# Effectiveness of the European Natura 2000 network at protecting Western Europe's agro-steppes

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## Highlights

- Agro-steppes, a key bird habitat, are declining inside and outside Natura 2000 sites.
- Agro-steppes are being converted mostly to permanent and irrigated crops.
- Declines of agro-steppe area were 45% slower within Special Protected Areas.
- The area lost in the studied SPAs could hold more than 500 great bustards.
- Effective protection of Network sites is needed to achieve CBD conservation targets.

# Abstract

Assessing progress towards achieving conservation targets is required for all countries committed to the Convention on Biological Diversity. The Natura 2000 network is the largest protected area network in the world and was created to protect Europe’s threatened species and habitats, often requiring active management. This study assesses the effectiveness of areas classified under the EU Birds Directive at protecting Western Europe’s agro-steppes, the last remnants of suitable habitat for several endangered bird species. We quantify agro-steppe habitat change in the last 10 years using high-resolution aerial images of 21 Special Protection Areas and surrounding areas. The selected SPAs hold one third of the global population of great bustards *Otis tarda*, a flagship conservation species. Agro-steppe area losses occurred across all sites surveyed but were 45% lower inside Natura 2000 compared to non-protected areas. Natura 2000 sites still lost over 35 000 ha of agro-steppe habitat in 10 years, an area that could hold more than 500 great bustards. These low yield farmlands are being converted predominately to permanent and irrigated crops. At the current rate of habitat conversion, agro-steppes could be reduced to 50% of the present area during the next century. Moreover, the greater conversions outside protected sites may transform the remaining agro-steppes into isolated “islands” with low population connectivity. Our study on agro-steppes illustrates the relevant contribution of Natura 2000 at protecting Europe’s key habitats, but also highlights crucial insufficiencies that still need to be addressed to achieve the CBD conservation targets and halt biodiversity loss.

# Keywords

Conservation; EU Policy; Farmland Habitats; Great bustard; Land Use Change; Natura 2000

# 1. Introduction

Protected areas are essential to maintain the biodiversity in our increasingly anthropogenic planet, and a key pillar to achieve environmental sustainability goals (United Nations, 2015). They play a fundamental role in halting the loss of biodiversity and contribute to meeting conservation targets to which the parties of the Convention on Biological Diversity have committed (CBD, 2011). Therefore, protecting Europe’s most valuable areas for threatened species and habitats is a fundamental part of the European Strategy for Biological Diversity (EC, 2011).

The Natura 2000 network of protected areas covers over 18% of the European Union (EU) territory and is the largest coordinated multinational network of protected areas in the world (Blicharska et al., 2016; Orlikowska et al., 2016). It results from the implementation of two complementary Directives, the Birds Directive (79/409/EEC) and the Habitats Directive (92/43/EEC), which aim to protect designated species and habitats (Kukkala et al., 2016). The Natura 2000 Network makes an important contribution to the protection of biodiversity in Europe, and has facilitated wildlife comeback in many countries (Deinet et al., 2013). A recent review examining the effectiveness, efficiency, relevance and coherence of all stages of the implementation of the network, concluded that it remains highly relevant and fit for the protection of species and habitats (EC, 2016).

In Europe, many species inhabit human transformed landscapes and have coexisted with humans for millennia (Blondel, 2006; Halada et al., 2011). Many Natura 2000 sites were designated to protect threatened biodiversity that live in farmland habitats. These protected areas and landscapes, classified as IUCN categories V and VI, include a variety of human activities, usually compatible with a sustainable use of natural resources (Dudley, 2008). Agro-steppes are a particularly good example of the co-existence of human activities and nature conservation. This semi-natural habitat, created by agricultural activities, hosts important populations of birds with threatened conservation status, such as great bustard (*Otis tarda*), little bustard (*Tetrax tetrax*) and lesser kestrel (*Falco naumanni*), protected by EU legislation (Suárez et al., 1997; BirdLife International, 2019). In Western Europe, these species depend on low intensity managed agro-steppe landscapes (Moreira et al., 2007; Stoate et al., 2009), as there are no remnants of their natural habitats. However, in the last few decades, due to their comparatively low economic output, important areas of agro-steppe have been abandoned or converted to intensive agriculture (Brotons et al., 2004; Moreira et al., 2007). In some cases, agro-steppe area loss has been prevented by economic incentives provided by EU Agri-Environmental Schemes (AES, EC/92/2078), often implemented in Natura 2000 sites (Stoate et al., 2009; Butler et al., 2010; Ribeiro et al., 2014), but the extent of agro-steppe area loss has not been quantified. Several studies report that the Natura 2000 status has not been able to prevent loss of natural habitats inside Europe's protected areas, jeopardizing the ecological functions and their connectivity between areas of the network for wide-ranging species (Traba et al., 2007; Guixé & Arroyo, 2011; Heino et al., 2015; Hellwig et al., 2019).

This study examines the efficiency of the Natura 2000 Network at protecting important farmland habitats - the agro-steppes of Western Europe - using Iberia as a case study. We predict that agro-steppe area losses will be smaller inside Natura 2000 Special Protection Areas (SPAs, classified under the EU Birds Directive) than in neighboring areas. We use population estimates of great bustard to illustrate the potential consequences of the ongoing loss of steppe area.

Using multi-date aerial images from 2004 to 2015 we (1) determine SPA's effectiveness at protecting agro-steppes, (2) quantify land use conversion inside and outside SPAs and identify land uses competing with agro-steppe, (3) determine the impact of agro-steppe area change on great bustard numbers, and (4) predict future agro-steppe area changes in Iberia under different agricultural scenarios.

# 2. Materials and Methods

## *2.1 Study site and species*

Agro-steppes are characterized by extensive cultivation of cereal in a low-intensity rotating system that includes legume crops, grazed fallows (Franco and Sutherland, 2004; Faria et al., 2012) and permanent pastures used for extensive grazing (Silva et al., 2010). In the Iberian Peninsula there are 67 SPAs with agro-steppe area (13 in Portugal with 297 577ha and 54 in Spain with 6 578 601ha). These areas were designated mostly because they host important populations of great bustard and little bustard, umbrella species that indicate a rich steppe bird community (Lane et al., 2001; Silva et al., 2014).

The great bustard is a large wide-range bird, considered a flagship species of agricultural steppe habitats (Santana et al., 2014). Due to its vulnerability and charisma, great bustards have been well surveyed and there are good estimates for their population throughout most of the European range (Alonso & Palacín, 2010), hence they are adequate to illustrate the consequences of agro-steppe area change on birds. During the 20th century, great bustards suffered major population declines due to overhunting, habitat loss and habitat degradation (Alonso & Palacín, 2010; Alonso, 2014). The European population recovered during the last decades and is currently stable or slightly increasing (Alonso & Palacín, 2010; Alonso, 2014). However, the species is still classified as Vulnerable (Alonso, 2014; Birdlife International, 2019) and is threatened by agricultural intensification, powerline collisions and other human-induced changes in land use (Raab et al., 2011; Alonso, 2014). In the Iberian Peninsula, where 60-70% of the global population is located, numbers are increasing in high-quality areas, but population declines are common in marginal sites and the species distribution is contracting (Pinto et al., 2005; Alonso, 2014; López-Jamar et al., 2010).

We studied 21 SPAs (four in Portugal and 17 in Spain) that cover 1 153 331 ha corresponding to 59% of the Natura 2000 agro-steppe area in Iberia - 86% and 54% of the network’s agro-steppe area of Portugal and Spain, respectively (Fig. 1). They host 14-15 000 great bustards, corresponding to 43% of the Iberian and 29% of the Word’s populations (Table 1; Alonso and Palacín, 2010; ICNF, 2016; MITECO, 2016). We selected the largest Iberian SPAs with agro-steppe habitat and with the presence of both little and great bustards (ICNF, 2016; MITECO, 2016). In Spain, to guarantee spatial coverage, we selected up to five SPAs per autonomous region, selecting the areas with the largest number of great bustards. SPAs with less than 40 individuals or designated as SPA after 2010 were not included.

### *2.2 Photo interpretation of aerial imagery*

Two sets of high spatial resolution (≤ 1m) aerial imagery were used to quantify land use change between 2004 and 2015 in the SPAs and surrounding control areas. Control areas were open agricultural areas, similar in size, located close to (usually adjacent) the limits of each SPA. The first (oldest) set of aerial imagery was obtained from Direção Geral do Território (http://www.dgterritorio.pt) and Centro Nacional de Información Geográfica (https://www.cnig.es) for Portuguese and Spanish areas, respectively. The second (most recent) set of aerial imagery was obtained from Google Earth. The aerial imagery dates for each SPA were dependent on the availability of images but were consistent within SPAs and their control areas (see Table 1). Photointerpretation of all imagery was performed by the same observer, using a Geographic Information System (QGIS, ver. 2.6.1, Brighton).

Land use change was quantified by assessing land use in points located on a rectangular point grid on both images available for each area (median older date: 2005; min=2004, max=2009; median recent date: 2013, min=2010, max= 2015; Table 1). The distance between grid points was the same within each SPA and corresponding control areas but varied across SPAs from 500 to 2500m, depending on the size of the sampled area. This method ensured a good spatial representation of all areas, with a minimum of *ca.* 200 sampled points (parcels identified) per area. Six land use categories were identified: woodland (including cork and holm oak montados/dehesas), built-up (houses or infrastructures), scrubland, permanent crop (mostly olive groves, vineyards and almond), irrigated crop, and agro-steppe (dryland, mainly cereal, crops and extensive grasslands such as fallows and permanent grasslands). High resolution digital land cover maps for Portugal (COS 2007; DGT, 2007) and Spain (SIGPAC; MAPA, 2014) were used to assist the identification of land cover. Dry season Normalized Difference

Vegetation Index (NDVI) images generated with Landsat satellite imagery with a 30m resolution help identifying highly irrigated crops. Field observations from Campo Maior SPA (at the border between Portugal and Spain) were used to validate the visual interpretation of land cover categories before analysing the other SPAs.

### *2.3 Data Analysis*

In order to understand and illustrate the impacts and the magnitude of agro-steppe area changes during the study period, we determined the relationship between agro-steppe area and the abundance of great bustards for the 21 SPAs studied (Table 1), using a Spearman correlation followed by a linear regression model with the number of great bustards as the response variable and agro-steppe area as the explanatory variable.

Changes in agro-steppe area were quantified in SPAs and control areas, by comparing the number of points in the grid (i.e., number of parcels) classified as agro-steppe in each period. Land conversion was calculated for all points classified as agro-steppe in at least one of the images in each SPA or corresponding control area. As the study period was not the same for all SPA due to imagery availability, we performed a meta-analysis approach, where each area (21 SPAs and 21 neighboring control areas) was analyzed separately. This approach combines the changes observed in all sites, allowing the calculation of overall effects, significance, and confidence intervals (Higgins and Green, 2008; Borenstein et al., 2009). The effect measure used was the “risk ratio” (Borenstein et al., 2009), which can be directly translated into the percentage of habitat gained or lost (a value of 0.5 represents a decrease of 50%, while a value of 1.50 represents an increase in 50%). We performed a random-effects (DerSimonian-Laird) meta-analysis, to account for differences across areas as the effect size varied from area to area. This analysis was performed using OpenMEE (Meta-analysis software for ecology and evolutionary biology; Wallace et al., 2017). We further used yearly land use change (in percentage and in hectares) to compare changes in agro-steppe inside and outside SPAs using ANOVAs and Tukey Post Hoc tests (using R; R 3.2.2).

The data was then pooled across all study sites to quantify area conversion between all land use categories and to identify the land uses competing with agro-steppe. Finally, we projected the observed land use/cover changes until 2110 using two scenarios of agricultural change. The first scenario assumes the continuation of the land use conversion rate observed in the current study (percentage of area loss per year). In this scenario the area of habitat converted each year progressively declines because the amount of habitat available to be converted declines. The second scenario assumes that the area converted each year remains constant (area loss per year); this may occur if the economic pressure that leads to habitat conversion continues to increase.

## 3. Results

We found a strong positive linear abundance-area relationship between great bustard numbers and agro-steppe area for the 21 Iberian SPAs studied (Spearman correlation Rs = 0.67, p-value = 0.0012; Fig. 2): for each 65.7 hectares of agro-steppe area gained/lost there is an increase/decrease of one great bustard (F= 9.47 (19), t= 3.08, p= 0.0062). No significant relationship was found between great bustard abundance and total SPA area (Rs= 0.24, p-value= 0.2928).

Land use classes were identified for a total of 13 063 land parcels (points) located in 42 SPAs and adjacent areas (number of points per area: mean = 311; min = 196; max = 601). In the studied period, on average 4.4 ± 1.3% of agro-steppe area was lost (estimated risk ratio = 0.96, p-value < 0.001; z-value -6.53) (Fig. 3, and A1 for detailed information with estimates and p-values for each area). Losses were greater outside than inside SPAs (Outside SPAs: 6.6 ± 2.3%, p-value < 0.001, z-value = -5.51; Inside SPAs: 2.2 ± 1.1%, p-value < 0.001, z-value = -4.12). The global heterogeneity is 53.8% (Q = 88.7 (41), p-value < 0.001). The rates of habitat loss are significantly different across the studied SPAs, justifying the use of the random-effects meta-analysis.

Overall, there were greater losses of agro-steppe in Portugal and in areas surrounding SPAs, but these were only significant when considering losses in percentage rather than in total area in hectares (percentage: [3, 38] = 6.2, p-value = 0.002; hectares: F [3, 38] = 1.96, p-value = 0.136; Fig. 4). SPAs lost, on average, 0.5% agro-steppe area per year, of 0.9 ± 0.3% in Portugal and 0.4 ± 0.3% in Spain (p-value= 0.190), corresponding to an average annual loss of 202.7 ± 94.9 and 161.6 ± 192.7 hectares, respectively. Outside SPAs, annual loss of agro-steppe was, on average 0.8%, 1.4 ± 0.6% in Portugal and 0.6 ± 0.5% in Spain (p-value = 0.023), corresponding to an average annual loss of 329.1 ± 132.1 and 342.3 ± 273.3 hectares, respectively.

The total net agro-steppe area loss was 6446 ha $year^{-1}$ outside SPAs and 3559 ha $year^{-1}$ inside SPAs (Fig. 5). Loss of agro-steppe area was mainly due to its conversion to permanent cultures and irrigated crops (Fig. 5 and A2). Changes between land use were generally greater outside SPAs (regardless of whether they resulted in the gain or loss of agro-steppe area), except in the conversion from scrublands to agro-steppe area, and in the conversion between agro-steppe area and irrigated crops (in percentage of area), which were greater inside SPAs (Fig. 5 and A2).

Unless the factors that are causing the current decline in agro-steppe habitat in Iberia are controlled, this decline is likely to continue. Both scenarios (constant loss in proportion and total area) suggest a decline of ca. 20% and 30% by 2050, inside and outside SPA boundaries, respectively (when compared to current area in 2010; Fig. 6). By 2110, agro-steppes may decline to 61% and 41% in SPAs and surrounding areas, respectively, assuming constant loss in the proportion of area; or to 53% and 20% in SPAs and surrounding areas, respectively, assuming constant loss in absolute total area over time (Fig. 6). In fact, several of the studied SPAs may lose all their agro-steppes during this period (Fig. 6).

# 4. Discussion

### *4.1. Is the Natura 2000 network adequately protecting agro-steppe habitats?*

We assessed the effectiveness of Europe's Natura 2000 network, the world's largest protected area network, for conserving agro-steppes, a semi-natural habitat that holds important populations of conservation priority species (Alonso & Palacín, 2010). Over 10 years (from 2004 to 2015), Iberia's SPAs lost approximately 35 590 hectares of agro-steppe - an area that could hold about 542 great bustards, ca. 1.5% of the current Iberian population. We found greater declines in agro-steppe area outside Natura 2000 areas, with an annual loss of 6446 hectares, while annual losses in Natura 2000 sites were 45% smaller: 3559 ha $year^{-1}$ , indicating that the legal status on these sites may be reducing, but not preventing, the overall trend to convert agro-steppes into other agricultural land uses.

Virtually all SPAs assessed in this study lost agro-steppe area, with a few of these SPAs suffering greater losses than the surrounding control areas (‘Vale do Guadiana’ in Portugal, and ‘Llanos y Complejo Lagunar de la Albuera’ and ‘La Nava – Campos Norte’ in Spain). These results suggest that agro-steppe areas are becoming increasingly isolated and restricted to protected areas, progressively becoming clusters of “steppe habitat islands”, potentially decreasing the connectivity between conservation priority sites. Maintaining connectivity is important for population viability and to facilitate dispersal (Guixé & Arroyo, 2011; Hanski, 2011; Alonso et al., 2019), which is particularly important under climate change (Hanski, 2011; Branbilla et al., 2015; Gillingham et al., 2015).

The Natura 2000 network is the centre piece of Europe’s biodiversity conservation strategy and has already enabled an important comeback of a very diverse range of mammals and birds, including the great bustard and the lesser kestrel (Deinet et al., 2013). However, losses of agro-steppe habitat inside SPAs will compromise the positive outcomes of past conservation efforts, such as projects funded through the EU LIFE Program, which increased steppe bird populations. Good examples include the recovery of lesser kestrels in the Castro Verde SPA (Catry et al., 2013) and the overall increase of great bustards in Iberia (Alonso, 2014). Although the response of different species to the land use changes here reported may vary (Santana et al., 2014), this study reveals a trend that can compromise the population recovery of great bustards and other priority species for which many SPAs were designated. Other studies have also questioned the full effectiveness of the Natura 2000 Network for a wide range of habitats and taxonomical groups (e.g. Dimitrakopoulos et al., 2004; Abellán & Sánchez-Fernández, 2015; Brambilla et al., 2015; Zehetmair et al., 2015).

### *4.2 Impacts of agro-steppe area loss on great bustard populations*

The abundance of great bustards is clearly proportional to the area of agro-steppe, so it provides a good example to illustrate the consequences of the agro-steppe losses reported in this study. Recent counts indicate that its Iberian populations are stable or increasing slightly (Alonso, 2014), apparently not yet responding to the losses of agro-steppe area described by this study, although a recent population decline has been documented in one of the studied SPAs (Palacín & Alonso, 2018). Lopéz-Jamar et al. (2010) and Alonso (2014) found that large high-quality areas tend to host increasing or stable populations of great bustards, contrasting with population declines in smaller or low-quality sites. The range contraction that this species is experiencing, presumably due to the joint effect of habitat loss and degradation and high conspecific attraction (Alonso, 2014), can be more aggravated if agro-steppe area continues to decline. It is also possible that declines have not been detected due to improved survey efforts in recent counts (Alonso & Palacín, 2010, Alonso, 2014), or because this species may take time to respond to habitat change due to their long life span (Alonso et al., 2010).

By including the largest SPAs with the high number of great bustards in this study, we may have underestimated the magnitude of agro-steppe conversion since larger areas are more likely to be better managed due to their important populations (although the SPAs selected vary considerable in size; Table 1). Smaller, but nonetheless important areas are more likely to be facing higher rates of land use changes, which could be linked to the range contraction occurring in Iberia (Pinto et al., 2005). The observed steady decline in agro-steppe habitat in Iberia, observed also inside SPAs, is likely to have major impacts on populations of great bustards and other steppe birds, already threatened in Europe due to anthropogenic mortality (Marcelino et al., 2017; D'Amico et al., 2018), habitat degradation (Silva et al. 2018), and climate warming (Catry et al., 2015; Silva et al., 2015). The loss of agro-steppe habitat is one of the factors behind little bustard's population declines observed in recent decades. In Portugal little bustards declined by 49% between 2003-2006 and 2016 (Silva et al., 2018), with similar trends found in some protected areas in Spain (Casas et al., 2019).

### ***4.3 Agro-steppes are being converted into permanent and irrigated crops***

We found that agro-steppes have been primarily converted to permanent cultures and irrigated crops, a process of agricultural intensification observed in other studies carried out in Iberia (Kleijn and Sutherland, 2003; Moreira et al., 2007; Stoate et al., 2009; Traba & Morales, 2019). The conversion to permanent cultures dramatically changes open landscapes to tree/shrub dominated ones. Traditional olive groves and vineyards are occasionally used for feeding or resting by great bustards, little bustards or sandgrouse (*Pterocles* spp.) (Lane et al., 2001; Benitez-Lopez et al., 2014), but the modern versions of these and other permanent cultures are intensively managed and inadequate for these birds (Jiguet, 2002; Delgado and Moreira, 2010; Bravo et al., 2012; Catry et al., 2013).

The conversion of non-irrigated into irrigated crops, occurring at similar rates inside and outside SPAs, will also result in habitat degradation or habitat loss since it changes the structure of the vegetation. These more intensive farming methods are also associated with increased disturbance, particularly detrimental to large steppe birds (Sastre et al., 2009). The increased use of herbicides and insecticides has deleterious effects on plants and arthropods which are important food resources (Traba et al., 2007; Stoate et al., 2009).

In addition to the decrease of agro-steppe habitat associated with these conversions, the decline in the quality of the remaining habitat (not quantified in this study), is also likely impacting the steppe bird community, as suggested by the sharp drop in little bustard populations in the last decade (Silva et al., 2018). The conversion of extensively managed cereal crops to permanent pastures, accompanied by an increase in livestock density and grazing intensity, may reduce habitat quality: the short vegetation resulting from overgrazing is unlikely to satisfy the ecological needs of great bustards, little bustards, and other grassland bird species (Faria et al., 2012). We could not ascertain why agro-steppe area loss was greater in Portugal than in Spain. This was observed both inside and outside SPAs, suggesting it may be due to pressure from agricultural markets, rather than to differences in the enforcement of EU directives (Statistics Portugal, 2019).

We examined two scenarios of agricultural change. If the current pressure on agro-steppe habitat is maintained (assuming current rates of habitat loss), this habitat may decline 20% by 2050 and 40% by 2110. Declines will be more severe if the demand for products derived from permanent or irrigated crops continues to increase. With the current high demand for Mediterranean products such as olive oil and wine (Statistics Portugal, 2019), agro-steppes within SPAs may soon be the only areas left to be converted.

### *4.4 The legal framework and policy implications*

Over a 10-year period, the Natura 2000 network may have helped prevent losses of ca. 36 000 ha of agro-steppe habitat in Iberia. The regions included in this study hold approximately 29% of the World´s population of great bustard (Alonso and Palacín, 2010) and large populations of other species of conservation concern. This study highlights the positive value of the Natura 2000 Network in protecting and conserving open farmland habitats in Iberia. Despite the observed relative success of the Natura 2000 network in reducing agro-steppe habitat losses, it is important to consider why losses occurred even within these protected sites. This study suggests there is need for a revision of the implementation of the legal requirements of the Birds Directive and in the use of Agri-Environmental Schemes (AES), developed in the framework of the European Common Agricultural Policy (CAP).

The Birds Directive explicitly requires governments to take measures to prevent deterioration of the habitats of species listed in its Annex 1, including great bustard, little bustard and lesser kestrel, present in the studied SPAs. Consequently, the observed replacement of agro-steppes by habitats that are unsuitable for these birds is a violation of the directive. The Birds Directive requires governments to prevent the deterioration of habitats of priority species outside protected areas, hence the observed agro-steppe habitat loss outside SPAs is also a contravention. Finally, the Directive classifies SPAs as “the most suitable territories in number and size” for the conservation of target species. The rapid degradation of agro-steppe habitats outside current protected areas highlights the need to add to the Network important areas that remain unprotected (Traba et al., 2007). Great bustards were found to nest up to 53km away from their lek areas in two of the SPAs studied here, with 25% of females nesting outside protected areas, in areas only used for nesting (Mangaña et al., 2011).

Agri-Environmental Schemes (AES) have been used to foster agricultural practices compatible with the conservation of biodiversity (Stoate et al., 2009), and these instruments have been used to minimize the conversion of agro-steppe habitat, for example, in the Castro Verde SPA, in southern Portugal (Deinet et al., 2013). The observed agro-steppe habitat losses, in most studied SPAs, indicate that AES schemes are insufficient to prevent the conversion of this habitat into more profitable types of land use. To increase the success and uptake of these schemes, it is thus important to consider local conditions, such as soil quality and the value of competing crops, so that the implementation of nature friendly practices remains an attractive alternative to farmers (Rodríguez-Rodríguez and López, 2019).

A further weakness of AES is the lack of restrictions to farming practices once the contract finishes, which may cancel the conservation benefits acquired during farmers’ participation (Henle et al., 2008; Stoate et al., 2009). It is important to correct this weakness because short-term habitat conservation is inadequate for long-lived birds (e.g. great and little bustards) that are highly philopatric to their breeding sites, and thus depend on long-term conservation management. The maintenance of Europe’s agro-steppes is essential to protect many vulnerable species associated with low intensity and low yield farming practices. Although these practices may currently be less profitable than some existing alternatives, such landscapes now attract nature-related tourism activities (e.g. Gameiro et al., 2020) that could generate additional sources of revenue for farmers. In agro-steppes and other human-dominated landscapes, farmers may have to diversify their economic activities to remain economically viable, a process that should be funded by agro-environment financial instruments.

## 5. Conclusion

Here we show that agro-steppe is declining both inside and outside Special Protection Areas, possibly turning Natura 2000 sites into “steppe-islands”. The main conservation shortcomings identified in our agro-steppe study – weak enforcement of the restrictions imposed by the Network, insufficient incentives to warrant the cooperation of farmers, and short-term habitat conservation – are likely to also affect the success of Natura 2000 sites in the protection of other key habitats throughout Europe, especially in human-dominated landscapes where conservation may often compete with economic activities (Zaharia et al., 2012; D’Amen et al., 2013). However, as found in a recent evaluation of the network (EC, 2016), the weaknesses that were identified are not inherent to the legislation, resulting instead from its poor implementation. Our results illustrate the important contribution of the Natura 2000 network to the protection of Europe’s biodiversity, but they also revealed important insufficiencies that need to be addressed to realize the full potential of the network and meet the goals of a new global biodiversity framework soon to be defined by the Convention on Biological Diversity.

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*Table 1: Area and great bustard numbers in each SPA included in the study. Most areas were designated as Natura 2000 sites in the early 2000s. Two images were compared to quantify habitat changes within a 10 year period.*

| # | SPA | Area (ha) | Great Bustard | Designation date | Older image | Recent image |
|---|---|---|---|---|---|---|
| **1** | Campo Maior | 9,580 | 40-50p | 1999 | 2004-2006 | 2013 |
| **2** | Moura/Mourão/ Barrancos | 84,913 | 51-100p | 1999 | 2004-2006 | 2011-2013 |
| **3** | Castro Verde | 85,343 | 1,000-1,200p | 1999 | 2004-2006 | 2011 |
| **4** | Vale do Guadiana | 76,543 | 5-10p | 1999 | 2004-2006 | 2011 |
| **5** | Llanos de Cáceres y Sierra Fuentes | 69,666 | 750p; 1,200w | 1989 | 2004-2006 | 2011-2013 |
| **6** | Campiña Sur – Embalse de Arroyos Conejo | 44,809 | 340r; 652w | 2004 | 2004-2006 | 2011 |
| **7** | La Serena y Sierras Periféricas | 154,974 | 350p; 500w | 2000 | 2004-2006 | 2010-2012 |
| **8** | Llanos de Alcantara y Brozas | 46,580 | 220p | 2003 | 2004-2006 | 2011-2013 |
| **9** | Llanos y Complejo Lagunar de La Albuera | 36,462 | 481r; 479w | 2004 | 2004-2006 | 2013 |
| **10** | Alto Guadiato | 33,964 | 93p; 150w | 2008 | 2008-2009 | 2011 |
| **11** | Campiñas de Sevilla | 35,735 | 80-100r | 2008 | 2008-2009 | 2013 |
| **12** | Oteros – Campos | 31,685 | 735p | 2000 | 2008-2009 | 2011 |
| **13** | La Nava – Campos Norte | 54,936 | 779p | 2000 | 2004-2005 | 2014 |
| **14** | Penillanuras – Campos Sur | 23,800 | 595p | 2000 | 2004-2005 | 2014 |
| **15** | Lagunas de Villafáfila | 32,549 | 2,791p | 1988 | 2004-2005 | 2014 |
| **16** | Tierra de Campiñas | 139,445 | 2,195p | 2000 | 2004-2005 | 2014 |
| **17** | Área esteparia del este de Albacete | 25,757 | 275p | 2005 | 2004-2005 | 2013-2015 |
| **18** | Zona esteparia de El Bonillo | 13,413 | 400p | 2005 | 2004-2005 | 2012-2013 |
| **19** | Área esteparia de La Mancha Norte | 107,246 | 1,700p | 2005 | 2004-2005 | 2012 |
| **20** | Área esteparia de la margen derecha del río Guadarrama | 12,703 | 339p | 2007 | 2009 | 2011-2015 |
| **21** | Estepas cerealistas de los ríos Jarama y Henares | 33230 | 560p | 1993 | 2006 | 2014-2015 |

Great bustard numbers in each area are shown as p = permanent, r = reproducing and w = wintering. Data from Natura 2000 datasheets (ICNF 2016; MITECO 2016).

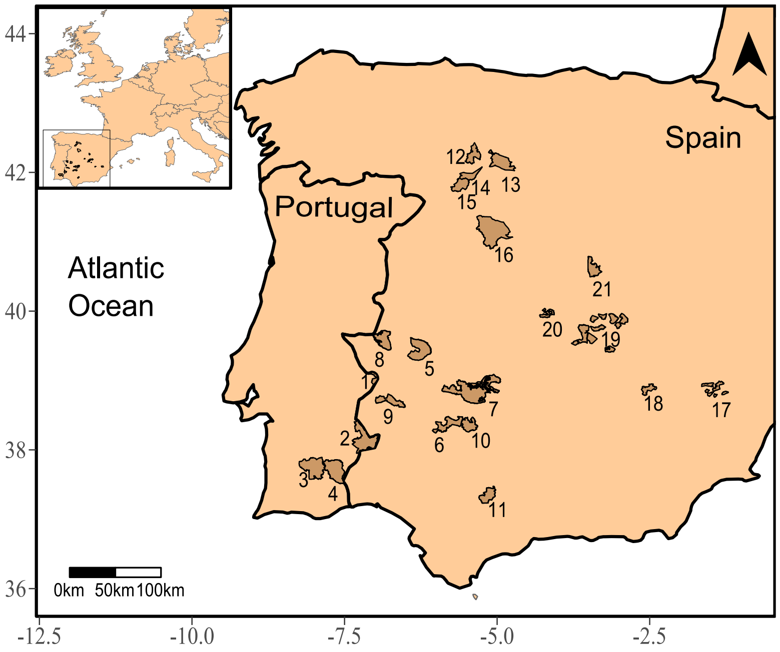


*Figure 1: Location of the 21 Special Protection Areas (SPAs) with agro-steppe habitat included in this study. Numbers refer to each SPA entry in Table 1.*

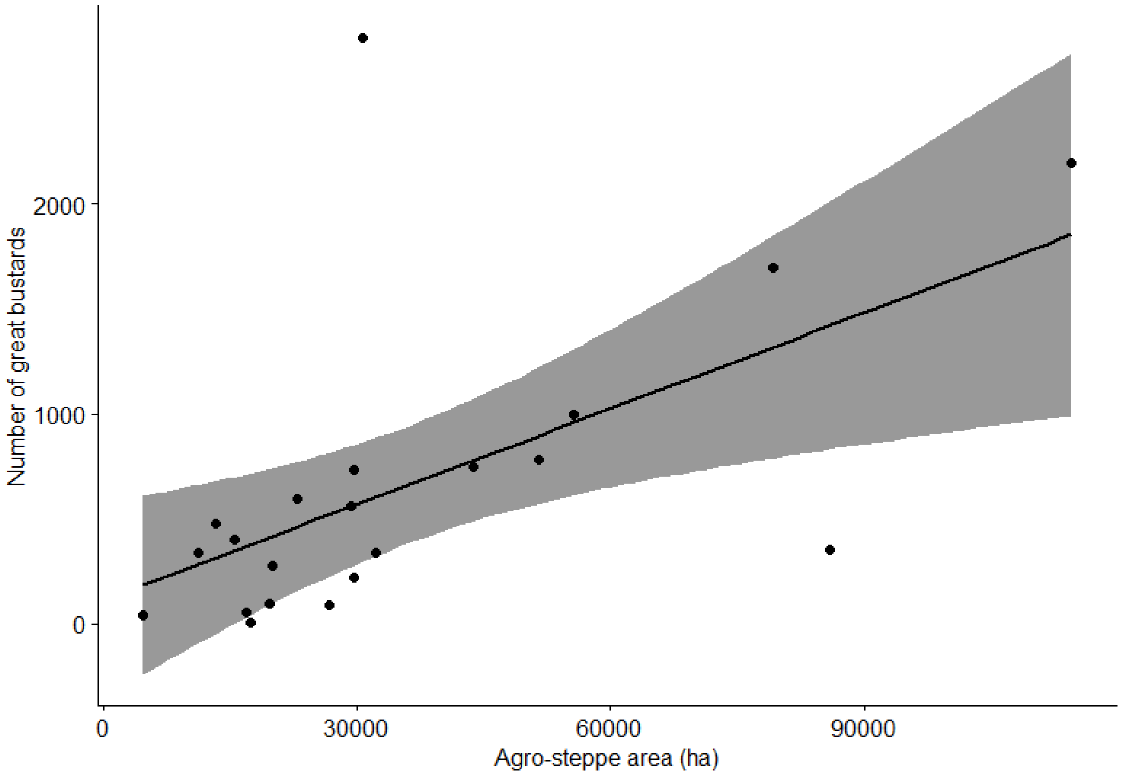


*Figure 2: Relationship between the number of great bustards and agro-steppe area in the 21 SPAs studied (Spearman correlation, Rs = 0.67, p-value = 0.0012). Shaded area represents the 95% confidence intervals. Data from Natura 2000 datasheets (ICNF 2016; MITECO 2016; see table 1).*

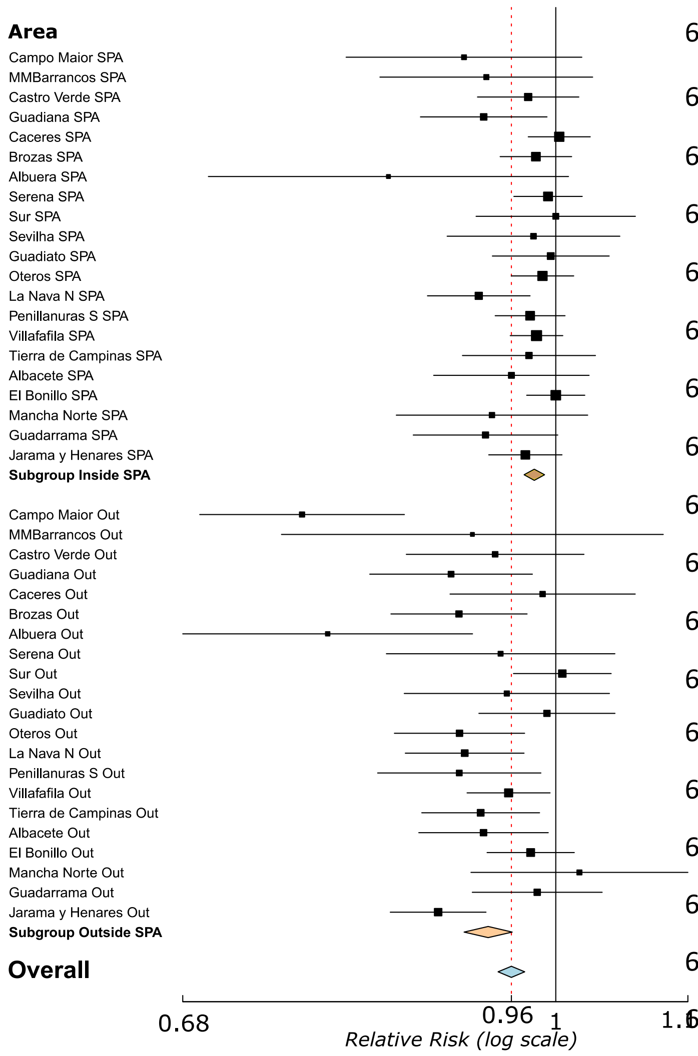


*Figure 3: Forest plot of agro-steppe habitat change in 21 SPAs and 21 adjacent control areas. The size of squares is proportional to the weight in the analysis and the horizontal lines represent the 95% CIs. Diamonds show overall and subgroup averages and CIs. The solid vertical line indicates relative risk = 1, i.e. no gain or loss of agro-steppe area. Squares to the left of the solid line indicate loss of agro-steppe area. A global estimate of 0.96 (vertical dashed line) represents the average loss of 4.4% of agro-steppe area. Figure A1 includes the estimates and sampled sizes for each site.*

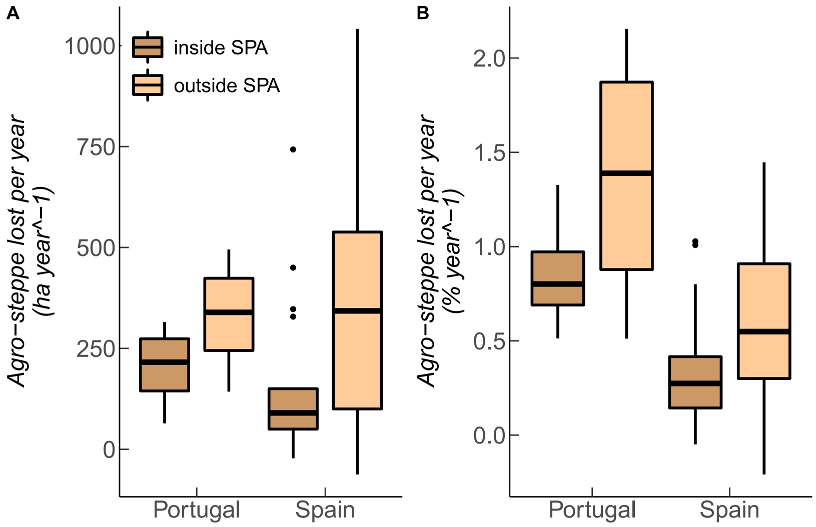


*Figure 4: Agro-steppe area losses in hectares (A) and percentage (B) in Portuguese and Spanish SPAs (dark) and in surrounding areas (clear).*

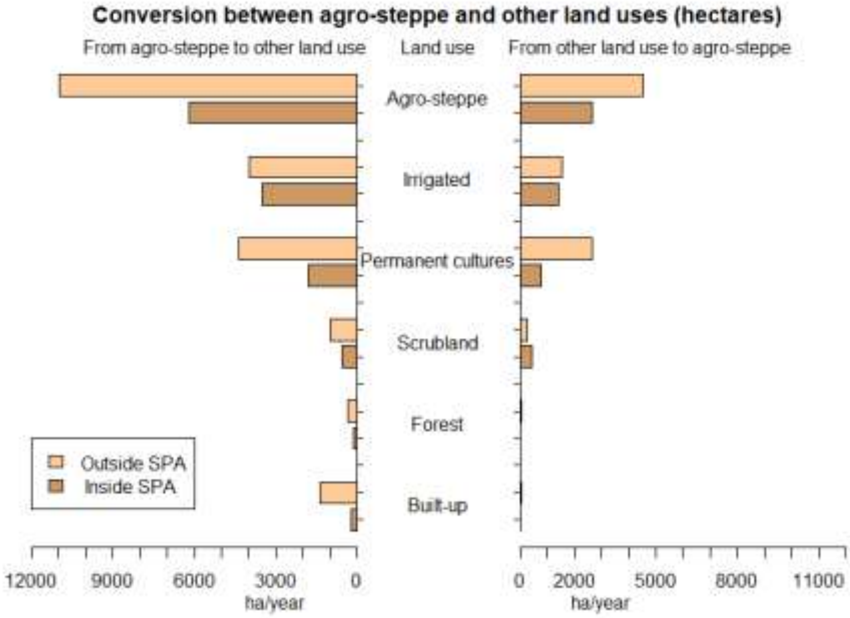


*Figure 5: Area (in hectares) converted per year from agro-steppe to other types of land use, both inside (dark) and outside (clear) SPAs. Agro-steppe bars refer to the total amount of area lost and gained per year.*

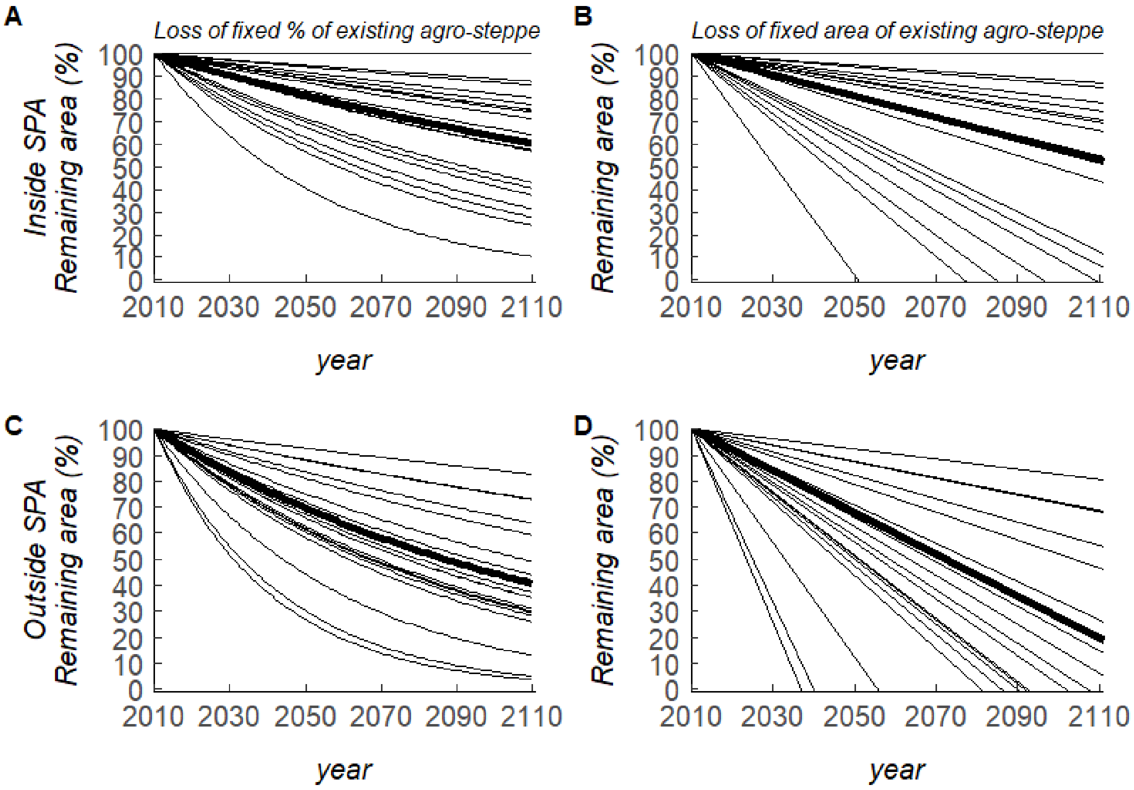
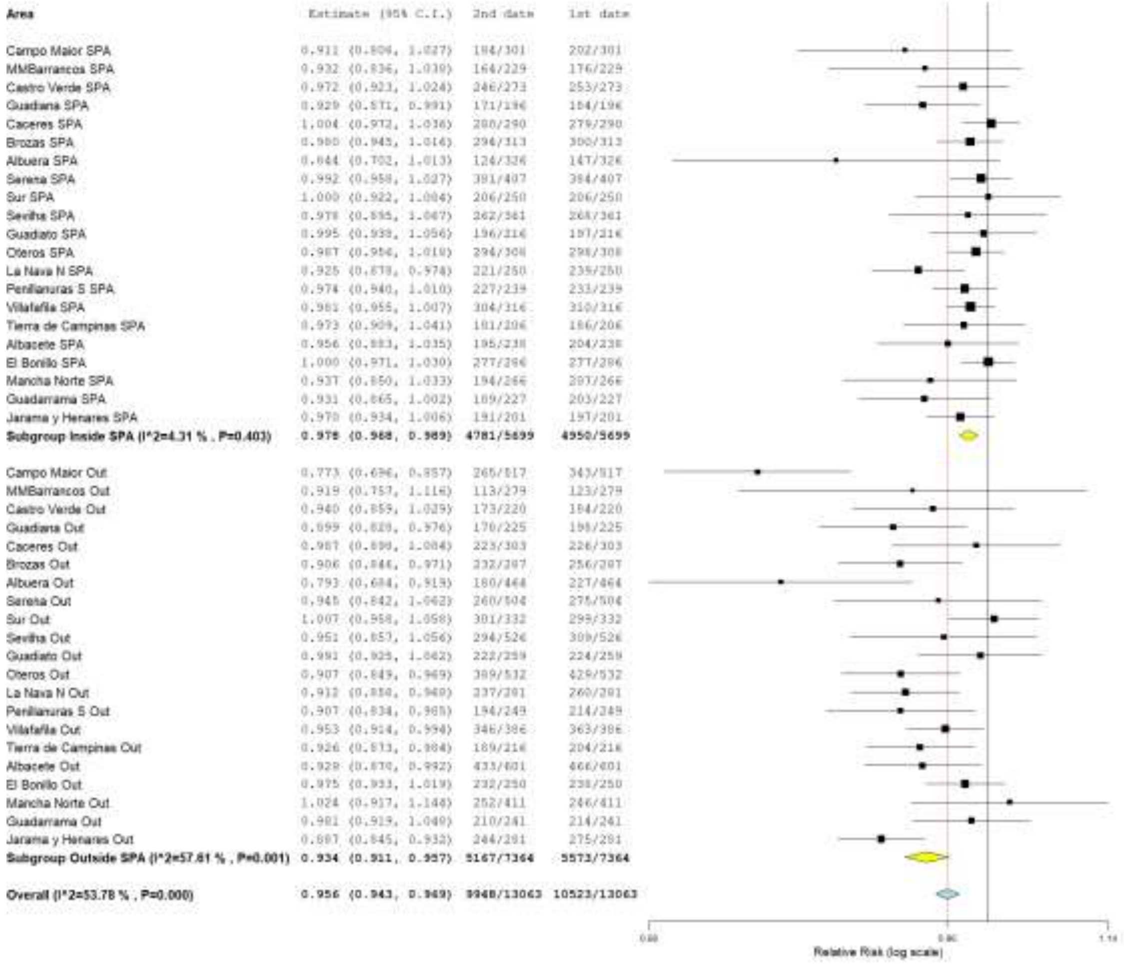


*Figure 6: Projection for the potential decline in agro-steppe area for the next hundred years, assuming either constant annual loss in percentage of the existing area (A) inside and (C) outside SPAs or loss of fixed area (annual loss observed during our study period) (B) inside and (D) outside SPAs. Each line represents a SPA/ Outside area and the thick line represents the overall tendency.*

# Appendix I



| Area | Estimate (95% C.I.) | 2nd date | 1st date |
|---|---|---|---|
| Campo Maior SPA | 0.911 (0.806, 1.027) | 184/301 | 202/301 |
| MMBarrancos SPA | 0.932 (0.836, 1.039) | 164/229 | 176/229 |
| Castro Verde SPA | 0.972 (0.923, 1.024) | 246/273 | 253/273 |
| Guadiana SPA | 0.929 (0.871, 0.991) | 171/196 | 184/196 |
| Caceres SPA | 1.004 (0.972, 1.036) | 280/290 | 279/290 |
| Brozas SPA | 0.980 (0.945, 1.016) | 294/313 | 300/313 |
| Albuera SPA | 0.844 (0.702, 1.013) | 124/326 | 147/326 |
| Serena SPA | 0.992 (0.958, 1.027) | 381/407 | 384/407 |
| Sur SPA | 1.000 (0.922, 1.084) | 206/250 | 206/250 |
| Sevilha SPA | 0.978 (0.895, 1.067) | 262/361 | 268/361 |
| Guadiato SPA | 0.995 (0.938, 1.056) | 196/216 | 197/216 |
| Oteros SPA | 0.987 (0.956, 1.019) | 294/308 | 298/308 |
| La Nava N SPA | 0.925 (0.878, 0.974) | 221/250 | 239/250 |
| Penillanuras S SPA | 0.974 (0.940, 1.010) | 227/239 | 233/239 |
| Villafafila SPA | 0.981 (0.955, 1.007) | 304/316 | 310/316 |
| Tierra de Campinas SPA | 0.973 (0.909, 1.041) | 181/206 | 186/206 |
| Albacete SPA | 0.956 (0.883, 1.035) | 195/238 | 204/238 |
| El Bonillo SPA | 1.000 (0.971, 1.030) | 277/286 | 277/286 |
| Mancha Norte SPA | 0.937 (0.850, 1.033) | 194/266 | 207/266 |
| Guadarrama SPA | 0.931 (0.865, 1.002) | 189/227 | 203/227 |
| Jarama y Henares SPA | 0.970 (0.934, 1.006) | 191/201 | 197/201 |
| **Subgroup Inside SPA (I^2=4.31 % , P=0.403)** | **0.978 (0.968, 0.989)** | **4781/5699** | **4950/5699** |
| | | | |
| Campo Maior Out | 0.773 (0.696, 0.857) | 265/517 | 343/517 |
| MMBarrancos Out | 0.919 (0.757, 1.116) | 113/279 | 123/279 |
| Castro Verde Out | 0.940 (0.859, 1.029) | 173/220 | 184/220 |
| Guadiana Out | 0.899 (0.828, 0.976) | 170/225 | 189/225 |
| Caceres Out | 0.987 (0.898, 1.084) | 223/303 | 226/303 |
| Brozas Out | 0.906 (0.846, 0.971) | 232/287 | 256/287 |
| Albuera Out | 0.793 (0.684, 0.919) | 180/464 | 227/464 |
| Serena Out | 0.945 (0.842, 1.062) | 260/504 | 275/504 |
| Sur Out | 1.007 (0.958, 1.058) | 301/332 | 299/332 |
| Sevilha Out | 0.951 (0.857, 1.056) | 294/526 | 309/526 |
| Guadiato Out | 0.991 (0.925, 1.062) | 222/259 | 224/259 |
| Oteros Out | 0.907 (0.849, 0.969) | 389/532 | 429/532 |
| La Nava N Out | 0.912 (0.858, 0.969) | 237/281 | 260/281 |
| Penillanuras S Out | 0.907 (0.834, 0.985) | 194/249 | 214/249 |
| Villafafila Out | 0.953 (0.914, 0.994) | 346/386 | 363/386 |
| Tierra de Campinas Out | 0.926 (0.873, 0.984) | 189/216 | 204/216 |
| Albacete Out | 0.929 (0.870, 0.992) | 433/601 | 466/601 |
| El Bonillo Out | 0.975 (0.933, 1.019) | 232/250 | 238/250 |
| Mancha Norte Out | 1.024 (0.917, 1.144) | 252/411 | 246/411 |
| Guadarrama Out | 0.981 (0.919, 1.049) | 210/241 | 214/241 |
| Jarama y Henares Out | 0.887 (0.845, 0.932) | 244/281 | 275/281 |
| **Subgroup Outside SPA (I^2=57.81 % , P=0.001)** | **0.934 (0.911, 0.957)** | **5167/7364** | **5573/7364** |
| | | | |
| **Overall (I^2=53.78 % , P=0.000)** | **0.956 (0.943, 0.969)** | **9948/13063** | **10523/13063** |

*Figure A1. Forest plot of agro-steppe habitat change in 21 SPAs and 21 adjacent control areas. The size of squares is proportional to the weight in the analysis and the horizontal lines represent the 95% CIs. Diamonds show overall and subgroup averages and CIs. The solid vertical line indicates relative risk = 1, i.e. no gain or loss of agro-steppe area. Squares to the left of the solid line indicate loss of agro-steppe area. 1st date and 2nd date columns include the number of points (parcels) identified as agro-steppe and the total number of points sampled. Heterogeneity (I^2) is present for both subgroups and for the overall analysis.*

# Appendix II

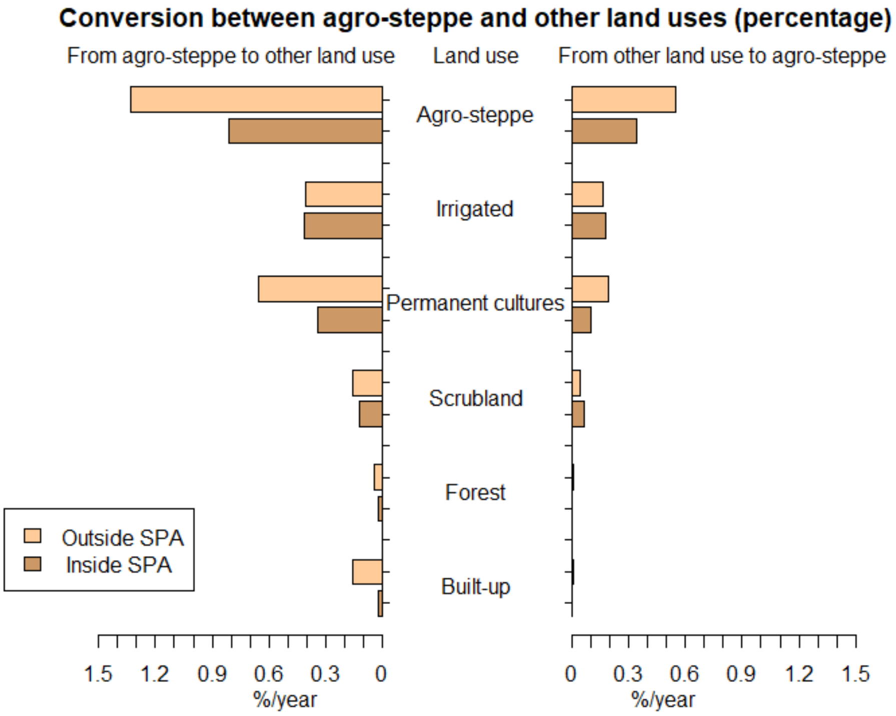


*Figure A2: Area (in percentage) converted per year from agro-steppe to other types of land use, both inside (dark) and outside (clear) SPAs. Agro-steppe bars refer to the total amount of area lost and gained per year.*