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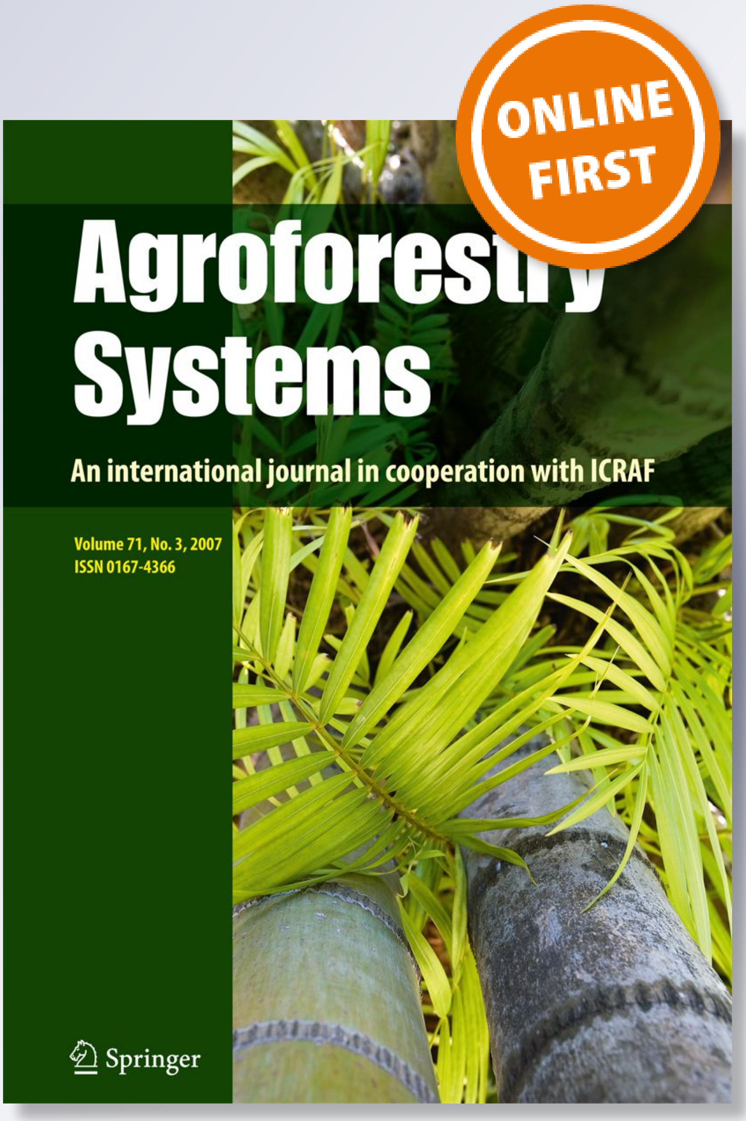


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# Bird species richness in artificial plantations and natural forests in a North African agroforestry system: assessment and implications

S. Hanane · S. I. Cherkaoui · N. Magri · M. Yassin

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**Abstract** Watershed tree plantations in Morocco are expanding under the National Watershed Management Plan and thus their value for native fauna and agroforestry system dynamics requires investigation. Using generalized linear mixed models, we assessed the relative value of artificial habitats—olive and eucalypt plantations—over four seasonal periods, by comparing their avifauna richness to those of natural habitats—Thuya forests. Bird species richness depended on both habitat type and season. Our results showed that natural Thuya forests supported higher bird diversity than both olive and eucalypt plantations. Moreover, bird diversity was higher in eucalyptus plantations compared to olive plantations during the winter period, while the opposite trend was observed in autumn. A principal component analysis also revealed a significant positive effect of shrub layer complexity (PC1) in all seasons, habitat artificiality (PC3) in spring, breeding season, and autumn, and tree size (PC2) during winter and autumn. Overall, our findings stress that, in our study area, artificial plantations do not have the same ecological value as the original habitat. We therefore advise restoring native forests rather than reforesting eucalypt species. Research programs should continue in order to assess the impact of conservation actions on biodiversity and determine how this agroforestry system would change under the increasingly detrimental effects of drought.

**Keywords** Birds · *Tetraclinis articulata* · *Olea europaea* · *Eucalyptus* sp. · Seasonality · Morocco

**Electronic supplementary material** The online version of this article (https://doi.org/10.1007/s10457-018-0281-z) contains supplementary material, which is available to authorized users.

S. Hanane (✉) · N. Magri · M. Yassin
Forest Research Centre, High Commission for Water, Forests and Combating Desertification, Avenue Omar Ibn Al Khattab, BP 763, 10050 Rabat-Agdal, Morocco
e-mail: sdhan333@gmail.com

S. I. Cherkaoui
Université Moulay Ismail, Ecole Supérieure de Technologie de Khénifra, BP 170, 54000 Khénifra, Morocco

## Introduction

Worldwide, forestry and agricultural strategies aim to increase reforestation and agricultural plantations. The overall objectives of these actions are to: (1) decrease rates of deforestation; (2) protect water and soil against erosion; (3) conserve biodiversity; (4) improve wood production and the standard of living of riparian populations; and (5) reduce atmospheric concentrations of carbon dioxide (Potter et al. 2007; Reino et al. 2009). Tree plantations have received special attention in the past decade both in Southern Mediterranean (e.g. Proença et al. 2010; Calviño-Cancela et al. 2012)

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and South America (e.g. Zurita et al. 2006; Jacoboski et al. 2016).

In the Mediterranean Basin, eucalypt (*Eucaplyptus* sp.) (Proença et al. 2010; Calviño-Cancela 2013) and olive (*Olea europaea*) orchards (Muñoz-Cobo 1987; Kristin et al. 1999; Rey 2011) are among the most numerous tree plantations in terms of surface area. Eucalypts are generally used for their timber (mainly for the pulp industry) while olive trees are used for olives and oils. Assessment of the biodiversity value of these plantations was conducted in Europe [e.g. Portugal: Proença et al. (2010); Spain: Calviño-Cancela et al. (2012), Calviño-Cancela (2013); Poland: Myczko et al. (2013)]. However, no such assessment has been carried out in Northern Africa (Morocco, Algeria, Tunisia, Libya, and Egypt).

In Morocco, forest degradation is equivalent to 30,000 hectares annually, which corresponds to 0.3% of the total forest area of the country. The main causes of forest degradation are increased human pressure, soil erosion, and climate change (M'Hirit and Blerot 1999). The Moroccan government has therefore undertaken intensive activities aimed at forest rehabilitation, erosion control, and soil and water conservation. Forest rehabilitation activities include the establishment of large plantations of fast-growing species, such as eucalypts and pines (Khattabi 1999), and fruit orchards, particularly olive trees (World Bank 2012). In Morocco, eucalypt plantations cover 202,356 ha (M'Hirit and Blerot 1999) while olive plantations reached one million hectares in 2016 (MAPM 2017). These two species are chosen because both can (1) withstand a dry climate (Lahrouni et al. 2015), (2) stabilize soil, and (3) provide a major source of revenue for the country (production of wood, pulp, olive fruit and oil, and honey).

Assessing the importance of plantations for biodiversity is essential for management process, planning and decision making. To date, little is known about the importance of fruit and exotic plantations for biodiversity in Morocco. Thus, this study was conducted to (1) evaluate and compare bird species richness in natural forests versus olive and eucalypt plantations, and (2) understand whether the use of these habitats is seasonally-dependent. Understanding spatiotemporal patterns in the use of natural and artificial habitats provides insight into management strategies to enhance habitat quality for birds.

Assessment of bird richness is widely conducted by comparing the number of bird species using a Before-After-Control-Intervention (BACI) approach (Bro et al. 2004; de Lucas et al. 2005; Kleijn et al. 2014). This is a powerful tool for addressing wildlife management problems (Bro et al. 2004) and evaluating the impact of management activities (Geldmann et al. 2013; Conner et al. 2016). In our study, data on bird species richness were not available before the establishment of these plantations. Therefore, we assessed bird richness by comparing the number of bird species between natural and artificial habitats, a useful approach for evaluating the impact of management activities on bird population (Zurita et al. 2006; Paillet et al. 2010; Sweeney et al. 2010; Calviño-Cancela 2013; de la Hera et al. 2013).

Given that (1) several studies in Southern Euro-Mediterranean countries have found lower bird richness in plantations compared to natural forests (Farwig et al. 2008; Proença et al. 2010; Calviño-Cancela 2013; de la Hera et al. 2013), (2) olive orchards are known to be important for many birds both while wintering (areas of concentrations) (Kristin et al. 1999; Rey 1995, 2011) and breeding (nesting support) (Hanane 2014a), and (3) the Central part of Morocco is mostly dry, we hypothesized that natural forests would contain higher bird diversity than olive and eucalypt plantations.

## Materials and methods

### Study area

This study was conducted in a Central Moroccan agroforestry system (15,736 ha) located within the Oued Mellah watershed (33°12′39.4″N; 7°02′88.4″). The area has a semi-arid climate with average annual rainfall of 320 mm, most of which falls during the winter rainy season (November–January). Temperature varies widely, being cooler during winter, with peaks in summer reaching as high as 42 °C. The altitude ranges from 331 to 663 m a.s.l. (Hanane and Yassin 2017).

This agroforestry landscape is mainly composed of three macrohabitats: natural Thuya forests (5599 ha), agricultural lands including olive plantations (2182 ha), and eucalypt plantations (187 ha). In natural forests, the tree layer consists mainly of Thuya

(*Tetraclinis articulata*) in association with wild olive (*Olea europaea oleaster*), Lentisk (*Pistacia lentiscus*) and Tizra tree (*Rhus pentaphylla*) (Hanane and Yassin 2017). Olive plantations, located most often in a cereal platform (ha) dominated by wheat (*Triticum turgidum* and *T. aestivum*) and barley (*Hordeum vulgare*), are mono-specific stands with olive trees almost uniformly separated (5–10 m between trees). They were planted within a Japan International Cooperation Agency (JICA) project for improvement of local peoples' livelihoods by revenue increase and erosion control. In most orchards, the shrub layer is generally absent whereas the herbaceous layer is ephemeral. These plantations, mainly dependent on rainfall, are distributed in very small patches (range = 1–11 ha) throughout the study area.

In the study area, three eucalypt species were planted (*Eucalyptus camaldulensis*, *E. gomphocephala* and *E. torquata*) in accordance with the Oued Mellah watershed management plan to rehabilitate degraded lands previously occupied by Thuya forests. The study area is crossed by three wadis: Laâtech, Laâouija and Zamerine. The Zamerine's waterbed feeds the Tamesna dam. Small single-family homes, with a distance of 1.85–3.53 km between them (Hanane and Yassin 2017), are found in the vicinity of cereal crops and forests. No human habitations exist in the studied forest area (HCEFLCD 2006; Hanane and Yassin 2017).

## Bird surveys

In the three habitat types (natural forests, olive plantations, and eucalypt plantations), bird communities were surveyed using the point count method (Bibby et al. 2000), an effective and efficient means of surveying bird communities (Felton et al. 2011). In each period, eight survey points were randomly distributed within each habitat with a minimum distance of at least 100 m between two points. Points were selected by drawing random points using the QGIS (Quantum GIS Development Team 2017) random selection tool. Surveys were conducted in December (26th to the 28th), March (29th to the 31th), May (23th to the 25th), and September (26th to 28th). These series of counts were conducted to sample peak presence of wintering birds, migrant birds (those using this area as a stopover site during migration), and breeding birds, respectively. All point counts were conducted > 50 m from forest edges to account for variation in species detectability within the edge (Bereczki et al. 2015; Terraube et al. 2016). All point count surveys were conducted by two personnel experienced with bird identification and point count surveys (I.C. and S.H.). Each point was surveyed for 10 min, after a 1 min pause to reduce the impact on bird activity from the surveyors' approach (Bonthoux and Balent 2012). During this period (10 min), we recorded all birds heard and seen at a fixed radius of 50 m (Sweeney et al. 2010; Anjos et al. 2011). All surveys were conducted during early morning and only under favorable meteorological conditions.

## Habitat data

In the three studied habitats, bird surveys and vegetation characteristics were collected within an 11.3 m radius (0.04 ha) circle (Haggerty 1998; D'Amato et al. 2009), centered at each of the eight survey bird points randomly distributed in each habitat. Within each sample plot, eight vegetation variables were measured or estimated: tree cover with visual estimation; average height (m) of the tallest three trees using a clinometer; average diameter (cm) at breast height with a measuring tape (± 0.01 m) of the three tallest trees; shrub cover using the method of Gayton (2003); average shrub height (m) using a 3-m ruler; number of shrub species; herbaceous cover using the method of Gayton (2003); and average height (m) of the herbaceous layer using a clinometer. To avoid observer-related biases in vegetation sampling (Prodon and Lebreton 1981), all vegetation parameter estimations were conducted by the same observer (S.H.).

In addition to these eight vegetation variables, we also recorded the proximity to natural forest, measured as the distance (m) to the closest natural forest edge, and proximity to artificial habitats, measured as the distance (m) to the closest olive plantation and the distance (m) to the closest eucalypt plantation. Distance values are either positive (indicating distances outside the habitat in question) or negative (indicating distances within the habitat in question). QGIS 2.18.14 was used to measure distances.

## Statistical analyses

Prior to statistical analysis, normality and homogeneity of variance of all the variables were assessed.

Variables that did not conform to the requirements for parametric tests were log-transformed or square root-transformed to meet the assumptions of the analysis.

Given that the 11 vegetation variables were inter-correlated, we performed a principal component analysis (PCA). For each PCA, a varimax normalized rotation was applied to the set of principal components with eigenvalues > 1.0, to obtain simpler and more interpretable gradients (Legendre and Legendre 1998). We interpreted the biological meaning of the principal components, which explain the greatest amount of combined variation within the habitat structure data, by examining the component loadings of each variable (McGarigal et al. 2000).

We investigated bird species richness as a function of habitat type (three classes), season (four classes: winter, spring migration, breeding, autumn migration), and PCA score (continuous variable) using a generalized linear mixed model (GLMM) with a Poisson error distribution and log link function. Sampling plot was included as a random factor in the model to account for the paired nature of the data.

One of the assumptions of parametric statistics is that observations are independent of each other. This assumption is often violated with spatial data, so it is important to test for and, where present, subsequently address spatial autocorrelation. Spatial autocorrelation of bird species richness was therefore assessed with a semivariogram (Goovaerts 1998) using residuals of the best model in terms of AICc value. Nugget to total sill ratio (NSR) was expressed as the percentage of total semivariance and was used to define for spatial dependency: $NSR < 0.25$ indicated strong spatial dependence, $0.25 < NSR < 0.75$ indicated moderate spatial dependence, and $NSR > 0.75$ indicated weak spatial dependence (Cambardella et al. 1994). When spatial autocorrelation was encountered, we used spatial generalized linear mixed models, fitted via penalized quasi likelihood (glmmPQL), with a Poisson error. glmmPQL enables the building of spatial models with dependent data not normally distributed and is among the best techniques for these kinds of data (Dormann 2007). We adopted an exponential spatial correlation structure, although tests with Gaussian and spherical structures produced the same results.

All statistical analyses were performed in R-3.0.2 software (R Development Core Team 2013). We used the package "lme4" for fitting generalized linear mixed models (Bates et al. 2014). The packages "sp" (Pebesma and Bivand 2005), "lattice" (Sarkar 2015) and "gstat" (Pebesma 2006) were used to draw semivariograms, and the package "MASS" was used to fit glmmPQL models (Venables and Ripley 2002). Differences in bird species richness across habitats were examined with Tukey post hoc comparisons using the 'glht' function in the 'multcomp' package (Bretz et al. 2016).

## Results

A total of 72 bird species were recorded in the three studied habitats (see Appendix A in Supplemental Material), with a maximum of 22 species recorded in natural forests and a minimum of 0 species in eucalypt plantations. Among these species, just one, the turtle dove (*Streptopelia turtur*), is classified as "Vulnerable" according the IUCN Red List of Threatened Species (BirdLife International 2015).

The PCA summarized the studied habitat variables into three independent axes which accounted for 78.64% of the variance of the original dataset. The first gradient (PC1) represented an axis of increasing shrub layer complexity (Table 1). This axis is at the same time negatively correlated with tree and herbaceous layer cover. The second gradient (PC2) was characterized by high loadings of variables related to tree size (Table 1). The third gradient (PC3) represented an axis of habitat artificiality (Table 1), as it was positively correlated with the distance to the nearest olive and eucalypt plantations and negatively correlated with distance to natural forest habitat (Table 1). The Kaiser–Meyer–Olkin measure of sampling adequacy (KMO) indicated that our data were suitable for the PCA (PCA: KMO = 0.777; Bartlett-test for sphericity, $\chi^2 = 964.33$, $P = 0.0000$).

In this agroforestry system, the effect of habitat on bird species richness varied with season (interaction effect: habitat type × season) (Table 2). The ratio of the nugget to the sill showed a spatial pattern in the data (Table 2). When we explicitly considered spatial autocorrelation in the modeling through the glmmPQL models, the same pattern of difference between the three habitats was observed (Table 2).

In all four seasons, the natural Thuya forest was the most attractive habitat, hosting the highest number of bird species (Table 2; Fig. 1). During spring migration

**Table 1** Results of the PCA to summarize original habitat variables (n = 96)

| Original variables | Eigen vectors | | |
|---|---|---|---|
| | PC1 | PC2 | PC3 |
| Shrub richness | **0.809** | 0.147 | 0.350 |
| Shrub cover (%) | **0.938** | − 0.120 | 0.208 |
| Shrub height | **0.867** | 0.127 | 0.310 |
| Diameter at breast height | − 0.024 | **0.767** | 0.372 |
| Tree height | − 0.183 | **0.822** | 0.234 |
| Herbaceous layer height | − 0.359 | − **0.711** | 0.195 |
| Tree cover (%) | − **0.814** | 0.473 | − 0.042 |
| Herbaceous layer cover (%) | − **0.744** | − 0.501 | 0.041 |
| Distance to the nearest natural habitat | − 0.140 | − 0.121 | − **0.818** |
| Distance to the nearest olive plantation | 0.263 | 0.114 | **0.595** |
| Distance to the nearest eucalyptus plantation | 0.101 | 0.124 | **0.781** |
| Eigenvalue | 3.817 | 2.325 | 1.722 |
| Explained variance (%) | 38.168 | 23.251 | 17.219 |
| Cumulative explained variance (%) | 38.168 | 61.418 | 78.637 |

**Table 2** Results of non-spatial and spatial GLMMs analyses of the number of bird species according to habitat types (natural forests, eucalypt and olive plantations) and seasons (winter, spring, breeding and autumn)

| | Non-spatial model (GLMM) | | | Spatial model (glmmPQL) | | |
|---|---|---|---|---|---|---|
| | $\chi^2$ | *df* | *P* | $\chi^2$ | *df* | *P* |
| Intercept | 52.411 | 1 | < 0.0001 | 82.476 | 1 | < 0.0001 |
| Habitat type | 13.392 | 2 | 0.0012 | 22.815 | 2 | < 0.0001 |
| Season | 7.905 | 3 | 0.0480 | 12.320 | 3 | 0.0063 |
| Habitat:season | 22.993 | 6 | 0.0008 | 42.791 | 6 | < 0.0001 |

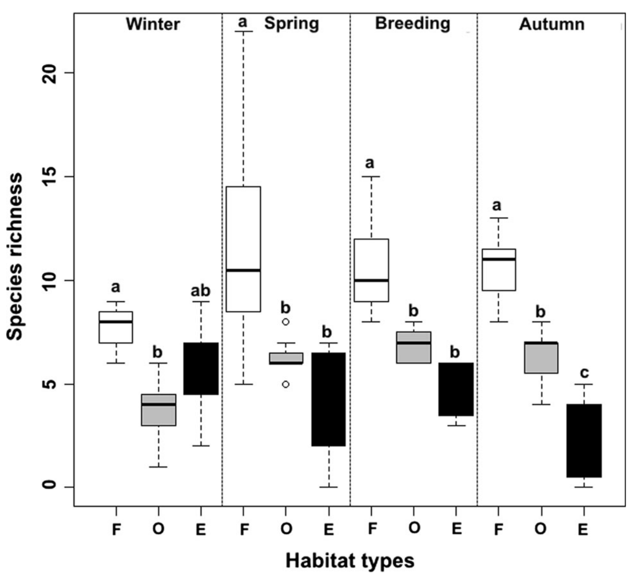


**Fig. 1** Boxplots representing seasonal species richness (number per plot) according to the habitat type (F = Natural Forests; O = Olive orchards; E = Eucalypt plantations). Each box shows the upper and lower quartile, the central bar represents the median (midpoint), while the whiskers show the minimum and maximum for each category. Different letters indicate significant differences at $P < 0.05$ in the number of bird species by the Tukey's post hoc test between the habitat types

and the breeding period, no significant difference in bird species richness was found between olive and eucalypt plantations (Fig. 1). However, this occupancy pattern changed during fall migration due to a significant decrease in the number of species in eucalypt plantations compared to olive plantations (Fig. 1). In winter, olive plantations hosted significantly lower bird richness than natural forests and eucalypt plantations (Fig. 1).

Because the interaction between the habitat type and season was statistically significant, we conducted models with PC1, PC2 and PC3 for each season separately. GLMM analyses revealed that PC1 (shrub layer complexity) was the sole predictor of species richness, with a significant effect in all seasons (Table 3). PC3 (habitat artificiality) significantly affected bird richness in spring, breeding season, and autumn (Table 3), whereas PC2 (tree size) had a significant effect during winter and autumn (Table 3). Overall, species richness increased with increasing PC1, PC2 and PC3 (Table 3).

Semivariograms, using residuals of the best model, indicated spatial autocorrelation during the breeding and winter periods (Table 3). When spatial autocorrelation was explicitly considered in the models using glmmPQL, the effect of PC2 (tree size) was found during winter (Table 3). The effects of PC1 (shrub layer complexity) and PC3 (habitat artificiality) were greatest during the breeding period (Table 3).

## Discussion

The aim of this study was to evaluate and compare bird species richness in natural forests and artificial tree plantations. Our research presents the first detailed data on the importance of human-managed habitats for birds in North Africa.

Our results revealed that the mean number of bird species depended on habitat type (natural versus planted) and season (winter versus spring/autumn-migration versus breeding). We demonstrated that natural forests have significantly higher bird species richness than artificial human-managed habitats. This finding agrees with other studies conducted in southern Europe (Proença et al. 2010; Calviño-Cancela 2013; de la Hera et al. 2013) and South America (Marsden et al. 2001; Zurita et al. 2006; Jacoboski

**Table 3** Parameters and standard errors (SE) of non-spatial (GLMM) and spatial (glmmPQL) models of bird richness in the four seasons as functions of PC1, PC2 and PC3

| Season | NSR | | Non-spatial model (GLMM) | | | Spatial model (glmmPQL) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Estimate ± SE | *z* value | *P* | Estimate ± SE | *t* value | *P* |
| Winter | 0.09 | Intercept | 1.80 ± 0.07 | 24.55 | 0.0001 | 1.80 ± 0.04 | 40.49 | 0.0000 |
| | | PC1 | 0.33 ± 0.09 | 3.72 | 0.0002* | 0.33 ± 0.05 | 6.14 | 0.0000* |
| | | PC2 | 0.17 ± 0.13 | 1.32 | 0.1869 | 0.17 ± 0.08 | 2.18 | 0.0411* |
| | | PC3 | 0.07 ± 0.08 | 0.85 | 0.3980 | 0.07 ± 0.05 | 1.39 | 0.1779 |
| Spring | 1.00 | Intercept | 2.03 ± 0.07 | 27.89 | < 0.0001* | – | – | – |
| | | PC1 | 0.33 ± 0.06 | 5.37 | < 0.0001* | – | – | – |
| | | PC2 | − 0.02 ± 0.05 | − 0.45 | 0.6510 | – | – | – |
| | | PC3 | 0.28 ± 0.07 | 3.99 | < 0.0001* | – | – | – |
| Breeding | 0.10 | Intercept | 2.10 ± 0.07 | 31.80 | < 0.0001* | 2.10 ± 0.05 | 45.31 | 0.0000* |
| | | PC1 | 0.19 ± 0.07 | 2.95 | 0.0032* | 0.19 ± 0.05 | 4.20 | 0.0004* |
| | | PC2 | − 0.12 ± 0.08 | − 1.45 | 0.1476 | 0.12 ± 0.06 | 2.06 | 0.0516 |
| | | PC3 | 0.20 ± 0.07 | 3.04 | 0.0024* | 0.20 ± 0.05 | 4.33 | 0.0003* |
| Autumn | 1.00 | Intercept | 1.99 ± 0.07 | 28.43 | < 0.0001* | – | – | – |
| | | PC1 | 0.26 ± 0.07 | 3.85 | 0.0001* | – | – | – |
| | | PC2 | 0.24 ± 0.09 | 2.70 | 0.0069* | – | – | – |
| | | PC3 | 0.31 ± 0.07 | 4.23 | < 0.0001* | – | – | – |

*NSR* nugget to sill ratio

et al. 2016). In this semi-arid area, the attractiveness of natural forests for birds is associated with the level of shrub layer complexity, which is significantly higher in natural forests than in human-managed habitats. Indeed, increased vegetation structure complexity has been shown to enrich associated bird communities (Laiolo 2002; Machtans and Latour 2003; Diaz 2006; Cherkaoui et al. 2009).

The use of habitat type in our study depended on season. During the spring migration and breeding period, olive and eucalypt plantations exhibited lower bird richness than natural forests. This is not surprising, as eucalypt plantations are generally known to support a reduced number of bird species (John and Kabigumila 2011; Calviño-Cancela 2013; Calviño-Cancela and Neumann 2015; Fontúrbel et al. 2016; Jacoboski et al. 2016). Our results found a positive effect of shrub layer complexity on bird richness in all seasons. Complex vegetation provides better opportunities for resting and refueling (Rguibi-Idrissi et al. 2007; Gargallo et al. 2011; Hama et al. 2013). The low cover (sometimes even a complete absence) of shrubs in plantation compared to natural Thuya forests may therefore explain the low bird species richness in both plantations. Several authors have reported the loss of suitable habitats for many species in such conditions (Zurita et al. 2006; Calviño-Cancela 2013; Jacoboski et al. 2016).

During the spring and breeding period, olive and eucalypt plantations provide breeding habitats complementary to natural forests. Indeed, although young, olive plantations can serve as breeding habitat (Kristin et al. 1999). We observed several breeding species within olive plantations [e.g. turtle dove, common blackbird (*Turdus merula*), woodchat shrike (*Lanius senator*), chaffinch (*Fringilla coelebs Africana*), common greenfinch (*Chloris chloris*), European goldfinch (*Carduelis carduelis*), and common linnet (*Linaria cannabina*)]. The use of olive orchards by turtle doves, a vulnerable species (BirdLife International 2015), has been widely documented in the Mediterranean Basin (Peiro 1990; Hanane and Baamal 2011; Hanane 2015, 2016, 2017). In the eucalypt plantations, the most common breeding bird was unequivocally the woodpigeon (*Columba palumbus*), which mainly used tall trees (Hanane 2013, 2014b).

During winter, lower numbers of species were observed in the olive plantations (compared to natural forests and eucalypt plantations). Natural forests and eucalypt plantation are generally denser and less open than olive groves and thus may be used as shelters by wintering birds during windy and stormy weather, contributing to the higher bird richness observed in these two habitats compared to olive groves, as reported by Herbers et al. (2004). Furthermore, at this time of year, olive plantations lack an herbaceous layer. Plowing activity and application of herbicides conducted in winter causes reduction of understory plant diversity, as reported, in Spain, by Rey (2011). In addition, in this semi-arid area, the young age of olive trees, combined with drought stress, does not allow these orchards to produce enough olives (due to water deficit during the initial development of the fruit), making them less attractive to frugivorous birds.

In addition to the spring and breeding periods, statistical analysis also showed the importance of artificial plantations for birds during fall migration. The flowering of the three eucalypt species present in the study area occurs from October (autumn) to January (winter). The presence of flowers, known to be the main food resource for birds in eucalypt canopies (Tellería and Galarza 1990; Calviño-Cancela 2013), may therefore increase use of this habitat by birds during autumn. Furthermore, emerging flowers also attract insects, thus increasing visits by insectivorous birds. The attractiveness of eucalypt plantations for birds has been demonstrated in southern Europe (Calviño-Cancela 2013; Calviño-Cancela and Neumann 2015). Although olive plantations contained fewer bird species than natural forests overall, during autumn, more species were observed in olive plantations than in eucalypt plantations. It is likely that the presence of olives during this period makes this habitat more attractive than eucalypts, at least for frugivores (Smith et al. 2007). The importance of olive fruits for frugivorous birds in North-West Africa has been previously reported (Rey et al. 1997; Rey 2011). Furthermore, the herbaceous layer of eucalypt plantations would have dried as a result of the summer drought, perhaps making eucalypt plantations less attractive for birds during autumn, compared to olive plantations.

## Conclusions, recommendations and perspectives

Our findings stress that artificial plantations in Central Morocco support fewer bird species than natural forests. For this reason, we recommend, to the extent possible, the restoration of native forests rather managing eucalypt plantations for bird richness.

Furthermore, although olive plantations contain lower bird species richness than natural forests, they remain nonetheless fairly attractive for birds. Agricultural landscapes are known to maintain some of the structural and functional (plant–animal interactions) properties of the natural habitats to which animals are adapted (Rey 2011). Olive plantations could play an even more important role as they grow older, but this depends on the maintenance of good conditions. Increasing the size of trees (DBH, canopy cover, and height) would provide better opportunities for resting, refueling and breeding (in the case of the vulnerable turtle dove). To quickly reach this objective, we encourage managers to establish an irrigation system (i.e. a dam close to the study area), which would have a twofold advantage:

1. Helping owners increase olive productivity, which can increase olive plantations areas.
2. Improving habitat quality by increasing structural complexity and fruit production (Foster 2007; Myczko et al. 2013) to support more bird species.

At the landscape level, olive hedges should be encouraged. The establishment of hedgerows, especially between cereal crops, would have the direct consequence of avoiding the harmful effect of plowing activities during the winter period. Unmown herbs provide food resources for granivorous and insectivorous birds (Myczko et al. 2013). In Central Morocco (Tadla region), planting hedges of olive trees, since the 1930s, has provided positive results for both olive productivity and biodiversity (Hanane 2014a).

Finally, research programs should be continued in order to assess the impact of conservation actions on biodiversity as well as determine how this agroforestry system would be affected by the increasingly detrimental effects of drought that are projected by climate change scenarios in this region (Tramblay et al. 2012).

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## References

Anjos L, Collins DC, Holt RD, Volpato GH, Mendonça LB, Lopes EV, Boçon R, Bisheimer MV, Serafini PP, Carvalho J (2011) Bird species abundance—occupancy patterns and sensitivity to forest fragmentation: implications for conservation in the Brazilian Atlantic forest. Biol Conserv 144:2213–2222

Bates D, Maechler M, Bolker B, Walker S (2014) lme4: linear mixed-effects models using Eigen and S4. R package version 1.1-7. Retrieved 20 September 2017 from http://cran.r-project.org/package=lme4

Bereczki K, Hajdu K, Báldi A (2015) Effects of forest edge on pest control service provided by birds in fragmented temperate forests. Acta Zool Hung 61:289–304

Bibby CJ, Burgess ND, Hill DA, Mustoe SH (2000) Bird census techniques, 2nd edn. Academic Press, New York

BirdLife International (2015) Streptopelia turtur. The IUCN red list for birds. http://www.birdlife.org/. Accessed 20 July 2017

Bonthoux S, Balent G (2012) Point count duration: five minutes are usually sufficient to model the distribution of bird species and to study the structure of communities for a French landscape. J Ornithol 153:491–504

Bretz F, Hothorn T, Westfall P (2016) Multiple comparisons using R. CRC Press, Boca Raton

Bro E, Mayot P, Corda E, Reitz F (2004) Impact of habitat management on grey partridge populations: assessing wildlife cover using a multisite BACI experiment. J Appl Ecol 41:846–857

Calviño-Cancela M (2013) Effectiveness of eucalypt plantations as a surrogate habitat for birds. For Ecol Manag 310:692–699

Calviño-Cancela M, Neumann M (2015) Ecological integration of eucalypts in Europe: interactions with flower-visiting birds. For Ecol Manag 358:174–179

Calviño-Cancela M, Rubido-Bará M, Van Etten EJB (2012) Do eucalypt plantations provide habitat for native forest biodiversity? For Ecol Manag 270:153–162

Cambardella CA, Moorman TV, Novak JM, Parkin TB, Karlen DL, Turco RF, Konopka AE (1994) Field-scale variability of soil properties in Central Iowa soils. Soil Sci Soc Am J 58:1501–1511

Cherkaoui I, Selmi S, Boukhriss J, Hamid R-I, Dakki M (2009) Factors affecting bird richness in a fragmented cork oak forest in Morocco. Acta Oecol 35:197–205

Conner MM, Saunders WC, Bouwes N, Jordan C (2016) Evaluating impacts using a BACI design, ratios, and a Bayesian approach with a focus on restoration. Environ Monit Assess 188:555

D'Amato AW, Orwig DA, Foster DR (2009) Understory vegetation in old-growth and second-growth *Tsuga canadensis* forests in western Massachusetts. For Ecol Manag 257:1043–1052 de la Hera I, Arizaga J, Galarza A (2013) Exotic tree plantations and avian conservation in northern Iberia: a view from a nest-box monitoring study. Anim Biodivers Conserv 36:153–163

de Lucas M, Janss GFE, Ferrer M (2005) A bird and small mammal BACI and IG design studies in a wind farm in Malpica (Spain). Biodivers Conserv 14(13):3289–3303

Diaz L (2006) Influences of forest type and forest structure on bird communities in oak and pine woodlands in Spain. For Ecol Manag 223:54–65

Dormann CF (2007) Effects of incorporating spatial autocorrelation into the analysis of species distribution data. Glob Ecol Biogeogr 16:129–138

Farwig N, Sajita N, Böhning-Gaese K (2008) Conservation value of forest plantations for bird communities in western Kenya. For Ecol Manag 255(11):3885–3892

Felton A, Andersson E, Ventorp D, Lindbladh M (2011) A comparison of avian diversity in spruce monocultures and spruce-birch polycultures in Southern Sweden. Silva Fenn 45:1143–1150

Fontúrbel FE, Candia AB, Gabriel B, Castano-Villa J (2016) Are abandoned eucalyptus plantations avifauna-friendly? A case study in the Valdivian rainforest. Rev Mex Biodivers 87:1402–1406

Foster MS (2007) The potential of fruit trees to enhance converted habitats for migrating birds in southern Mexico. Bird Conserv Int 17:45–61

Gargallo G, Barriocanal C, Castany J, Clarabuch O, Escandell R, Lopezlborra G, Rguibi-idriss H, Robson D, Suarez M (2011). Spring migration in the western Mediterranean and NW Africa the Piccole Isole project. Monografies Del Museu de Ciencies Naturals-Barcelona 6: 17–279, 281–359, 363

Gayton DV (2003) British Columbia grasslands: monitoring vegetation change. FORREX Series 7. FORREX—Forest Research Extension Partnership, Kamloops

Geldmann J, Barnes M, Coad L, Craigie ID, Hockings M, Burgess ND (2013) Effectiveness of terrestrial protected areas in reducing habitat loss and population declines. Biol Cons 161:230–238

Goovaerts P (1998) Geostatistical tools for characterizing the spatial variability of microbiological and physicochemical soil properties. Biol Fert Soils 27:315–334

Haggerty TM (1998) Vegetation structure of Bachman's sparrow breeding habitat and its relationship to home range. J Field Ornithol 69(1):45–50

Hama F, Gargallo G, Benhoussa A, Zerdouk S, Rguibi Idrissi H (2013) Autumn body condition of Palaearctic trans-Saharan migrant passerines at an oasis in southeast Morocco. Ringing Migr 28(2):77–84

Hanane S (2013) Importance des reboisements en pins pour les oiseaux forestiers nicheurs: cas du Pigeon ramier dans une plantation de pin d'Alep au Moyen-Atlas Central, Maroc. Forêt Méditerranéenne XXXIV 3:209–214

Hanane S (2014a) Les périmètres irrigués du Maroc: une aubaine pour deux espèces d'oiseaux migrateurs, la Tourterelle des bois (*Streptopelia turtur*) et la Caille des blés (*Coturnix coturnix*). Rev Ecol-Terre Vie 69(3–4):225–233

Hanane S (2014b) Effects of human disturbance on nest placement of the Woodpigeon (*Columba palumbus*): a case study from the Middle Atlas, Morocco. Integr Zool 9:349–359

Hanane S (2015) Nest-niche differentiation in two sympatric *Streptopelia* species from a North African agricultural area: the role of human presence. Ecol Res 30(4):573–580

Hanane S (2016) Effects of orchard type and breeding period on Turtle Dove nest density in irrigated agroecosystems. Bird Study 63:141–145

Hanane S (2017) The European Turtle-Dove *Streptopelia turtur* in Northwest Africa: a review of current knowledge and priorities for future research. Ardeola 64(2):273–287

Hanane S, Baamal L (2011) Are Moroccan fruit orchards suitable breeding habitats for Turtle Doves *Streptopelia turtur*? Bird Study 58:57–67

Hanane S, Yassin M (2017) Nest-niche differentiation in two sympatric columbid species from a Mediterranean *Tetraclinis* woodland: considerations for forest management. Acta Oecol 78:47–52

Haut-Commissariat aux Eaux et Forêts et à la Lutte Contre la Désertification (HCEFLCD) (2006) SAPROF for Watershed Management Project in the Kingdom of Morocco. Final report. Japan Bank for International Cooperation, p 385

Herbers JR, Serrouya R, Maxcy KA (2004) Effects of elevation and forest cover on winter birds in mature forest ecosystems of southern British Columbia. Can J Zool 82(11):1720–1730

Jacoboski LI, Mendonça-Lima A, Hartz SM (2016) Structure of birds communities in eucalyptus plantations: nestedness as a pattern on species distribution. Br J Biol 76:583–591

John JRM, Kabigumila JDL (2011) The use of bird species richness and abundance indices to assess the conservation value of exotic Eucalyptus plantations. Ostrich 82:27–37

Khattabi A (1999) Socio-economic importance of eucalyptus plantations in Morocco. Global concerns for forest resource utilization. Springer, Berlin, pp 73–82

Kleijn D, Cherkaoui I, Goedhart PW, van der Hout J, Lammersma D (2014) Waterbirds increase more rapidly in Ramsar-designated wetlands than in unprotected wetlands. J Appl Ecol 51:289–298

Kristin A, Valera F, Hoi H, Hoi C (1999) Foraging assemblages of birds in different olive plantations during the second half of March. Folia Oecol 26:231–237

Lahrouni M, El Abbassi A, El Messoussi S (2015) Olive tree growth dynamics under semi-arid conditions of AlHaouz region in Morocco. J Mater Environ Sci 6(9):2428–2436

Laiolo P (2002) Effects of habitat structure, floral composition and diversity on a forest bird community in north-western Italy. Folia Zool 51:121–128

Legendre P, Legendre L (1998) Numerical ecology. Elsevier Science, Amsterdam

M'Hirit O, Blerot P (1999) The great book of Moroccan forests (Le grand livre de la forêt marocaine). Editions Mardaga, Brussels **(in French)**

Machtans CS, Latour PB (2003) Boreal forest songbird communities of the Liard Valley, Northwest Territories, Canada. Condor 105:27–44

Marsden SJ, Whiffin M, Galetti M (2001) Bird diversity and abundance in forest fragments and Eucalyptus plantations around an Atlantic forest reserve, Brazil. Biodivers Conserv 10(5):737–751

McGarigal K, Cushman SA, Stafford S (2000) Multivariate statistics for wildlife and ecology research. Springer, New York

Ministère de l'Agriculture et des pêches Maritimes (MAPM) (2017) L'Agriculture en chiffres. Maroc, p. 29

Muñoz-Cobo J (1987) Las comunidades de aves de los olivares de Jaén. Ph.D. thesis, Universidad Complutense, Madrid

Myczko Ł, Rosin ZM, Skorka P, Wylegała P, Tobolka M, Fliszkiewicz M, Tryjanowski P (2013) Effects of management intensity and orchard features on bird communities in winter. Ecol Res 28(3):503–512

Paillet Y, Bergès L, Hjältén J, Odor P, Avon C, Bernhardt-Römermann M, Bijlsma RJ, De Bruyn L, Fuhr M, Grandin U, Kanka R, Lundin L, Luque S, Magura T, Matesanz S, Mészáros I, Sebastià MT, Schmidt W, Standovár T, Tóthmérész B, Uotila A, Valladares F, Vellak K, Virtanen R (2010) Biodiversity differences between managed and unmanaged forests: meta-analysis of species richness in Europe. Conserv Biol 24:101–112

Pebesma EJ (2006) The gstat package. www.gstat.org. Accessed 9 Sep 2017

Pebesma EJ, Bivand RS (2005) Classes and methods for spatial data in R. R News 5(2):9–13

Peiro V (1990) Aspectos de la reproduccion de la Tortola comun (*Streptopelia turtur*) en Madrid. Med Ser Biol 12:89–96

Potter C, Klooster S, Hiatt S, Fladeland M, Genovese V, Gross V (2007) Satellite-derived estimates of potential carbon sequestration through afforestation of agricultural lands in the United States. Clim Change 80:323–336

Prodon R, Lebreton J-D (1981) Breeding avifauna of a Mediterranean succession: the holm oak and cork oak series in the eastern Pyrenees. 1. Analysis and modelling of the structure gradient. Oikos 37:21–38

Proença VM, Pereira HM, Guilherme J, Vicente L (2010) Plant and bird diversity in natural forests and in native and exotic plantations in NW Portugal. Acta Oecol 36:219–226

Quantum GIS Development Team (2017) QGIS Geographic Information System, Version 2.18.14-Las Palmas. Open Source Geospatial Foundation, Chicago

R Development Core Team (2013) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. ISBN 3-900051-07-0. http://www.R-project.org. Accessed 17 Aug

Reino L, Beja P, Osborne PE, Morgado R, Fabião A, Rotenberry JT (2009) Distance to edges, edge contrast and landscape fragmentation: interactions affecting farmland birds around forest plantations. Biol Conserv 142(4):824–838

Rey PJ (1995) Spatio-temporal variation in fruit and frugivorous birds abundance in olive plantations. Ecology 76:1625–1635

Rey PJ (2011) Preserving frugivorous birds in agro-ecosystems: lessons from Spanish olive orchards. J Appl Ecol 48:228–237

Rey PJ, Gutierrez JE, Alcintara J, Valera F (1997) Fruit size in wild olives: implications for avian seed dispersal. Funct Ecol 11:611–616

Rguibi-Idrissi H, Dakki M, Barlein F (2007) Migration et hivernage de quelques passereaux au Maroc: Mise au point à partir des données de baguage-reprise. Ostrich 78(2):343–349

Sarkar D (2015). Lattice: trellis graphics for R. https://cran.r-project.org/package=lattice. Accessed 9 Sep 2017

Smith SB, McPherson KH, Backer JM, Pierce BJ, Podlesak DW, McWilliams SR (2007) Fruit quality and consumption by songbirds during autumn migration. Wilson J Ornithol 119(3):419–428

Sweeney O, Wilson M, Irwin S, Kelly T, O'Halloran J (2010) Are bird density, species richness and community structure similar between native woodlands and non-native plantations in an area with a generalist bird fauna? Biodivers Conserv 19:2329–2342

Tellería JL, Galarza A (1990) Avifauna y paisaje en el Norte de España: efecto de las repoblaciones con árboles exóticos. Ardeola 37:229–245

Terraube J, Archaux F, Deconchat M, Halder I, Jactel H, Barbaro L (2016) Forest edges have high conservation value for bird communities in mosaic landscapes. Ecol Evol 6(15):5178–5189

Tramblay Y, Badi W, Driouech F, El Adlouni S, Neppel L, Servat E (2012) Climate change impacts on extreme precipitation in Morocco. Glob Planet Change 82–83:104–114

Venables WN, Ripley BD (2002) Modern applied statistics with S, 4th edn. Springer, New York

World Bank (2012). Maroc—Plan Maroc vert: Projet Pilier II "Agriculture solidaire et intégrée au Maroc". Washington: World Bank. http://documents.worldbank.org/curated/en/115561468279278623/Maroc-Plan-Maroc-vert-Projet-Pilier-II-Agriculture-solidaire-et-intégrée-au-Maroc

Zurita GA, Rey N, Varela DM, Villagra M, Bellocq MI (2006) Conversion of the Atlantic forest into native and exotic tree plantations: effects on bird communities from the local and regional perspectives. For Ecol Manag 235:164–173. https://doi.org/10.1016/j.foreco.2006.08.009