 ha). Cattle grazing (85%) and Permanent Crop (100%) systems were the most persistent during the study period.

3.2. *Drivers of farming system dynamics*

Transitions between farming systems were significantly related to structural, biophysical and, to a much lesser degree, policy variables (Figs. 2–4; Appendix 3). For the Traditional system (Fig. 2), transition to the Annual Crop system was most likely in farms with more productive soils (p = 0.027) and larger percentage of oak woodlands (p = 0.022); transition to Cattle Grazing was most likely in larger farms (p = 0.021), and transition to Sheep Grazing was most likely in poor quality soils (p = 0.061). For the Annual Crop system (Fig. 3), transition to the Traditional system was most likely in areas with more oak woodlands (p = 0.015) and poorer soils (p = 0.044); transitions to Cattle or Sheep Grazing were most likely in farms with poorer soils (p < 0.001), although the latter was also most likely in farms with a lower percentage of oak woodland (p = 0.030). Transition from Cattle to Sheep Grazing was most likely in poorer soils (p = 0.020), inside the SPA (p = 0.057) and in smaller farms (p = 0.073) (Fig. 4). For Sheep grazing, there was enough data to model persistence and transition to Cattle grazing, but no significant effects were detected.

3.3. *Farming intensity and heterogeneity*

Agricultural intensity was much higher for Permanent Crops than for the other farming systems, which all showed broadly similar intensity values (Fig. 5). Land-use heterogeneity was highest for the Traditional and the Annual Crop systems and null in the Permanent Crop system (monoculture). Cattle and Sheep Grazing

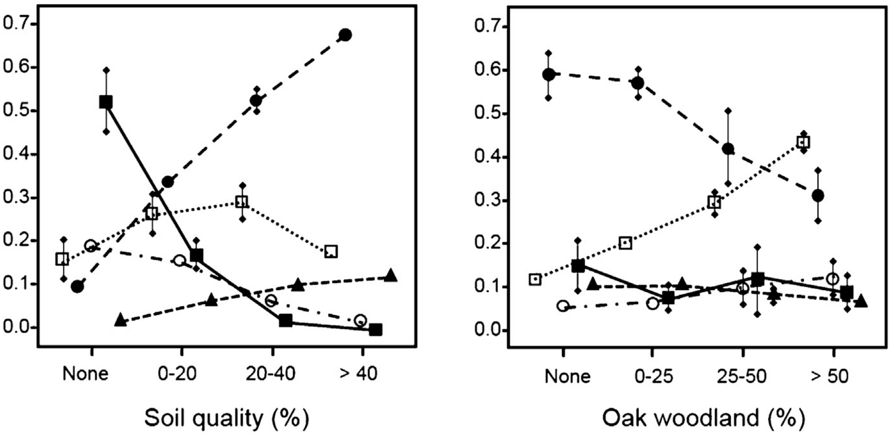

Fig. 3. Estimated transition probabilities (and 95% confidence intervals) in relation to explanatory variables for the Annual Crop system: persistence (black dots), and transitions to Traditional (white squares), Cattle Grazing (white dots), Sheep grazing (black squares), and Permanent Crops (triangles).

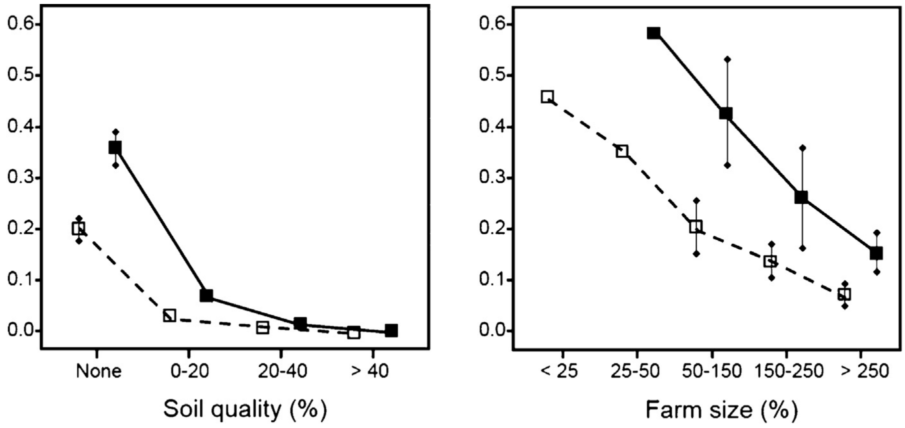

Fig. 4. Estimated transition probabilities (and 95% confidence intervals) in relation to explanatory variables for the Cattle Grazing system: transitions to Sheep Grazing inside (black squares) and outside (white squares) the AES area.

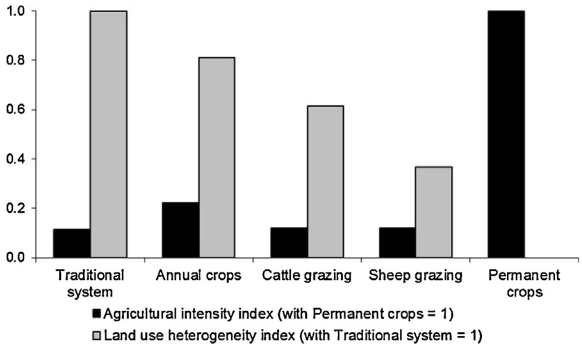

Fig. 5. Indexes of agricultural intensity level and land-use heterogeneity across farming systems identified in the study area.

systems showed intermediate heterogeneity values. Average intensity was very similar in 2000–2002 (0.15 ± 0.05 SD) and 2008–2010 (0.18 ± 0.18 SD), while heterogeneity was much higher in the former (0.74 ± 0.22 SD) than in the later period (0.57 ± 0.23 SD).

4. Discussion

Our results showed that there was a strong farming system dynamics between 2000–2002 and 2008–2010, which affected about 40% of the farmed area. Overall, there were marked declines in the Traditional and Annual Crop Farming systems, which were matched by strong increases in the Cattle Grazing, Sheep Grazing and Permanent Crop systems. The changes observed were possibly influenced to some extent by the CAP reform of 2003, though confirmation of this hypothesis would require more in-depth socio-economic analysis.

One of the most notorious changes observed in our study was the replacement of cereal-based systems (Traditional and Annual Crops) by specialized livestock farming systems (Sheep and Cattle Grazing). One factor possibly contributing to these changes was the decoupling of payments from production introduced by the CAP reform. The Portuguese government decided to use the option provided by CAP to decouple crop payments, while keeping livestock payments partially or fully coupled for sheep and suckler cows, respectively, which may have created economic incentives for the maintenance of or conversion into specialized livestock systems. A similar effect was predicted in *ex-ante* impact assessments of the effects of the decoupling, which foresaw shifts from the traditional cereal–fallow–sheep system towards livestock grazing systems (e.g. Serrão and Coelho, 2005; Nagy, 2006; Tranter et al., 2007).

The large scale loss of the Traditional system is particularly noteworthy, considering that it was supported by a specific AES and by legal restrictions to land-use conversion within the SPA of Castro Verde. This result thus suggests that the AES was not able to sustain this system despite its value for biodiversity conservation, probably as a consequence of the too low per-hectare AES payments. In particular, the cut on the AES payments decided in the 2001 national revision of the AES programme, from about 80–56 euros/ha, and the expectations then set for the upcoming CAP reform, probably led many farmers not to revalidate their five-year AES contracts that were coming to an end by then. This is supported by the decrease in the number of farms participating in AES between the two time periods, from about 35 to 16%. As a consequence, many farmers probably decided to move to the livestock grazing system, which were likely seen as better economic alternatives compared to the Traditional system, despite the AES support.

Another noteworthy trend was the dramatic increase in the Permanent Crop system, which was nearly absent in 2000–2002. This

Table 3
Transition matrix illustrating farming systems dynamics between 2000–2002 and 2008–2010. Each row shows the percentage of area of each farming system persisting (underlined) or changing to another farming system.

Farming systems	2008–2010				
	Traditional	Annual crops	Cattle grazing	Sheep grazing	Permanent crops
2000–2002					
Traditional	15.8	4.4	36.4	40.9	0.9
Annual crops	23.1	36.1	15.7	9.8	14.0
Cattle grazing	0.7	1.5	85.3	9.7	2.1
Sheep grazing	2.4	0.9	20.6	73.5	0.0
Permanent crops	0.0	0.0	0.0	0.0	100.0

system encompasses mainly farms that specialized into intensive olive plantations, most of them changing from the Annual Crop system. A possibility to explain this pattern is that the decoupling of subsidy payments left farm management free to follow market oriented strategies (Fragoso et al., 2011), and the high profitability of intensive olive groves likely made them a very attractive alternative for farmers.

4.1. Local drivers of farming system dynamics

The overall trends in farming system dynamics uncovered by our study masked considerable variability among farms, which could be explained to a large extent by farm level differences in structural and biophysical features. In fact, factors such as farm size, soil quality and oak woodland cover were critical drivers of farming system transition of individual farms, which at the same time appeared to be little affected by policy factors such as land-use restrictions imposed by the Special Protection Area of Castro Verde, and the incentives made available through AES.

One of the key determinants of farm transitions was soil quality, probably because it influenced production options and thus the choice of the farming system (e.g. Lesschen et al., 2007). Overall, soil quality strongly influenced the dynamics for three farming systems, with poor quality soils favouring transitions to the Traditional and the Livestock Grazing systems (particularly sheep), whereas good quality soils favoured transitions to Annual Crops, especially when coming from the Traditional system.

Farm size showed particularly strong effects in transitions to livestock systems, with larger farms being more likely to turn to Cattle Grazing and smaller ones to Sheep Grazing. This is consistent with livestock farming systems typical to this region, where sheep led by a shepherd graze during the day and is gathered into barns at night, whereas cattle commonly graze in fenced parks where it also remains during the night. This entails important differences in both systems in terms of needs for labour per hectare, with much smaller needs in cattle systems, thus favouring them for larger farms.

Cover by oak woodlands was another important factor, probably because legal restrictions to tree cutting precluded major land-use changes. However, transition patterns were difficult to interpret, as higher percentages of oak woodlands were related to changes from the Traditional to the Annual Crop system, as well as the inverse transition. In the latter case, it is possible that constraints to land-use change due to the presence of oak woodlands could have led landowners to disinvest towards the more extensive Traditional system. Alternatively, absent landowners confronted with structural difficulties imposed by the presence of oak woodlands or unable to further invest in more demanding productions, preferred to reduce activity to the minimum level of compliance with maintenance of the land in good agricultural and environmental conditions in order to receive the single payment (Costa et al., 2011).

Surprisingly, the availability of the Castro Verde AES did not appear a relevant driver of farming system transitions. Influence of a policy driver was only detected in the case of the Special Protection Area, which was found to influence farm transitions from Cattle Grazing to Sheep Grazing systems. Reasons for this effect are unknown, but they may reflect farmers' decisions to move to a less demanding system in an area dominated by poor soils, where other options such as farmland afforestation and conversion to permanent crops were legally restricted. Overall, however, the maintenance or change of farming system was probably highly dependent on farmers' motivations and attitudes in relation to different policies (e.g. Burton et al., 2008; De Snoo et al., 2013), so further research is required to elucidate the psychological and social processes driving farmersí decisions.

4.2. Farming intensification and land-use heterogeneity

The farming system transitions observed in our study resulted in an overall decline of within-farm heterogeneity, though there was no tendency for increasing intensification. Loss of heterogeneity was a consequence of farm-level specialization on either Permanent Crop or Livestock Grazing systems, with the concurrent loss of the mosaic of cereal fields, grazed fallows and pastures, and ploughed land associated with the Traditional system (Delgado and Moreira, 2000). In spite of these changes, the overall Intensification level was maintained, probably because the intensity levels of most farming systems in the region were roughly equivalent. The exception was the Permanent Crop system, which was both far more intensive than all the others and had virtually no land-use heterogeneity (i.e. monoculture).

4.3. Conservation implications

The High Nature Value Farmland type analyzed in this study has a high biodiversity value, mainly due to their importance for a range of farmland birds of conservation concern (Suárez et al., 1997; Bota et al., 2005). Conservation of these species require a diverse agricultural mosaic, which favour the coexistence of species with contrasting habitat requirements (Reino et al., 2010), and species using different habitats during the annual cycle (Moreira et al., 2004). In these circumstances, the changes in farming systems observed during the study period, from the heterogeneous Traditional farming system to the specialized systems based on Livestock Grazing or Permanent Crops, may have had negative implications for farmland bird conservation. A full appreciation of the biodiversity consequences of these changes is still lacking, but it is likely that they will result in declines of species requiring cereal (e.g. corn bunting *Emberiza calandra*, fan-tailed warbler *Cisticola juncidis*, quail *Coturnix coturnix*) and ploughed fields (e.g. short-toed lark *Calandrella brachydactyla*, tawny pipit *Anthus campestris*, and black-eared wheatear *Oenanthe hispanica*), while favouring species associated with grazed pastures (e.g. calandra lark *Melanocorypha calandra*) (Delgado and Moreira, 2000; Reino et al., 2010).

The decline of the Traditional farming system observed in our study occurred despite the operation since 1995 of an AES specifically targeted to favour its persistence within the SPA of Castro Verde. This result underlines the fragility of AES, which can be overshadowed by other drivers of land-use change including large scale horizontal agricultural policies, such as decoupling of support from production, and small scale structural and biophysical factors constraining farmer options. Improving the efficacy of AES thus requires a better integration with other agricultural policies and fine-tuning to meet local specificities. As designing AES at the farm level may be unfeasible in most cases, the farming system approach used in our study may provide a practical alternative, by grouping farms according to their agricultural typology and providing information on the key factors driving major land-use transitions. AES could thus be designed to meet the specificities and constraints of each farming system, thereby optimizing investments on the farming systems that need to be maintained and encouraging transitions benefiting biodiversity in unfavourable farming systems.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.agee.2013.11.002.

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