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Afforestation programs such as the one promoted by the EU Common Agricultural Policy have spread tree plantations on former cropland. These afforestations attract generalist forest and ubiquitous species but may cause severe damage to open habitat species, especially birds of high conservation value. We investigated the effects of young (< 20 yr) tree plantations dominated by pine *P. halepensis* on bird communities inhabiting the adjacent open farmland habitat in central Spain. We hypothesize that pine plantations with larger surface, and areas at shorter distances from plantations, would result in lower bird species richness and conservation value of open farmland birds. Regression models controlling for the influence of land use types around plantations revealed significant positive effects of distance to pine plantation edge on community species richness in winter, and negative effects on an index of conservation concern (SPEC) during the breeding season. However, plantation area did not have any effect on species richness or community conservation value. Our results indicate that pine afforestation of Mediterranean cropland in heterogeneous agricultural landscapes has an overall low detrimental effect on bird species that are characteristic of open farmland habitat.

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Low effect on open-farmland birds of young afforestations in heterogeneous Mediterranean croplands

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Abstract Afforestation programs such as the one promoted by the EU Common Agricultural Policy have spread tree plantations on former cropland. These afforestations attract generalist forest and ubiquitous species but may cause severe damage to open habitat species, especially birds of high conservation value. We investigated the effects of young (< 20 yr) tree plantations dominated by pine *P. halepensis* on bird communities inhabiting the adjacent open farmland habitat in central Spain. We hypothesize that pine plantations with larger surface, and areas at shorter distances from plantations, would result in lower bird species richness and conservation value of open farmland birds. Regression models controlling for the influence of land use types around plantations revealed significant positive effects of distance to pine plantation edge on community species richness in winter, and negative effects on an index of conservation concern (SPEC) during the breeding season. However, plantation area did not have any effect on species richness or community conservation value. Our results indicate that pine afforestation of Mediterranean cropland in heterogeneous agricultural landscapes has an overall low detrimental effect on bird species that are characteristic of open farmland habitat.

Keywords: conservation status, distance effects, land use types, pine plantations, species richness.

INTRODUCTION

A significant amount of abandoned cropland, low productive cropland and pastureland has been converted into tree plantations in the last few decades, and ca. 7% of forest land in the world are tree plantations at present (FAO, 2011). Different afforestation programs have contributed to the spread of such tree plantations at the regional level. For instance, the Common Agricultural Policy (CAP) has favoured the conversion of farmland into tree plantations in the European Union since 1992 by means of a scheme of aid for forestry measures in agriculture (EEC Council Regulation No. 2080/92), which has resulted in the afforestation of ca. 8 millions ha to date (European Commission, 2013a,b). Further, afforested cropland is expected to increase in the near future in countries such as Spain due to subsidies to afforestation of extirpated vineyards (Spanish Agrarian Guarantee Fund, 2012).

Tree plantations pursue a number of environmental and societal services such as soil retention and carbon sequestration (Rey Benayas et al., 2007). However, they may have noticeable effects on biological communities. Thus, Bremer & Farley (2010) found that tree plantations are most likely to contribute to biodiversity when established on degraded lands rather than replacing natural ecosystems, and when indigenous tree species are used rather than exotic species. Similarly, a meta-analysis of faunal and floral species richness and abundance in timber plantations and pasture lands on 36 sites across the world concluded that plantations support higher species richness or abundance than pasture land only for particular taxonomic groups (i.e. herpetofauna), or specific landscape features (i.e. absence of remnant vegetation within pasture) (Felton et al., 2010).

Agro-ecosystems are important for maintenance of bird diversity in Europe, especially for species of conservation concern (BirdLife International, 2004a). The Directorate-General for Agriculture and Rural Development (2012), using the European farmland bird index as a barometer of change for the biodiversity of agricultural land in Europe, shows a decline in these bird populations of ca. 20% between 1990 and 2008 (see also Donald et al., 2002; Gregory et al., 2005; Butler et al., 2010; Scholefield et al., 2011; Guerrero et al., 2012). Cropland afforestations in southern Europe, which are mostly based on coniferous species, may cause severe damage to open habitat species, especially ground-nesting birds, many of which are of conservation concern in Europe (European Bird Census Council, 2010). These negative effect is mostly due to the replacement of high quality habitat and increasing risk of predation (Shochat et al. 2001, Santos et al. 2006, Caplat and Fonderflick 2009, Reino et al. 2009, Voříšek et al. 2010, Butler et al. 2010, Fonderflick et al. 2010, Reino et al. 2010). For instance, an assessment of nest predation rates on open farmland habitat adjacent to tree plantations in central Spain resulted in 94.2% of artificial nests that were predated three weeks after the start of the experiment (Sánchez-Oliver, Rey Benayas & Carrascal, 2014a). Conversely, tree plantations are a suitable habitat for forest generalist and ubiquitous species, which may lead to an increase in local species richness around them in agricultural landscapes (Rey Benayas, Galván & Carrascal, 2010; Sánchez-Oliver, Rey Benayas & Carrascal, 2014b).

In this study we aim at investigating the effects of young (<20 yr) tree plantations on bird communities inhabiting the adjacent open farmland habitat in a Mediterranean landscape mosaic located in central Spain. Specifically, we ask if distance to and area of tree plantations affect species richness and conservation value of the birds communities under the hypotheses that they (1) define a surrounding (buffer) area that will have a detrimental effect on bird species that are characteristic of open farmland habitat, particularly for ground-nesting species that are of high conservation value, and (2) will attract forest generalist and ubiquitous species of low conservation value. We predict that the effects of tree plantations may depend on land use type around them (Sánchez-Oliver et al., 2014b) and that they will be most noticeable in the breeding season than in winter due to territorial behaviour of birds.

METHODS

Study area

Field work was carried out on open farmland adjacent to afforested cropland located in Campo de Montiel (La Mancha natural region, southern Spanish plateau, UTM 30 S 469411 4289409; Figure 1). The study area spreads on ca. 440 km^2 with altitude ranging between 690 and 793 m a.s.l. The climate is continental Mediterranean with dry and hot summers and cold winters. Mean annual temperature and total annual precipitation in the area during the last 30 years were 13.7 °C and 390 mm, respectively (Agencia Española de Meteorología, 2012). These figures were 15.8ºC and 362.9 mm in 2012, when our bird surveys took place (Junta de Castilla-La Mancha, 2013).

The area is a representative mosaic of different crops, pastures and semi-natural or introduced woody vegetation that are characteristic of large areas in Mediterranean landscapes. Croplands were mostly occupied by herbaceous crops (wheat and barley) and permanent woody crops (olive groves and vineyards). Natural vegetation consisted of holm oak (*Quercus rotundifolia L.*) woodland and riparian forests that have been mostly extirpated from this region. Until 1992, woodland cover was restricted to open holm oak patches, usually grazed by sheep and goats. Major land use changes in the last 20 years are the abandonment of herbaceous cropland and vineyard extirpation and their subsequent afforestation with the native Aleppo pine (*Pinus halepensis* Mill.) alone or mixed with holm oak. These tree plantations are of small area due to property size and noticeably dominated by pines as they establish better and grow faster than other planted species such as holm oak.

Selection of tree plantations for bird survey at adjacent farmland habitat

First, all tree plantations in the study area were located using both orto-photos (Geographic Information System of Farming Land 2010; hereafter SigPac) and Google Earth®, and were later verified in the field. We found 99 tree plantations on former cropland that took place in 1992 or later. Tree plantations < 1 ha were directly discarded. In addition, a target tree plantation had to be placed at least 2-km away from another plantation in the transect direction to avoid that surveyed birds associated to open farmland adjacent to a given tree plantation were affected by another tree plantation. Following these criteria, we finally selected 40 tree plantations to assess bird community on farmland adjacent to tree plantations. We measured the area of every tree plantation (Table 1) using ArcGIS 10.0 (ESRI Inc.). As they are young, the tree canopy is little developed (mean tree cover = 38.8% ± 25.7%, mean tree height= 3.6 m ± 1.5 m, and mean dbh = 13.3 cm ± 6.5 cm).

Bird survey

Bird census were carried out in winter (January and February) and breeding season (April and May) of 2012 to assess the wintering and breeding bird communities, respectively. Census method consisted of outward line transects of 1000-m length with belts of 100-m at each side of the observer and initiated at the tree plantation edge (Bibby et al. 2000, Gregory et al. 2004).Two census-transects for each plantation and season were carried out in different days, one in the morning between sunrise and three hours later and one in the evening two hours before sunset (80 transects in total). The two transects from each tree plantation spanned on different directions that were established *a priori* to meet the criterion used for selection of tree plantations (see above). They were walked at an average speed of 2.5 km h^{-1}. We noted and geo-localized the presence of every bird except those that were over-flying the census area (i.e., distance to the tree plantation edge and situation with respect to the transect progression line; Table S1 in supplementary material). All censuses were conducted by the same well trained field ornithologist (JS S-O) on windless and rainless days.

The European endangered status of each species was obtained from BirdLife International (2004b) using the Species of European Conservation Concern (SPEC index) scores. This index uses four categories: SPEC 1 (global conservation concern), SPEC 2 (concentrated in Europe and with an unfavourable globally threatened or near threatened conservation status or data deficient), SPEC 3 (not concentrated in Europe but with an unfavourable conservation status), and Non-SPEC (favourable conservation status). We assigned a value of 4 to species that were included in the Non-SPEC category. Finally, we used a transformed SPEC index by subtracting the SPEC value of each surveyed species to 5 in order that species of highest conservation concern attained the greatest value (4), whereas the species of lowest conservation concern attained a value of 1 (de la Montaña, Rey Benayas & Carrascal, 2006). The average values of transformed SPEC index were calculated considering the recorded species in each transect (Table S1 in supplementary material).

To have a reference of the avifauna that colonizes farmland habitat in the studied region, for comparison with our bird survey, we used (1) the species list (47 species) of the common farmland bird indicator for Southern Europe (European Bird Census Council, 2010) and the list (36 species) of common farmland bird index (Directorate-General for Agriculture and Rural

Development 2012), and (2) the mean density of breeding species found at the habitat categories labelled as (a) dry arable lands, (b) vineyards, (c) olive groves, (d) agricultural mosaics with woody cultivations, and (e) pastures within the Mesomediterranean region of Central Spain obtained from Carrascal & Palomino (2008) (Table S1 in supplementary material).

Land use types

We measured percentage of land use types in all 80 transects on farmland habitat where bird survey took place using ArcGIS 10.0 (ESRI Inc.). The length and width of transects make them representative samples of land use types in the studied landscape. Land use types were identified by means of land use layers taken from SigPac (Geographic Information System of Farming Land, 2010) and verified in the field. We initially distinguished 21 land use types that were aggregated into the following eleven categories for statistical analyses according to their larger covers in the study region (i.e., avoiding those habitat categories of very low representativeness): streams and rivers, roads and rural tracks, olive groves, scattered buildings, afforestations, semi-natural woodland, fruit and dried fruit groves, waste lands, pastures, dry herbaceous cropland, and vineyard. The percentage of area occupied by each land use type across transects is shown in Table 1.

Statistical analyses

For statistical analyses we did not consider water birds (e.g., Common Sandpiper *Actitis hypolecus*, Mallard *Anas plathyrhinchos,* and Grey Heron *Ardea cinerea*), aerial feeders (European Bee-eater *Merops apiaster* and the Hirundinidae family species), and raptors. Species richness and bird community SPEC score were analyzed by means of Generalized Linear Models (GLM), with distance to tree plantation and plantation area as target predictors. Distance to tree plantation edge was treated as a dummy variable, i.e. 0 for close or <400 m vs. 1 for away or 600-1000 m. Area of tree plantation was included as a continuous covariate (in logarithm). As land use type may affect abundance of bird species around plantations, we included in the models the cover of six land use categories with a percentage higher than 1% as control covariates (namely, roads and rural tracks, olive groves, waste lands, pastures, dry herbaceous croplands and vineyards). GLMs were carried out with Gretl (release 1.9.5, http://gretl.sourceforge.net/). Statistical significance of the predictor variables was calculated using quasi-ML standard errors. We also tested for homogeneity of slopes of plantation area in the close and away transect sectors in *a posteriori* regression analyses. No interaction term distance*area was significant, so the effects of plantation area are generalizable across distance from the edge of the plantations.

RESULTS

We detected a total of 3643 individuals belonging to 47 species in winter and 1149 individuals belonging to 37 species in the breeding season at our 80 1-km transects (Table S1 in supplementary material). Thirty two species were included in the Non-SPEC category – least conservation concern –, 12 in the SPEC 3, nine in the SPEC 2, and two in the SPEC 1 – highest conservation concern (Table S1 in supplementary material).

Models revealed significant effects of distance to tree plantation edge on community species richness in winter (i.e., communities away from the plantations were ca. 30% richer in species that those close) but not in the breeding season (Table 2). The plantation area term did not have any effect on species richness in both seasons.

Distance to tree plantation edge showed a significant effect on the SPEC index during the breeding season (i.e., 19% higher index close to tree plantations), but not in winter. Plantation area did not have any effect on the SPEC index in either season (Table 2).

DISCUSSION

Overall, we found that young tree plantations established on former cropland in a Mediterranean mosaic located in central Spain had (1) a detrimental effect on bird species richness in winter and (2) a marginal positive effect on conservation value of bird communities at adjacent open farmland habitat in the breeding season.

Previous studies on the effects of tree plantations in open habitat bird species have mostly found negative effects, particularly for the most specialized and of more conservation concern (Shochat et al. 2001, Santos et al. 2006, Devictor et al. 2008, Caplat & Fonderflick 2009, Reino et al. 2009, 2010, 2013, Butler et al. 2010, Voříšek et al. 2010, Fonderflick et al. 2010, Morgado et al. 2010, Méndez et al. 2011). For instance, Fonderflick et al. (2013) found that the abundance of open-habitat birds decreased significantly in the vicinity of edges, this negative response extended within 150 m from the edge, and the effect was disproportionately higher in open-habitat species with high conservation concern. Accordingly, we found this detrimental effect for species richness in winter (Table 2A).

Nevertheless, conservation status concern of the bird assemblage in the breeding season was higher at close distance to the tree plantation edge and was not affected by the area of tree plantations (Table 2). The Little Bustard, a large and high conservation concern species, was associated to larger plantations in the breeding season in this study area (Table S1). The small size of the plantations (5.8 ha in average) together with the little development of some of them (e.g. tree cover of 1.7%, Table 1) may produce detrimental effects only at very short distances from them (e.g. <150 m, Fonderflick et al., 2013; Sánchez-Oliver et al., 2014a). Further, these plantations may mirror remnants of natural or semi-natural woody vegetation such as woodland patches and hedgerows that may be even beneficial for some farmland bird species (e.g. buntings), as they offer opportunities for forage, refuge and breeding (Concepción & Díaz, 2010, 2011; Morgado et al., 2010; Batáry et al., 2012). Importantly, the hypothesized detrimental effect of the tree plantations seems to be diluted by the high heterogeneity of the landscape and the important proportion of woody crop, such as olive groves (Table 1) (Tryjanowski et al., 2011; Myczko et al., 2013). In agreement, other studies have shown that landscape heterogeneity is a relevant factor affecting the occurrence and abundance of farmland birds (Morales, García & Arroyo, 2005; Batáry, Matthiesen & Tscharntke, 2010; Batáry et al., 2011; Flohre et al., 2011; Concepción & Díaz, 2011; Sánchez-Oliver et al., 2014a).

We conclude that distance to, but not area of, young pine plantations established on former Mediterranean cropland exert an overall detrimental effect on bird species richness at open farmland that seems to be diluted by the high heterogeneity of the landscape. Thus, these tree plantations should not be favoured, and even be extirpated, in homogenous agricultural landscapes that are highly valuable for ground-nesting bird species and open farmland communities (Traba et al., 2006; Butler et al., 2010; Sanderson et al., 2013). We recommend long-term assessments of afforestation in agricultural landscapes to fully understand and, consequently, reduce its impacts on biodiversity, particularly on ground-nesting birds.

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Table 1. Mean, standard deviation (sd) and range (min / max) of area of tree plantations and land-use categories in 1-km x 200-m 80 transects on farmland habitat adjacent to the 40 tree plantations (two transects per plantation) that were surveyed in Central Spain.

	Mean	sd	min	max
Area of tree plantation (ha)	5.8	6.6	1.3	36.5
Cover of the tree layer (%)	38.8	25.7	1.7	100.0
Average pine height (m)	3.6	1.5	1.0	7.2
Average trunk diameter of pines (dbh cm)	13.3	6.5	4.0	33.2
Streams and rivers (% cover)	0.3	0.9	0.0	6.4
Roads and rural tracks (% cover)	1.7	1.6	0.0	7.7
Olive groves (% cover)	14.2	21.5	0.0	94.5
Scattered buildings (% cover)	0.3	1.0	0.0	7.3
Afforestation (% cover)	0.8	2.5	0.0	22.7
Semi-natural woodland (% cover)	0.1	0.8	0.0	9.5
Fruit and dried fruit groves (% cover)	0.2	2.1	0.0	26.6
Waste lands (% cover)	1.7	4.6	0.0	31.8
Pastures (% cover)	6.5	15.8	0.0	99.2
Dry herbaceous cropland (% cover)	40.4	32.8	0.0	100.0
Vineyards (% cover)	33.9	32.2	0.0	100.0

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Table 2. Species richness and the average SPEC index related to conservation concern (in an inverse scale from 1-safe to 4-highly threatened) of the bird fauna inhabiting areas close to (0-400 m) and away (600-1000 m) from forest plantation edges, in winter (A) and in the breeding season (B). Figures are mean ± sd. The regression coefficient and p-value of the effects of distance to plantation edge and plantation area (log-transformed) were obtained using generalized regression models that compare close vs. away (as a dummy variable: 0-close, 1-away) controlling for the effects of land use type (see Methods for more details).

	Close	Away	Distance		Area of plantation	
A. Winter	Mean±sd	Mean±sd	Coeffic.	p-value	Coeffic.	p-value
Species richness	2.76±2.06	3.56±2.25	0.127	0.015	-0.045	0.570
Transformed SPEC index	1.39±0.68	1.48±0.64	0.054	0.337	-0.028	0.694
B. Breeding season						
Species richness	3.20±1.88	3.01±1.87	0.000	0.996	-0.041	0.490
SPEC index (inverse of)	1.86±0.67	1.60±0.72	-0.116	0.037	0.011	0.879

Figure 1. Location of the study area in central Spain within the Ciudad Real province and distribution of the young forest plantations (in black) and transects (grey) on adjacent cropland that were investigated in this study.