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**RIHO MARJA**

# The relationships between farmland birds, land use and landscape structure in Northern Europe

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# The relationships between farmland birds, land use and landscape structure in Northern Europe

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*In memory of Urmas Kokassaar*

# CONTENTS

# ABSTRACT

Farmland landscape structure and land use changes during the last century have had a dramatic influence on farmland biodiversity in Europe. Landscape structure has changed from being heterogeneous to more homogeneous. At the same time, farmland land use intensity has increased. All of this has had a negative influence on farmland biodiversity.

The current thesis examines the relationships between farmland birds and landscape structure and land use in Northern Europe (the Baltic countries, Finland and North Western Russia). The first part of the thesis (Papers I and II) gives an overview of the relationships between farmland birds and landscape structure via landscape metrics. The predictive, landscape metric-based models were created to examine how the size of the research area influences the relationship between bird diversity and landscape structure. Three landscape metrics (Patch Density, Edge Density and Shannon's Diversity Index) were calculated at three spatial scales: in 100- and 200-metre buffer zones around the count points and in a 1 km$^2$ square at 1 m × 1 m grain size. In most cases we found that the proportion of variance explained between the bird variables and landscape metrics increased as the study area increased, thus clearly demonstrating the effect of scale. Therefore a larger research area is recommended for landscape metrics. At larger scales, as assumed, all used landscape metrics were equally good predictors for bird species richness.

The second part of the thesis (Papers III and IV) concentrates on very common landscape elements in Northern Europe – drainage ditches, specifically on their effect on the diversity and temporal dynamics of farmland birds. Initially the aim was to quantify a relative value of ditches for farmland birds depending on the type of the surrounding fields. Count plots were situated within either arable fields or grasslands, or combinations thereof, and contained two types of ditches, with only grassy margins or with high vegetation such as bushes and trees. The results established that species richness and the abundance of farmland birds are positively related to the presence of ditches with high vegetation, but the plausible role of ditches with only grassy margins remained unclear. For some species, the relationship was more pronounced in arable land than in grassland.

In addition, the population dynamics of two typical open farmland bird species, Skylark (*Alauda arvensis*) and Meadow Pipit (*Anthus pratensis*), were investigated on fields with open in-field and subsurface drainage systems. The results provided evidence that both species' trends were significantly positive on open drainage fields, while trends on subsurface drainage fields were not significantly directional. This strongly suggests that the foraging resources and nest survival of individuals breeding in open drainage field habitats are more extensive than those of subsurface drainage fields.

The third part of the thesis (Paper V) indicates the importance of mixed land use and sheds light on the temporal dynamics and intra-seasonal variations of farmland birds. Pastures, abandoned grasslands, abandoned cereal fields and

multispecies grasslands exhibited a particularly high habitat value for most farmland birds. Species richness figures generally declined on all fields by the end of July, but on arable crops the number of species had already halved by early June. The number of individuals steadily declined on abandoned fields and heavily fluctuated on arable fields, and the mean values over the season were similar among field types. There were also species-specific differences in the most abundant species. For instance, Skylark numbers were fairly stable on all fields other than abandoned fields, on which they progressively declined starting in June. Meadow Pipits were most numerous on arable fields at the spring arrival and during the last counts in July. The latter increase appears to coincide with the decline on grass field-types. The numbers of Starling (*Sturnus vulgaris*) increase on pastures and grasslands as the season progresses. The results provided strong support for diversity in agricultural land use over the landscape as a prerequisite for rich avifauna. This is due not only to the species-specific habitat selection by breeding birds but also to intra-seasonal variation in field utilisation for both breeding and non-breeding purposes.

The regional agricultural policy should support mixed land use and the conservation of landscape elements, especially the retention of ditches in farmland and particularly those with a complex structure and in landscapes dominated by crop production, as they face the heaviest pressure of intensified production. The retention of the remaining landscape elements as part of agri-environmental and relevant land use policies could contribute to the stabilisation and enhancement of populations of farmland birds in Europe.

# LIST OF ORIGINAL PUBLICATIONS

I Uuemaa, E., Mander, Ü., Marja, R. 2013. Trends in the use of landscape spatial metrics as landscape indicators: A review. Ecological Indicators 28: 100–106.

II Marja, R., Uuemaa, E., Mander, Ü., Elts, J., Truu, J. 2013a. Landscape pattern and census area as determinants of the diversity of farmland avifauna in Estonia. Regional Environmental Change 13: 1013–1020.

III Marja, R., Herzon, I. 2012. The importance of drainage ditches for farmland birds in agricultural landscapes in the Baltic countries: does field type matter? Ornis Fennica 89: 170–181.

IV Marja, R., Herzon, I., Rintala, J., Tiainen, J., Seimola, T. 2013b. Type of agricultural drainage modifies the value of fields for farmland birds. Agriculture, Ecosystems and Environment 165: 184–189.

V Herzon, I., Marja, R., Menshikova, S., Kondratyev, A. 201X. Farmland bird communities in an agricultural landscape in Northwest Russia: seasonal and spatial patterns. Agriculture, Ecosystems and Environment (In press).

The author's contribution to the above-mentioned papers is as follows:

| | I | II | III | IV | V |
|---|---|---|---|---|---|
| Idea | EU, ÜM | RM | RM | IH | AK, IH, RM |
| Data collection | EU, ÜM | RM, JE | RM, IH, JE | JTi, TS | IH, SM, AK |
| Methodological design | EU, ÜM | RM | RM, IH | RM, IH, JR, JTi | AK , SM, IH, RM |
| Analysing the results | EU, ÜM, RM | RM | RM | RM | RM |
| Manuscript preparation | EU, ÜM, RM | RM, EU, ÜM, JE, JTr | RM, IH | RM, IH, JR, JTi | IH, RM, AK, SM |

RM (Riho Marja), IH (Irina Herzon), ÜM (Ülo Mander), EU (Evelyn Uuemaa), JE (Jaanus Elts), JTr (Jaak Truu), JR (Jukka Rintala), JTi (Juha Tiainen), SM (Svetlana Menshikova), AK (Alexander Kondratyev), TS (Tuomas Seimola).

# 1. INTRODUCTION

In landscape ecology, the principle of "Landscape Structure and Function" (see Forman and Godron, 1986) states that an individual landscape element at the scale of landscape can be recognized as a patch, a narrow corridor or a background matrix. All landscape elements have a size, shape, type and configuration. Plants, mushrooms, insects, birds, animals etc. and also energy, water and mineral nutrients are heterogeneously distributed among these landscape elements. Determining the spatial distribution of landscape elements makes it possible to understand landscape structure. All ecological objects continually move or flow between landscape elements. Determining and predicting these flows or interactions between ecological objects among landscape elements offers an understanding of landscape functions. This principle provides a common framework for the multidisciplinary understanding of landscapes (Forman and Godron 1986; Turner, 1989).

Modern agriculture has had a very strong influence on farmland biodiversity in Europe (Chamberlain et al., 2000; Donald et al., 2001; Benton et al., 2003; Bianchi et al., 2006, Tscharntke et al., 2012a). For instance, 300 million farmland birds have been lost in Europe since 1980 (Birdlife, 2012). Birds closely associated with agricultural landscapes are a key indicator group for evaluating sustainability in land use. Their combined population changes are part of the Structural Indicators for Environment in the European Union (Gregory and van Strien, 2010). There have been various reason for the loss of farmland biodiversity since World War II: the increased use of pesticides and fertilizers, the loss of non-cropped habitat elements, overall spatial homogenisation, land use changes etc. under the Common Agricultural Policy of the European Union (EU) (Benton et al., 2003; Donald et al., 2006; Butler et al., 2007; Stoate et al., 2009; Butler et al., 2010). Agri-environment schemes have been created in order to halt the decline in farmland biodiversity. In 1985 agri-environment schemes were optional for Member States of the European Economic Community, but since 1992 they are compulsory for all EU Member States (European Commission, 2005).

All bird species are somehow related with landscape structure and land use (Forman and Godron, 1986). For instance, farmland habitat consists of two parts: agricultural practice, which creates land use (grassland, arable land, abandoned land) and semi-natural landscape elements (ditches, stone heaps, farmyards). Together they create overall farmland landscape heterogeneity. Both are highly important for farmland birds. One possible way to measure landscape heterogeneity is via landscape metrics. Previously, the relationship between landscape metrics and bird species richness and their habitat preferences had enjoyed researchers' closest attention. These studies highlighted the fact that overall landscape heterogeneity (via landscape metrics) has a positive influence on bird abundance and diversity (Uuemaa et al., 2013). Nevertheless, at least three dilemmas arise when one uses landscape metrics in bird-related studies: (1) the spatial variation of the range of habitats; (2) the coarse-grained resolution of the land cover data and the different grain size (pixel size) resolution (Mayer and Cameron 2003a, 2003b; Bennett et al. 2006), and (3) the situation that landscape indices do not take into account habitat cover *per se* (Heikkinen et al., 2004), but merely calculate a matrix of various land cover and landscape elements. Thus landscape indices are important predictors of bird species richness, but land use must also be taken into account in these investigations. An understanding of the effects of landscape structure on farmland birds is relevant to agri-environmental schemes and is vital to the development of better agri-environment measures for land use planning and management. It is well known that agri-environment schemes do not successfully protect biodiversity (Kleijn et al., 2001; Batáry et al., 2011a; Elts, Lõhmus 2012).

In Northern Europe (e.g. the Baltic countries, Scandinavia and North Western Russia, which represent hemi-boreal and boreal zones) a matrix of agricultural land, forests and wetlands, together with the network of ecologically compensating landscape elements (Dunning et al., 1992) such as ditches, farmyards, local roads, hedges close to the road and ditches, stone-heaps and single trees, constitute landscape structure. In most countries of Europe, the network of ditches has been created during initial drainage operations (Herzon and Helenius, 2008). Although land drainage has been one of the causes of the decline in farmland biodiversity in Europe (Stoate et al., 2009), man-made elements such as agricultural open ditches and their network also have a positive influence on agricultural biodiversity (de Snoo and van der Poll, 1999; Hinsley and Bellamy, 2000; Aquilina et al., 2007). Nonetheless, with the technological development of subsurface drainage, most of the narrow open ditches in farmland have been replaced by subsurface pipes in order to gain a greater production area, remove physical obstacles to farming, lower costs and drain more efficiently. The replacement has been finalised in the most productive regions of Southern and Central Europe, but in Eastern and Northern Europe it is still an ongoing process subsidized by national governments (Herzon and Helenius, 2008), leading to a secondary homogenisation of the agricultural landscape (Stoate et al., 2009). In some countries, such as Finland, the Baltic countries, Poland and the Netherlands, however, drainage ditches are still a ubiquitous feature of the agricultural landscape (Herzon and Helenius, 2008).

In Northern Europe, drainage ditches constitute one of the most common landscape elements and contribute significantly to the landscape heterogeneity of agricultural land. The extent of this network can be extensive: for example, in Estonia it amounts to 65,000 km (anon, 2011), in Latvia 78,000 km (Viesturs Jansons, pers. comm.), and in Lithuania 62,000 km (Kudakas and Kinčius, 2005). The ditch, with its margins of grassy vegetation and often bushes and trees, can be a complex ecosystem structured by several zones such as open water, wet soil, aquatic and semi-aquatic vegetation, slope and a margin with several layers of vegetation (Dajdok and Wuczyński, 2005; Banach 2008). Ditches in farmland were demonstrated to harbour a diversity of aquatic macrophyte and macroinvertebrate species characteristic of small fresh waters (Davies et al., 2008) and to provide resources for species occupying other habitats [(e.g., overwintering sites for invertebrates, dispersal routes for amphibians or birds (Hinsley and Bellamy, 2000; review in Herzon and Helenius, 2008)]. Resources within semi-natural margins provide different food (invertebrates and seeds of native plants) from that of the crop (Bradbury and Kirby, 2006; reviewed Herzon and Helenius, 2008), which is also sustained over a longer time. On arable fields, the application of herbicides and insecticides considerably reduces the number of invertebrates, which are the most important food taxa for farmland birds (reviewed Wilson et al., 1999; Vickery et al., 2009). Finally, undisturbed ditch margins by arable fields are unique breeding places for edge species (bird species that breed and/or feed on field edges), thereby increasing overall bird diversity and abundance over the landscape. It has been shown that communities of this ecological group are generally poorer on arable land than on grasslands (Batáry et al., 2011a). Therefore the presence of grassy strips (such as margins), soft and wet ditches and banks within arable fields is likely to provide an important supplementary habitat (Dunning et al., 1992), especially for invertebrate-feeding birds and waders (Eglington et al., 2008; Eglington et al., 2009). Ditches and the permanent high vegetation on such fields offer shelter on spring arrival or for juveniles (for instance, the threatened Ortolan Bunting *Emberiza hortulana*; Vepsäläinen et al., 2007; Corncrake *Crex crex*; Donaghy, 2007).

Farmland land use classes (arable fields, grasslands and abandoned land) differ as habitats for birds in terms of their vegetation structure, height, pattern of food resources, and disturbance regime. For instance, also intensively managed arable fields have benefits for farmland birds in grassland-dominated landscapes (Robinson et al., 2001) and as an additional food resource in winter (Orlowski, 2006), because it creates mosaic land use cover. Previous studies in the region have also indicated the positive impact of abandoned fields on farmland birds (Tryjanowski 1999; Herzon et al., 2006; Auninš and Priednieks, 2008; Orlowski, 2010). The biodiversity value of such fields is likely to be especially high since species are "protected" from some destructive disturbance such as excessive nutrient input, pesticides and also mechanical disturbance during sensitive periods of the breeding cycle. It is, however, important to point out that abandoned fields also need systematic cutting after 4–6 years because of overgrowing and habitat loss.

The aim of this thesis is to analyse the importance of land use heterogeneity and landscape structure diversity for the richness and abundance of farmland birds (Figure 1). Firstly, the overall importance of landscape metrics for biodiversity was reviewed (Paper I; Uuemaa et al., 2013) and the influence of landscape pattern on the richness and diversity of farmland bird species at different scales was analyzed (Paper II; Marja et al., 2013a). Secondly, a relative value of landscape structure elements such as drainage ditches on farmland birds depending on surrounding fields of contrasting vegetation types and management were quantified (Paper III; Herzon and Marja, 2012). Thirdly, the impact of land use and landscape structure such as draining systems on common farmland birds population densities was analyzed (Paper IV; Marja et al., 2013a, and Paper V; Herzon et al., In press). Finally, the spatial and temporal dynamics of farmland bird communities were investigated (Paper V; Herzon et al., In press).

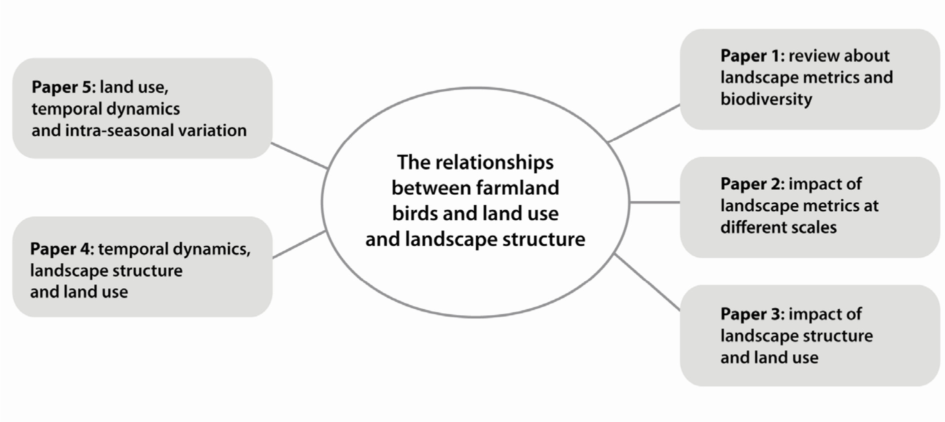

**Figure 1.** A schematic illustration of the process for examining and explaining the impact of patterns of land use and landscape diversity on farmland bird populations.

# 2. MATERIAL AND METHODS

## 2.1. Study areas

The study areas were situated in three research areas across Eastern Estonia (Paper II), the three Baltic countries in Estonia, Latvia and Lithuania (Paper III), in Western, Southern and Eastern Finland (Paper IV), and in the Gatchina region in North Western Russia (Paper V).

## 2.2. Fieldwork

The fieldwork was conducted in the spring and summer during the years 2002–2011. A point count method (Papers II and III), territory mapping (Paper IV) and transect count (Paper V), all described in Bibby et al. (1992), were used. There were two visits to each point or transect, with the main dates being in mid-May and in mid-June (Papers II, III and V) and additionally ten visits between end-April to end-July (Paper V). Three visits to each field (a detailed description in Kuussaari et al., 2004 and Tiainen et al., 2007) were made during the period 2nd to 20th May, with the second visit from 18th May to 2nd June and the third one from 1st to 18th June (Paper IV). Fieldwork was always carried out by experienced field ornithologists. No counts were conducted on days when visibility was poor or in windy/rainy conditions.

Bird records were mapped onto field forms (Papers II, III, V) using different activity codes (elaborated by Koskimies and Väisänen, 1991). The duration of the count at each point was five minutes (Papers II and III). For each point or transect, the maximum count of breeding individuals from two visits was used (Bibby et al., 1992). All birds without breeding behaviour (feeding flocks), migrating birds (except Paper V) and birds passing high overhead were excluded.

In Paper IV, observations of territoriality and breeding (singing males, territorial fights, alerting pairs, and also nests) were recorded on field maps, with special emphasis on the simultaneous observations of con-specifics of the same sex. In the case of simultaneous observations, local silent individuals were also used as evidence for the separation of adjacent territories. The interpretation of territory was performed on species maps, onto which the records were later transferred. The interpretation of Skylark and Meadow Pipit territories was based on observation clusters that were separated mostly with observations of singing males etc. (for details see e.g. Tiainen et al., 2007; Vepsäläinen et al., 2010). All bird territory interpretations were made by the same person in all years.

## 2.3. Landscape metrics

Three landscape metrics were calculated using the FRAGSTATS program (McGarigal et al., 2002): Patch Density (PD), Edge Density (ED) and Shannon's Diversity Index (SHDI; Table 1). The chosen metrics are easily understandable and interpretable and have been successfully adopted in previous studies (Paper I). PD best describes landscape fragmentation. ED was chosen because many farmland birds are edge specialist species but feed on farmland. SHDI describes overall landscape structure and diversity and takes into account different land cover and land use classes that PD and ED do not.

**Table 1.** Landscape metrics used.

| **Landscape indices** | **Description** |
|---|---|
| Patch Density (PD) | $PD = \frac{N}{A}(10000)(100)$<br>N = total number of patches in the landscape<br>A = total landscape area ($m^2$) |
| Edge Density (ED) | $ED = \frac{E}{A}(10000)$<br>E= total length (m) of the edge in the landscape<br>A = total landscape area ($m^2$) |
| Shannon's Diversity Index (SHDI) | $SHDI = -\sum_{i=1}^{m}(P_i \bullet \ln P_i)$<br>Pi = proportion of the landscape occupied by patch type (class) i |

As the optimal size of the area around count points is still unclear, the landscape metrics were calculated at three levels: in circle-sized buffer zones around the count points with a radius of 100 metres (circle area 3.14 hectares) and 200 metres (12.54 hectares), and in a 1 km$^2$ research square (100 hectares; Figure 2). According to studies of passerine farmland bird species, the majority of the foraging trips by adult passerine birds while feeding nestlings are made within 100 m (median value; Schifferli et al., 1999; Morris et al., 2001; review in Schifferli, 2001). This was not the case for Lapwing (*Vanellus vanellus*) and Corncrake. Therefore both 100 m and 200 m buffer zones were chosen.

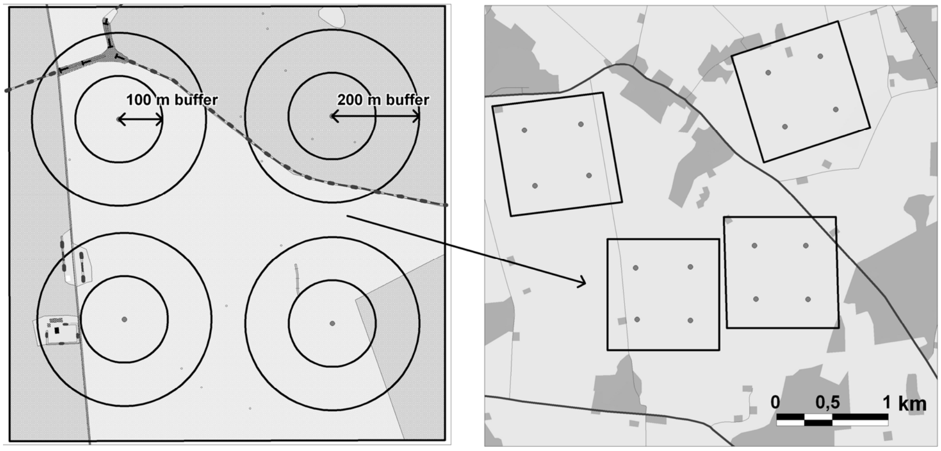

**Figure 2.** Buffer zones (with a radius of 100 and 200 metres) around the counting spot (indicated by a black point inside the buffer zones).

Most authors usually consider landscape structure dependency within their own study areas (Mayer and Cameron 2003b). Thus the use of landscape metrics varies considerably between research papers. Therefore entire research area (100 hectares) and, in addition, two different-sized buffer areas around the count spot were used. In the case of buffers, landscape metrics were considered only for the landscape around a specific count spot. However, landscape metrics were not considered in the zone that exceeded the 200 m buffer, because in this case buffer zones may overlap and reach the limits of the 200 m buffer (scaling limitation). Likewise, landscape metrics were not calculated within a radius of less than 100 m around the count spot, because when areas are too small, landscape metrics can lose their meaning (Wu et al. 2002). In addition, the sizes of farmland bird territory (median value) on farmland overlap with the 100–200 m buffer areas (Schifferli et al. 1999; review in Schifferli 2001) that were analysed. Previous studies considering Finnish farmland birds suggested that the impact of spatial autocorrelation on bird assemblages was not significant in samples positioned at least 500 m apart (Piha et al., 2007, Vepsäläinen et al., 2010), and that also applies well to the present analysis.

## 2.4. Land use data

**Paper II**

For land use data a vector-shaped Estonian Basic Map was used (1:10 000; mapping was done in 2001–2004; Estonian Land Board). Similar land use types were chosen due to evidence of their importance in determining bird distribution in the region (see for instance Piha et al., 2003; Prins et al., 2005; Herzon and O’Hara, 2007). Crop types (pasture, grassland, rape, cereals) were mapped during the fieldwork.

## Paper III

Landscape and habitat variables (crop types and non-cropped areas and elements) were mapped during the fieldwork. Proportions of forest, lengths of drainage ditches and other landscape variables were calculated using LUPA software and based on topographic maps (LUPA, 2002; Herzon and O'Hara, 2007) for a 100-metre buffer zone around the count plots (3.14 hectare). The distance to the nearest field edge (i.e. forest, orchard, bog or settlements) and major road was estimated in the field and validated from the topographic maps to an accuracy of up to 200 m.

## Paper IV

Habitat and landscape data were acquired from two national databases. Data on field boundaries and annual crops were obtained from the field register of the Finnish Agency of Rural Affairs (http://www.mavi.fi/) and the National Land Survey of Finland (http://www.maanmittauslaitos.fi/). These data were complemented with field observations when necessary (often fields are subdivided into more than one crop, and the exact locations of such crop parcels are not recorded in the register). Data on forest-farmland boundaries were based on the Landsat raster database of CORINE land cover from 2006 (resolution 25 m). Raster data were processed using the GRASS GIS 6.4.1 software (GRASS Development Team, 2011: http://grass.osgeo.org).

Fields drained with open ditches were identified from aerial images at a scale of 1:10 000 (National Land Survey of Finland), and were additionally cross-checked based on habitat records during the bird censuses. A corresponding sample of fields with installed subsurface drainage systems was selected randomly from the same survey landscapes and under the same crop (arable or grassland) in the years 2002–2009. The positioning of a field in relation to a surrounding forest was calculated by dividing the area of forest within a 30-m buffer from the field's edges by the area of the field. The final sample included 129 fields with open drainage and 129 fields with subsurface drainage, covering a total of 957 ha.

## Paper V

Habitat mapping was completed during the field visits using land use maps (1:10 000). Field types were described on the basis of the detailed characteristics of vegetation and management at a particular time period. The various field types were identified as: root vegetables, spring and winter cereals, first-year sown grasses, monospecific grassland, multiple species grassland, pasture, abandoned arable land and abandoned grassland. Two types of abandoned fields were distinguished. Former arable fields were characterised by vegetation dominated by arable weeds (e.g., *Cirsium sp.*, *Urtica dioica*), the lack of sown fodder species and a well-established litter layer. Former grasslands were grasslands that lacked signs of management from the previous year (cut or grazed sward). If a field was returned to use in a survey year (mown or pastured), it was regarded as a grassland or pasture. Abandoned agricultural fields were not surveyed when scrub and tree cover exceeded 30 % of the field area.

## 2.5. Ornithological data

**Paper II**

The following indices were calculated for the characterization of observed bird fauna: the number of breeding species and Shannon's Heterogeneity Index (Shannon's H). Ecological guilds of true field (6 species), edge (11 species), farmyard (6 species) and dendrophilous (24 species) within the farmland specialist group (Tiainen and Pakkala, 2001) were studied separately.

**Paper III**

For each count plot, the maximum count of individuals recorded during two visits was used for analysis. Abundance was interpreted as the number of individuals, which means, for example, that a singing male (i.e. a potentially breeding pair) was interpreted as two individuals (Koskimies and Väisänen 1991; Bibby et al., 1992). In the case of two birds (male and female) seen together, they were also interpreted as two individuals. A bird not displaying breeding behaviour was counted as a single individual. This interpretation was done in a consistent way by the same person and based on the original field maps. All migrating birds and birds passing high overhead were excluded from the analysis. Only data from the 100-m circle were used in this analysis, in order to reflect possible associations with ditches. Farmland bird ecological groups (Tiainen and Pakkala, 2001) as well as the nine most numerous farmland bird species that breed on fields or on field edges were chosen for analysis.

**Paper IV**

Skylark and Meadow Pipit abundances during the years 2002–2009 on fields under the two drainage systems and two habitat (crop) types were analysed.

**Paper V**

In 2006 three permanent transects in three landscape sub-areas were additionally established for the monitoring of field use by birds prior to and during the breeding season. These transects crossed 32 arable fields (total transect length 19.4 km), 10 abandoned fields (4.9 km), 49 grasslands (34.8 km) and 16 pastures (16 km).The counts were repeated every 10 days from April 26 to July 28. The aim was to explore the sequence and intensity of field use by birds starting at the arrival of breeding birds and up to the post-breeding movements of family groups. Swallows and swifts were included in the analysis of the temporal dynamics of field use based on the repeated transects in 2006.

For data from 2008, 2010 and 2011 (230 fields), the maximum count of individuals from two visits was used. Only records of individuals breeding and feeding within fields and edges were included in this analysis. Birds passing high overhead or species whose abundance is strongly affected by meteorological conditions (swallows and swifts) were not included in the community metrics.

## 2.6. Statistical analysis

**Paper II**

The species richness and diversity variables were analyzed by generalized additive mixed models (GAMM) in R (R Development Core Team, 2013). R packages *mgcv* (Wood, 2011) and *nlme* (Pinheiro et al., 2011) were used. The effect of overdispersion on estimation was controlled for and standard errors were estimated using a quasi-GLM model (Zuur et al., 2009). The study areas (count points with 100 or 200 m radius or research square 1 km$^2$), were modelled as a random factor with repeated measures over two study years. Every single model included the following variables: the response variable was the bird variable (number of breeding species, Shannon's H, number of true field, edge, farmyard and dendrophilous species respectively), and the explanatory variable was landscape metrics (PD, ED or SHDI, as fixed factor). Thus three models with the different landscape metrics separately for each spatial scale were compared.

**Paper III**

Generalised linear models and zero inflated models (with package *pscl*, Jackman et al., 2011) were carried out in R (R Development Core Team, 2013). For each response variable, one multivariate model was carried out containing all explanatory variables. The explanatory variables are described in Table 2: land use type (fixed at three levels of arable n=30, grasslands n=48 or mixed n=50), the length of ditches with high vegetation (n=94), the length of grassy ditches (n=64), the scrub-forest proportion within 3.14 hectare, the distance from a plot to the field edge, and the distance from a plot to the nearest road (detail description in Table 2). The above variables were chosen due to evidence of their importance in determining bird distribution in the region (Prins et al., 2005; Herzon and O'Hara, 2007). Two interactions of the variables were additionally considered: the length of ditches with high vegetation by land use and the length of grassy ditches by land use.

**Table 2.** Descriptive statistics (means and standard deviations) of the explanatory variables, bird community indices, and species abundances. Birds, length of ditches and proportion of forest are within a 100 m radius around the count plots, and distance to the nearest field edge or road is within a 200 m radius.

| Explanatory landscape and bird variables | Number of individuals | Mean | SD |
|---|---|---|---|
| Length of ditches with high vegetation (m), $D_{VEG}$ | | 113.40 | 98.69 |
| Length of grassy ditches (m), $D_{GRASSY}$ | | 84.34 | 113.33 |
| Scrub-forest proportion of 3.14 hectare (%), SCRUB-FOREST | | 28.01 | 36.66 |
| Distance from a plot to the field edge (m), EDGE | | 176.84 | 67.91 |
| Distance from a plot to the nearest minor road 6–10 m (m). No sampling plots near major roads. ROAD | | 123.04 | 90.12 |
| Community indices | | | |
| $SR_{ALL}$ | | 8.99 | 4.39 |
| $SR_{OPEN}$ | | 1.88 | 0.79 |
| $SR_{EDGE}$ | | 1.93 | 1.27 |
| $SUM_{OPEN}$ | | 10.33 | 4.29 |
| $SUM_{EDGE}$ | | 5.79 | 4.70 |
| True field species | | | |
| Corncrake | 54 | 0.42 | 0.96 |
| Meadow Pipit | 72 | 0.56 | 1.00 |
| Lapwing | 38 | 0.29 | 0.78 |
| Skylark | 876 | 6.84 | 2.71 |
| Edge species | | | |
| Whitethroat | 188 | 1.46 | 1.35 |
| Whinchat | 221 | 1.72 | 2.01 |
| Yellowhammer | 128 | 1.00 | 1.35 |
| Marsh Warbler | 94 | 0.73 | 1.48 |
| Grasshopper Warbler | 47 | 0.37 | 0.92 |

### Paper IV

Skylark and Meadow Pipit abundances on fields under the two drainage systems and two habitat (crop) types were analysed by generalized additive mixed models (GAMM) in R (R Development Core Team, 2013). Repeated measurements were performed (annual repeats) and Poisson errors for count data were assumed. R packages *mgcv* (Wood, 2011) and *nlme* (Pinheiro et al., 2011) were used. The effect of overdispersion on estimated standard errors was controlled for by using a quasi-GLM model (Zuur et al., 2009) and the spatial variation in counts between fields by including a random intercept in the models. Transect length (log transformed) was treated as an offset variable. In order to control temporal correlation in the series of counts, the exponential correlation (corExp) function was fitted (Zuur et al., 2009).

The drainage type (factor with two classes: fields with open drainage and fields with subsurface drainage) was the main explanatory variable of interest here. Four other variables were fitted into the models: (1) crop type (factor with two classes: grassland or arable), (2) forest cover in a 30-m buffer per field area (continuous variable, “Forest edge”), and (3) X and (4) Y-coordinates of field centre points (continuous variables). Interactions of drainage type by year and of drainage type by crop type were included in the models. Field size (log transformed) was treated as an offset variable. In the models, the effect of spatial autocorrelation was, at least partially, controlled for by site (random intercept: field identifier) and the effects of X and Y coordinates.

### Paper V

The effect of seasonality (i.e. timing of the count on the permanent transects, one to 10) and field type (factor with four classes: arable fields, grasslands, pastures and abandoned fields) and their interaction were modelled with generalized additive mixed models (GAMM) in R (R Development Core Team, 2013). The original field types: arable land (root vegetables, spring cereal, winter cereal, first-year sown grasses), grassland (mono-specific grassland and multiple species grassland), pasture and abandoned fields (abandoned arable land and abandoned grassland) were pooled to improve the sample sizes. Repeated measurements were performed and the Poisson distribution in R packages *mgcv* (Wood, 2011) and *nlme* was calculated (Pinheiro et al., 2011). The effect of overdispersion on estimated standard errors was controlled for by using a quasi-GLM model (Zuur et al., 2009) and spatial variation in counts between fields by including a random intercept in the models. Transect length (log transformed) was treated as an offset variable. In order to verify temporal correlation in the series of counts, an exponential correlation (corExp) function was fitted (Zuur et al., 2009). Only the overall species richness and the number of individuals and the abundances of the most common species were modelled, because these data were not zero-inflated.

In addition, the influence of seasonality on bird community similarity among the field types was measured in the partial redundancy analyses (partial RDA) with the *vegan* package (Oksanen et al., 2013). The full model with seasonality and field types (pooled as above) and their interaction was run. The species matrix was modified using the Hellinger transformation (Legendre and Gallagher, 2001). This transformation allows the use of the partial RDA ordination method, which is Euclidean-based, on the data, which contains numerous zeros. Pseudo-*F* values with corresponding p values by tests based on 999 permutations were calculated.

For the comparative analysis of the eight field types, the maximum count of individuals from two visits in a standardised survey in 2008, 2010 and 2011 was used. The community metrics of species richness and abundance of all birds for each year was calculated. The community metrics and abundances of individual species were related to transect length (i.e. densities). The means over the three survey years for further testing was taken, because some of the field types were too rare in at least one of the years due to crop rotations. Kruskal–Wallis non-parametric ANOVA was applied, and the means were compared by pairwise comparisons using the Wilcoxon rank sum test with Bonferroni-corrected p-values. Based on the procedure described above, the community similarity among the field types conditioned over three years in the partial RDA was assessed.

A confidence level of 95 % was accepted in all cases.

# 3. RESULTS

## 3.1. The relationships between birds and landscape metrics (Papers I and II)

The relationship between landscape metrics and bird species richness and their habitat preferences has also been widely studied (Paper I). Several studies have shown that bird species generally respond more strongly to the composition of land cover classes than to the configuration of the landscape. The shape of the patches appears to play a minor role in bird diversity.

The number of breeding species, Shannon's H, the number of edge species and dendrophilous species were positively related with all of the selected landscape metrics at all scales (except for edge species with SHDI at the research square level; Table 3). The positive effect of bird variables and landscape metrics was, however, not always linear (Supplementary material, Table 1). The effect of scale was ascertained because in most cases the model's proportion of variance explained between the bird variables and landscape metrics increased with the increasing size of the research area.

**Table 3.** Results of generalized additive mixed models characterizing the relationship between landscape metrics and bird variables. The significance levels (p) are + <0.05, ++ <0.01 and +++ <0.001; ns: non-significant relationship between bird variable and landscape metrics. NA – not available, model crashed. $R^2$ – the adjusted r-squared for the model (defined as the proportion of variance explained).

| **Landscape indices** | **Scale** | **Sample size** | **No. of breeding species** | | **Shannon's H** | | **Number of true field species** | | **Number of edge species** | | **Number of farmyard species** | | **Number of dendrophilous species** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $R^2$ | p | $R^2$ | p | $R^2$ | p | $R^2$ | p | $R^2$ | p | $R^2$ | p |
| PD | 100 m buffer zone | 240 | 0.14 | +++ | 0.13 | +++ | 0.00047 | +++ | 0.2 | +++ | -0.01 | +++ | 0.064 | ++ |
| PD | 200 m buffer zone | 240 | 0.23 | +++ | 0.23 | +++ | -0.0016 | +++ | 0.25 | +++ | -0.004 | +++ | 0.14 | +++ |
| PD | 1 $km^2$ research square | 60 | 0.34 | +++ | 0.31 | +++ | 0.064 | +++ | 0.45 | +++ | -0.016 | ns | 0.15 | ++ |
| ED | 100 m buffer zone | 240 | 0.065 | +++ | 0.072 | +++ | -0.0037 | +++ | 0.092 | +++ | -0.012 | +++ | 0.029 | + |
| ED | 200 m buffer zone | 240 | 0.15 | +++ | 0.16 | +++ | -0.0009 | ns | 0.17 | +++ | -0.009 | +++ | 0.08 | +++ |
| ED | 1 $km^2$ research square | 60 | 0.34 | +++ | 0.28 | +++ | 0.084 | +++ | 0.27 | ++ | 0.022 | ns | 0.17 | + |
| SHDI | 100 m buffer zone | 240 | 0.088 | +++ | 0.097 | +++ | 0.11 | ns | 0.0052 | +++ | NA | ns | 0.041 | +++ |
| SHDI | 200 m buffer zone | 240 | 0.2 | +++ | 0.2 | +++ | 0.016 | ns | 0.2 | +++ | 0.001 | ns | 0.08 | +++ |
| SHDI | 1 $km^2$ research square | 60 | 0.2 | +++ | 0.23 | +++ | 0.027 | +++ | -0.008 | ns | -0.013 | ns | 0.2 | +++ |

## 3.2. The influence of small-scale landscape elements on farmland birds (Papers III and IV)

Overall species richness, the species richness of edge species, and the abundance of edge species were significantly positively related with the length of ditches with high vegetation on the arable plots (Table 4). The abundance of Whitethroat (*Sylvia communis*) was significantly positively connected with the length of ditches with high vegetation on arable plots and with grassy ditches on grassland plots. Skylark abundance was negatively associated with ditches with high vegetation on grassland plots (Table 4). The length of ditches with high vegetation and grassy ditches was significantly positively related to the abundance of the other three species (Meadow Pipit, Corncrake and Lapwing) on the arable and/or mixed plots (Table 5).

**Table 4.** Final Generalized Linear Models relating farmland bird metrics (a – overall results; b – species-specific results) to landscape characteristics and land use. One, two or three + or – signs refer to significance levels of < 0.05, < 0.01 or <0.001, respectively.

| **Landscape and habitat variables**<br>(a) Overall results | | | **Bird variables** | | |
|---|---|---|---|---|---|
| | $SR_{ALL}$ | $SR_{OPEN}$ | $SUM_{OPEN}$ | $SR_{EDGE}$ | $SUM_{EDGE}$ |
| Model AICc | 705.9 | 359.9 | 764.6 | 404.1 | 759.9 |
| Value/df | 1.5 | 0.3 | 1.9 | 0.8 | 2.8 |
| Land use | | | | | |
| arable plots | – – – | | | – – – | – – – |
| mixed plots | | | | | – – – |
| grassland plots | +++ | | +++ | +++ | +++ |
| DVEG (m) | | | | | |
| DGRASSY (m) | ++ | | | | |
| SCRUB-FOREST (%) | | | | | + |
| ROAD (m) | – – – | | – – | | – – |
| EDGE (m) | – | + | ++ | | |
| Ditches by land use type | | | | | |
| DVEG on arable plots | + | | | + | +++ |
| DVEG on mixed plots | | | | | |
| DVEG on grassland plots | | | | | |
| DGRASSY on arable plots | | | | | |
| DGRASSY on mixed plots | | | | | ++ |
| DGRASSY on grassland plots | ++ | | | | |

| **Landscape and habitat variables** | | | **Bird variables** | |
|---|---|---|---|---|
| (b) species-specific results | Skylark | Whitethroat | Whinchat | Yellow-hammer |
| Model AICc | 614.9 | 515.3 | 481.4 | 368.9 |
| Value/df | 1.1 | 2 | 2.1 | 1,7 |
| Land use | | | | |
| arable plots | | − − − | − − | − |
| mixed plots | | − | − | |
| grassland plots | +++ | +++ | | |
| DVEG (m) | − − − | | | |
| DGRASSY (m) | | ++ | | +++ |
| SCRUB-FOREST (%) | | | ++ | − − |
| ROAD (m) | | − − | | |
| EDGE (m) | | | +++ | ++ |
| Ditches by land use type | | | | |
| DVEG on arable plots | | + | | |
| DVEG on mixed plots | | | | |
| DVEG on grassland plots | − − − | | | |
| DGRASSY on arable plots | | | | |
| DGRASSY on mixed plots | | | + | |
| DGRASSY on grassland plots | | ++ | | +++ |

**Table 5.** Results of the Zero inflated models relating bird species with landscape characteristics and land use. Count model coefficients (CMC, based on the Poisson model with a log link) show abundance if the species is present. Zero-inflation model coefficients (ZIMC, based on the binomial model with a logit link) show whether the species is present. NA denotes cases in which the estimation of occurrence probability was approaching infinity, which means that a respective species was not registered on a given field type. One, two or three + or – signs refer to significance levels of < 0.05, < 0.01 or <0.001 respectively.

| **Landscape and habitat variables** | | | **Bird variables** | | |
|---|---|---|---|---|---|
| | CMC | ZIMC | CMC | ZIMC | CMC |
| | Marsh Warbler | | Meadow Pipit | | Corncrake |
| Model AICc | 258.7 | | 235.5 | | 188.6 |
| *Land use* | | | | | |
| arable plots | – | | | | NA |
| mixed plots | | | – – – | | – – – |
| grassland plots | +++ | + | +++ | | ++ |
| $D_{VEG}$ (m) | | | | | |
| $D_{GRASSY}$ (m) | + | | – | | |
| SCRUB-FOREST (%) | | | | | – – – |
| ROAD (m) | | | | | |
| EDGE (m) | | | – – – | | |
| *Ditches by land use type* | | | | | |
| $D_{VEG}$ on arable plots | | | | | |
| $D_{VEG}$ on mixed plots | | | + | | +++ |
| $D_{VEG}$ on grassland plots | | | | | |
| $D_{GASSY}$ on arable plots | | | | | |
| $D_{GRASSY}$ on mixed plots | | | +++ | | +++ |
| $D_{GRASSY}$ on grassland plots | | | – | | |

| | Lapwing | | Grasshopper Warbler | |
|---|---|---|---|---|
| Model AICc | 155.3 | | 168.3 | |
| *Land use* | | | | |
| arable plots | – – | | ++ | + |
| mixed plots | | | +++ | ++ |
| grassland plots | | | – – | – |
| $D_{VEG}$ (m) | | | – – | – – |
| $D_{GRASSY}$ (m) | +++ | | | |
| SCRUB-FOREST (%) | | | +++ | + |
| ROAD (m) | | | | + |
| EDGE (m) | | | +++ | ++ |
| *Ditches by land use type* | | | | |
| $D_{VEG}$ on arable plots | +++ | | | |
| $D_{VEG}$ on mixed plots | | | | |
| $D_{VEG}$ on grassland plots | | | | |
| $D_{GRASSY}$ on arable plots | | | | |
| $D_{GRASSY}$ on mixed plots | | | | |
| $D_{GRASSY}$ on grassland plots | +++ | | | |

For grassy ditches there was no statistical difference in the relationship between their length and bird communities on arable plots as compared to grassland plots. On mixed plots, the length of grassy ditches was more closely correlated to the abundance of edge species and Whinchat than grassland plots.

Bird occurrences were closely correlated with landscape structure and land use characteristics (Table 4). Most of the bird community attributes had higher values on grassland than on arable plots. Fewer individuals of the edge species, including the Whitethroat, were registered on the mixed plots than on the grassland plots. Open farmland specialist species richness and abundance are positively correlated to the distance to the edge of the field area, but overall species richness was negatively correlated. The numbers of all species, the abundance of open farmland specialist and edge species and Whitethroat were significantly and negatively related to the proximity of the road to the count plots.

In Paper IV, Skylark and Meadow Pipit populations increased significantly during the study period on fields with open drainage (Table 6, Figure 3a and 3b). On subsurface drainage fields, Skylark and Meadow Pipit population trends were stable. The variance in Skylark abundance between the drainage types was not statistically significant, but the number of territories on arable crop fields was considerably lower than the number on grassland fields (Table 6). Fields with open drainage supported many more breeding Meadow Pipit pairs than fields with subsurface drainage. The number of forest edges and geographical coordinates had a significant negative impact on the abundance of Skylarks and Meadow Pipits. The interaction between crop and drainage type was not significant for either Skylark or Meadow Pipit.

**Table 6.** Relationships of Skylark and Meadow Pipit abundances with significant landscape characteristics and land use in GAMM. – negative effect, NS – not statistically significant effect.

| | **Skylark** | | **Meadow Pipit** | |
|---|---|---|---|---|
| **Model parameter** | **Estimator** | **p-value** | **Estimator** | **p-value** |
| Intercept | 0.24 | 0.02 | –0.33 | 0.006 |
| Factor crop type (arable) | –0.27 | <0.0001 | –0.26 | <0.0001 |
| Factor drainage type (fields with subsurface drainage) | | NS | –0.69 | <0.0001 |
| Year × Factor drainage type (fields with open drainage) | 0.1 | <0.0001 | 0.08 | <0.0001 |
| Year × Factor drainage type (fields with subsurface drainage ) | | NS | | NS |
| Factor crop type × Factor drainage type | | NS | | NS |
| Forest edge | –1.16 | <0.0001 | –0.78 | <0.0001 |
| X-coordinate (field centre) | –0.19 | 0.007 | –0.29 | <0.0001 |
| Y-coordinate (field centre) | –0.46 | <0.0001 | –0.54 | <0.0001 |
| Model AIC | 3131.8 | | 3880.1 | |

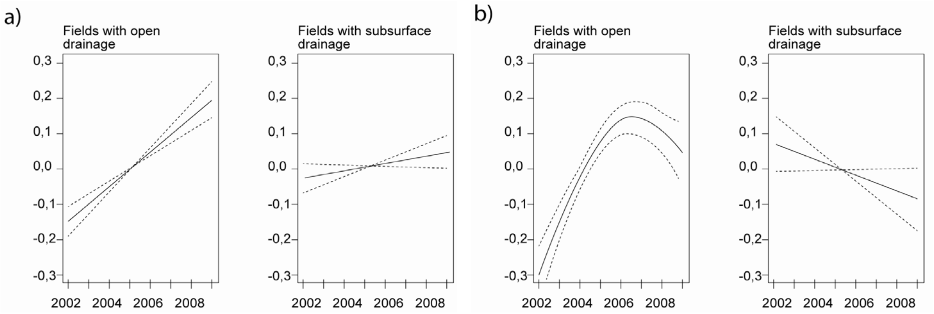

**Figure 3.** Estimated population trends of Skylark (a) and Meadow Pipit (b) based on the generalized additive mixed models for different drainage types in 2002–2009. The model smoother (solid line) is the estimate of log-scale population change with 95% point-wise confidence intervals (dotted line). The smoother is centred at 0. The y-axis shows the contribution of the smoother to the fitted values.

## 3.3. Effect of land use and the temporal dynamics of the intra-seasonal variation on farmland birds (Paper V)

Based on the results from the permanent transects in 2006, field type and its interaction with seasonality were significant predictors in all GAMMs (Table 7). The numbers of species declined on all field types by the end of July, but on arable crops species richness had already halved by early June (Figure 4). Pastures held the highest mean value for species richness (Table 7). The number of individuals steadily declined on abandoned fields and heavily fluctuated on arable fields (Figure 5). Clear species-specific differences were found in the most abundant species (Table 7). Skylark numbers were fairly stable on all fields except for abandoned fields, on which they progressively declined, starting in June. Some decline also took place on grasslands by the end of June (Supplementary material, Figure 1). Whinchat (*Saxicola rubetra*) had consistently higher abundances on abandoned fields, with a particularly strong increase by the end of the season (Table 7, Supplementary material, Figure 2). Meadow Pipits were most numerous on arable fields at the spring arrival and during the last counts in July. The latter increase seems to coincide with the decline on grass field-types (Supplementary material, Figure 3). Starling (*Sturnus vulgaris*) numbers increased on pastures and grasslands as the season progressed (Supplementary material, Figure 4).

**Table 7.** Effects of seasonality and field type on the overall species richness and abundance of farmland birds, and the abundance of the most common species in Gatchina district in 2006.

| | **Variable** | **Estimator** | **p** | **Trend** |
|---|---|---|---|---|
| Species richness | Field type | | | |
| | Arable [1] | -0.204 | 0.171 | |
| | Grassland [1] | 0.073 | 0.607 | |
| | Pasture [1] | 0.415 | 0.009 | |
| | Seasonality×Field type | | 0.001 | |
| | Seasonality×abandoned | -0.924 | <0.001 | fluctuating, declining from late June |
| | Seasonality×arable | -0.947 | <0.001 | declining, main declining from late May |
| | Seasonality×grassland | -0.392 | 0.001 | fluctuating, slightly declining from late June |
| | Seasonality×pasture | -0.421 | | slightly declining from mid-June |
| Abundance | Field type | 0.387 | 0.388 | |
| | Arable 1 | 0.385 | 0.376 | |
| | Grassland 1 | 0.770 | 0.108 | |
| | Pasture 1 | | | |
| | Seasonality×Field type | | 0.006 | |
| | Seasonality×abandoned | -2.142 | <0.001 | steadily declining |
| | Seasonality×arable | 0.288 | 0.174 | no trend; highly fluctuating with a peak at the end of May |
| | Seasonality×grassland | -0.423 | 0.427 | no trend |
| | Seasonality×pasture | 0.367 | | no trend |
| Skylark | Field type | | | |
| | Arable 1 | 0.772 | 0.005 | |
| | Grassland 1 | 0.823 | 0.002 | |
| | Pasture 1 | 0.782 | 0.008 | |
| | Seasonality×Field type | | | |
| | Seasonality×abandoned | -2.574 | 0.002 | declining from late May |
| | Seasonality×arable | -0.508 | <0.001 | steady, slight increase in June |
| | Seasonality×grassland | -1.280 | <0.001 | steady, slight decline from late June |
| | Seasonality×pasture | -0.375 | 0.161 | no trend |

| | **Variable** | **Esti-mator** | **p** | **Trend** |
|---|---|---|---|---|
| Whinchat | Field type | | | |
| | Arable [1] | -2.456 | <0.001 | |
| | Grassland [1] | -0.969 | 0.016 | |
| | Pasture [1] | -0.523 | 0.237 | |
| | Seasonality×Field type | | | |
| | Seasonality×abandoned | 3.140 | <0.001 | increasing |
| | Seasonality×arable | 2.927 | 0.022 | increasing |
| | Seasonality×grassland | 4.273 | <0.001 | increasing |
| | Seasonality×pasture | 2.678 | <0.001 | increasing |
| Meadow Pipit | Field type | | | |
| | Arable [1] | -1.921 | 0.025 | |
| | Grassland [1] | -0.037 | 0.961 | |
| | Pasture [1] | 0.856 | 0.327 | |
| | Seasonality×Field type | | | |
| | Seasonality×abandoned | -1.681 | 0.003 | declining from mid-June |
| | Seasonality×arable | -0.422 | <0.001 | declining till early June, then increasing (U shape) |
| | Seasonality×grassland | -1.379 | <0.001 | fluctuating |
| | Seasonality×pasture | 0.568 | <0.001 | slightly increasing in early July |
| Starling | Field type | | | |
| | Arable [1] | -0.062 | 0.949 | |
| | Grassland [1] | 0.150 | 0.849 | |
| | Pasture [1] | 1.988 | 0.015 | |
| | Seasonality×Field type | | | |
| | Seasonality×abandoned | -1.219 | 0.674 | no trend |
| | Seasonality×arable | -1.268 | 0.098 | no trend |
| | Seasonality×grassland | 3.420 | <0.001 | increasing till early July |
| | Seasonality×pasture | 4.017 | <0.001 | increasing till early July |

[1] compared with abandoned fields

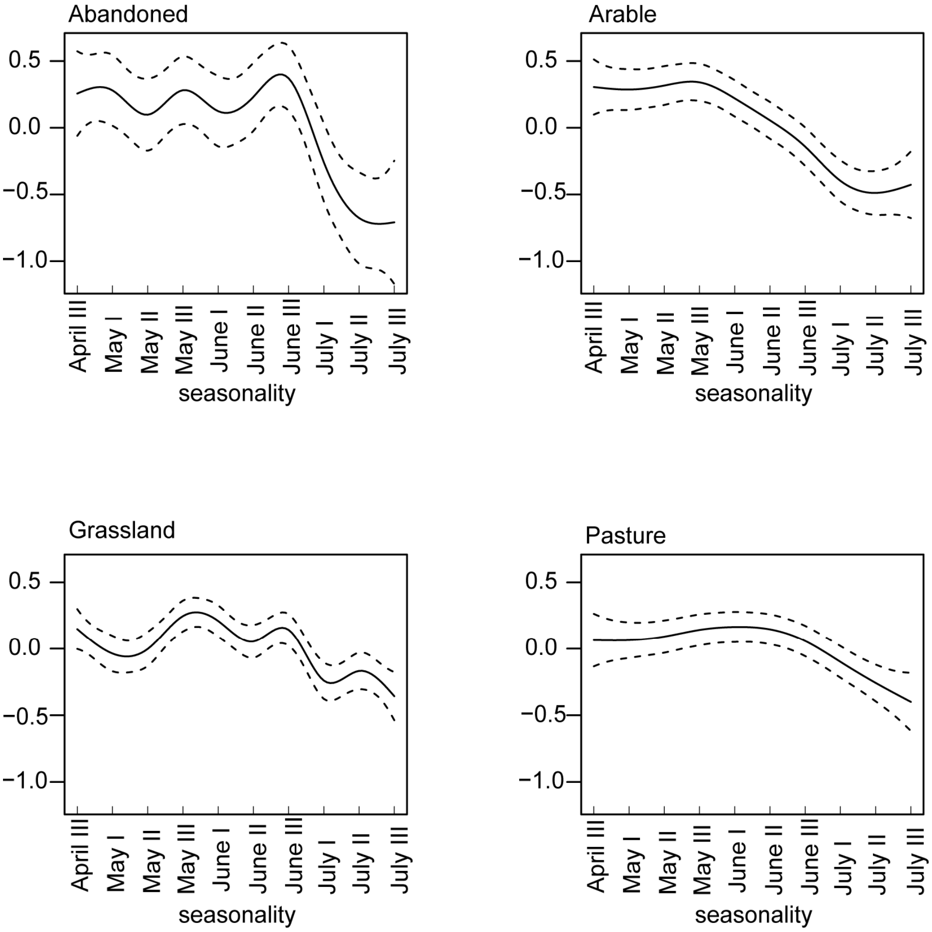

**Figure 4.** Estimated changes in farmland birds' species richness trends according to timing of the count on abandoned fields, arable fields, grassland and pastures during the period from 26 April to 28 July 2006. The model smoother (solid line) is the estimate of log-scale species richness change with 95% point-wise confidence intervals (dotted line). The smoother is centred at 0. The y-axis shows the contribution of the smoother to the fitted values.

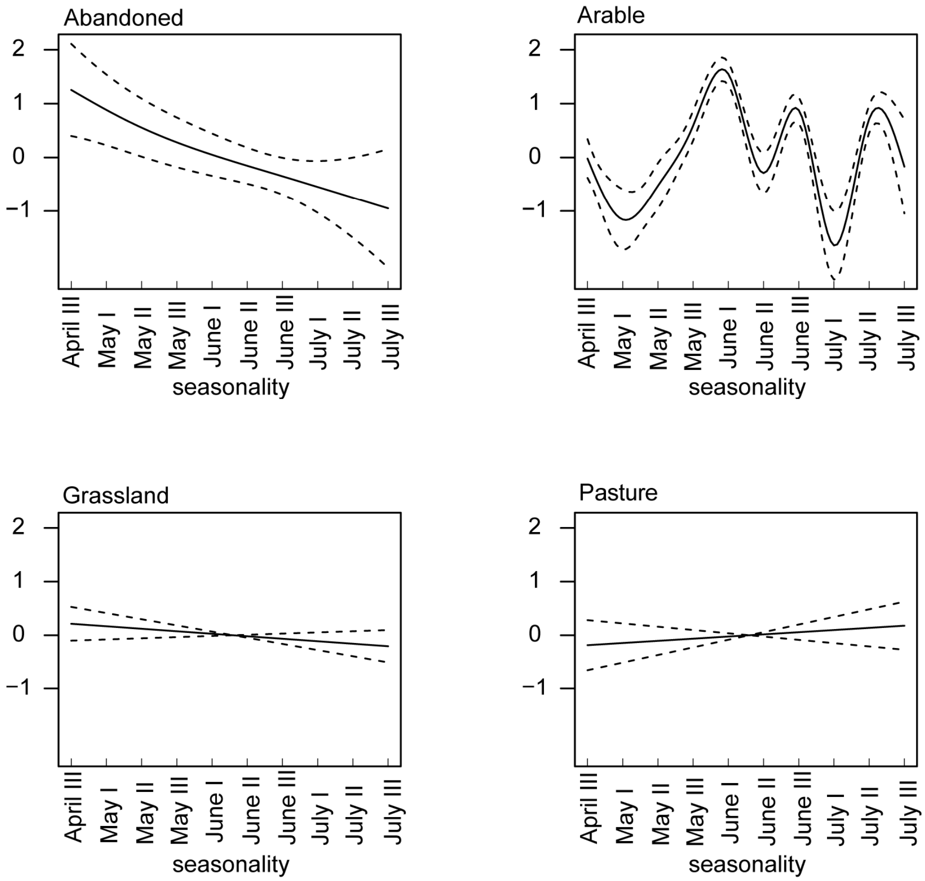

**Figure 5.** Estimated changes in the farmland birds' abundance trends according to timing of the count on abandoned fields, arable fields, grassland and pastures during the period from 26 April to 28 July 2006. The model smoother (solid line) is the estimate of log-scale abundance change with 95% point-wise confidence intervals (dotted line). The smoother is centred at 0. The y-axis shows the contribution of the smoother to the fitted values.

Also in partial RDA, both, field type and seasonality, as well as their interaction, were significant predictors for community composition (all at $p < 0.001$). Seasonality on its own explained 5.9 % of community composition ($F_{9,909}$ 6.6), and field type explained 3.6 % ($F_{3,909}$ 12.4), while their interaction 3.6 % ($F_{39,882}$ 1.3). On arable fields, a highly distinct species composition was observed during the two early counts, when registrations of migrating birds prevailed. Utilised grasslands, meadows and pastures had the most distinct community composition during the peak of the breeding season: pastures were used by such specialist species as Snipe (*Gallinago gallinago*) and Yellow Wagtail (*Motacilla flava*). By July, the abandoned fields differed most strongly from the other fields: they were set apart by the prevalence of Whitethroat and Whinchat.

## 3.4. Bird communities among field types (Paper V)

Root vegetables, spring and winter cereal fields, first-year sown grasses and monospecific grasslands were characterised by the lowest species richness and abundance (Figure 6) as well as numbers of many species (Supplementary material, Table 2). Pastures, abandoned arable fields, abandoned grasslands and multiple-species grassland were associated with high overall species richness and abundance. Also abundance of most species was at its highest on these fields. Several species – corncrake, yellow wagtail, meadow pipit, and whinchat – were rarely found on other field types. The data also indicated further differences in the distribution of some species according to the stage of grassland establishment (first-year sown grass or older) and whether an abandoned field had previously been arable or grassland (Supplementary material, Table 2). The numbers of shrub-associated species (e.g. Whitethroat, Marsh Wabler *Acrocephalus palustris*, Grasshopper Warbler *Locustella naevia*, Red-backed Shrike *Lanius collurio*) on abandoned grasslands were two – three times higher than on the abandoned arable fields.

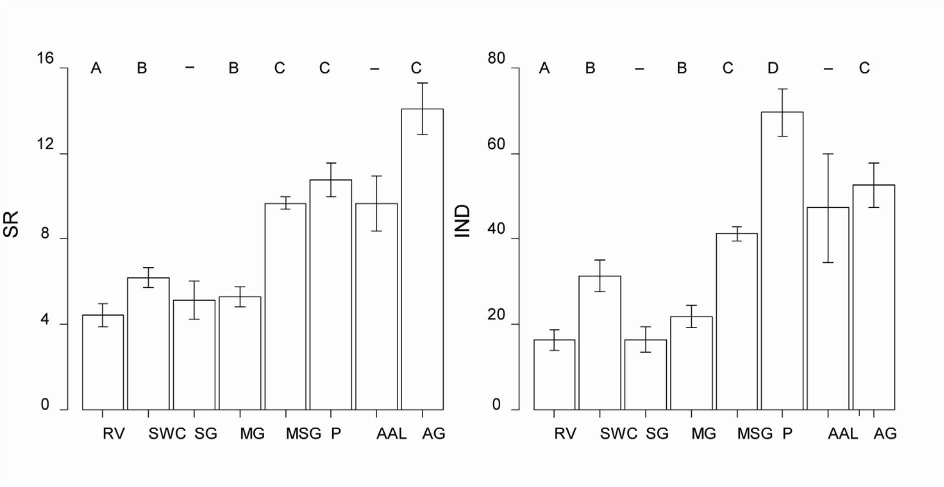

**Figure 6.** Species richness (SR) and abundance (IND) of farmland birds standardised by the transect length and by field types (mean and standard error) for years 2008, 2010 and 2011. Field types: root vegetables (RV), spring and winter cereal (SWC), first-year sown grasses (SG), monospecific grassland (MG), multiple-species grassland (MSG), pasture (P), abandoned arable land (AAL) and, abandoned grassland (AG).

In partial RDA, field type was a significant predictor of species community composition (which described 11.1% of species composition, $F_{7,652}$ 11.7 p=0.005). Year described 0.7% of species composition, $F_{1,651}$ 5.1 p=0.001. The main axis represents a gradient from fields of simple swards (all crop fields, sown and monospecific grasslands) towards fields of progressively more diverse ones (Figure 7). There is a concurrent gradient in species composition from mainly species nesting in fields (Lapwing) to shrub associated species (e.g., Whinchat, Whitethroat). The gradient also relates to the likely management intensity, since root vegetables and cereal crops are usually managed most intensively. The second gradient distinguishes between used (pasture and associated foraging species) and abandoned grasslands.

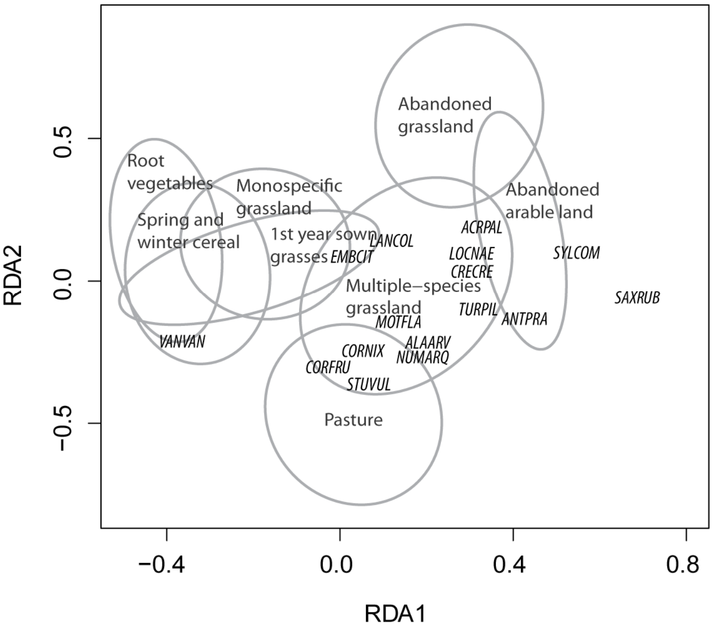

**Figure 7.** Differentiation of farmland bird community by field type in redundancy analysis for data in years 2008, 2010 and 2011. For visibility, only the most numerous bird species with n > 90 and species with the highest fraction of variance fitted by the two first factorial axes are indicated. Skylark ALAARV – *Alauda arvensis*, Marsh Warbler ACRPAL – *Acrocephalus palustris*, Meadow Pipit ANTPRA – *Anthus pratensis*, Hooded Crow CORNIX – *Corvus corone cornix*, Rook CORFRU – *Corvus frugilegus*, Corncrake CRECRE – *Crex crex*, Yellowhammer EMBCIT – *Emberiza citronella*, Red-backed Shrike LANCOL – *Lanius collurio*, Grasshopper Warbler LOCNAE – *Locustella naevia*, Yellow Wagtail MOTFLA – *Motacilla flava*, Curlew NUMARQ – *Numenius arquata*, Whinchat SAXRUB – *Saxicola rubetra*, Starling STUVUL – *Sturnus vulgaris*, Whitethroat SYLCOM – *Sylvia communis*, Fieldfare TURPIL – *Turdus pilaris*, and Lapwing VANVAN – *Vanellus vanellus*.

# 4. DISCUSSION

## 4.1. The relationships between birds and landscape metrics (Papers I and II)

The relationship between landscape metrics and bird species richness and their habitat preferences has also been widely studied (Paper I). Landscape metrics have been used most widely for the evaluation of the influence of environmental changes on bird richness (Lindenmayer et al., 2003; Thomson et al., 2008; Wrbka et al., 2008). Several studies have shown that bird species generally respond more strongly to the composition of land cover classes than to the configuration of the landscape (Paper I).

The number of farmland bird breeding species and Shannon's diversity index correlated significantly with all tested metrics at all tested scales (Paper II). This indicates that if the value of landscape metrics (PD, ED or SHDI) is high, then bird species richness and diversity is higher. Nevertheless, landscape heterogeneity is not only a direct factor explaining species richness or diversity in semi-boreal and boreal agricultural landscapes, because landscape metrics do not directly take into account habitat quality (Heikkinen et al., 2004). The habitat composition of the surrounding landscape also influence local habitat quality and farmland birds' habitat selection, because the proximity to other habitats allows them to be used as foraging areas (Barbaro et al., 2007), but this is not always the case (see Batáry et al. 2011b). Based on previous studies (reviewed in Paper I) and this study (Paper II), one can conclude that landscapes with different farming intensity, habitat composition (ditches, bushes, stone walls, forest patches etc.) and land use richness have a strong positive effect on overall farmland bird species richness and diversity.

PD and ED correlations with bird variables were highly similar (p values and $R^2$ values) because these two metrics themselves are highly correlated although describe different aspects (PD describes landscape fragmentation and ED density of edges). Furthermore, also SHDI demonstrated similar results with PD and ED, although it measures landscape composition. According to the study it is challenging to recommend which metrics is more suitable to predict farmland bird species richness because results are quite similar (Table 3).

One remarkable scale effect was found in the relationship between landscape metrics and the bird variables of the investigated farmland (Table 3). Overall species richness and diversity were highly positively associated with landscape metrics at all scales, and the following trend was found: the $R^2$ values increased as the research area increased. Opposite results were found by Mayer and Cameron (2003a), who observed no scale effect for woodland birds, although the scale effect was significant for wetland and successional/scrub bird richness. Bhöning-Gaese (1997) did not find a significant difference between species richness and habitat diversity relationships at very large scales (4 and 16 km$^2$). In addition, it was found that map extent is very important in the characterization of farmland bird communities and landscape metrics, which corresponds with the findings of Mayer and Cameron (2003a, 2003b). More specifically, the 100-metre buffer zone (3.14 hectare) clearly showed the lowest model's $R^2$ values. Therefore we recommend that a larger area (at least 10 hectares) be used for the calculation of landscape metrics.

An understanding of relationships between farmland birds and landscape pattern measured by landscape metrics at different scales and different metrics would be of great value in associating them with agri-environment schemes. It is easy to calculate and measure different metrics, and this information is useful for land use planning and agri-environment schemes, and also in the high nature farmland (HNV) concept. Landscape metrics can also be indicators and good predictors of bird richness and/or diversity.

## 4.2. The influence of small-scale landscape elements on farmland birds (Papers III and IV)

Papers III and IV investigated open farmland ditches as small-scale landscape elements for the description and habitat selection of farmland bird fauna. The ditches quite often divide fields of different types (arable or grassland) in the region. This combination of contrasting field types increases overall habitat heterogeneity and the complementarity of resources on a landscape level (Dunning et al., 1992, Andrén et al., 1997, Tscharntke et al., 2012b).

The results (Paper III) indicated that the importance of ditches for farmland birds in an arable setting as compared to grassland seems to hold true only for ditches with high vegetation (with some bushes or trees). Ditches with high vegetation in arable settings were especially attractive for edge species. Their presence boosts the abundance and also slightly raises the species richness of this group, and therefore also the overall diversity of the bird community. Grassland fields themselves support higher biodiversity (Andow, 1991), including that of birds in the region (Auninš et al., 2001; Herzon et al., 2008).

More detailed auto-ecological studies are needed in order to detect the real relationship between grassy ditches and the bird community. It is plausible that the lack of notable relationship between grassy ditches and bird community stems from the fairly limited ecological effect of such ditches in terms of breeding individuals, which cannot be detected with a generally small sample size (Paper III). The effect may be more subtle, and it may function through a modified breeding performance and population stability rather than the number of breeding individuals in a local field.

Paper IV was the first long-term and large-scale study specifically exploring the population densities and temporal dynamics of breeding farmland birds on different field types, open drainage fields and subsurface drainage fields. The study specifically verified that the two open farmland bird species studied here, Skylark and Meadow Pipit, favour open drainage over subsurface drainage. Both species exhibited an increasing population trend on open drainage fields during the period 2002–2009. The results show the importance of non-cropped in-field habitat elements for biodiversity in agricultural landscapes (Wilson et al., 2005; Billeter et al., 2008). The grassed strips, which may even be as narrow as 0.2–0.3 m as they are for the field drains, are likely to provide safe nesting sites on spring arrival (which are notably absent in crop fields ploughed in spring during the onset of nesting), more diverse and stable food resources (Weibel et al., 2001), enhance nest survival (Wilson, 2001) and therefore contribute to better reproductive success (Haukioja et al., 1985). It has further been demonstrated that the management of such in-field heterogeneity is more important to farmland bird populations than the off-field management of the margins (Butler et al., 2007).

The small passerine species modelled in Paper III (including their young in breeding season) are also a key prey for several raptors, for example Merlin (*Falco columbarius*), Eurasian Sparrowhawk (*Accipiter nisus*), and Montagu's Harrier (*Circus pygargus*) (del Hoyo et al., 1994). Some of these such as Meadow Pipit, Marsh Warbler, Whitethroat, Whinchat, and Yellowhammer (*Emberiza citrinella*) are important host species for Cuckoo (*Cuculus canorus*, Moksnes and Røskaft, 1995; Soler and Møller, 1996; Honza et al., 2001). This indicates that ditches have a wider ecological importance in agricultural landscapes, supporting the next trophic level of bird communities.

Paper IV demonstrated that local trends differ depending on the drainage system. The results by Tiainen and Seimola (2010) further show that the landscape-level distribution of focal species is aggregated in open drainage field habitats. This study also highlights the importance of the remaining open drainage fields. The subsurface draining of these fields may adversely impact the current status of species in open farmland habitats in the region.

## 4.3. Effect on land use and the temporal dynamics of the intra-seasonal variation on farmland birds (Paper V)

Paper V is the first study that presents the long-term exploration of the spatial distribution and intra-seasonal variation of birds associated with a large farmland area in the North Western region of the Russian Federation. The importance of fields for bird use outside the peak breeding season is often neglected in European studies on farmland (exceptions are Delgado and Moreira, 2000; Atkinson et al., 2002; Laiolo, 2004; Brambilla et al., 2009). The role of arable fields for migrating species (Rosin et al., 2011) and those breeding outside farmland can be particularly easily overlooked in studies focused only on the breeding season.

The results of Paper V indicated clear seasonal patterns for farmland birds. For example, numbers pertaining to species richness generally declined on all field types by the end of July, but on arable crops the number of species' already begun to decrease by early June. Thus the usage of arable fields by birds was clearly seasonal. The decline of bird species richness on arable crops coincides with the final sowing of crops by June, when foraging flocks such as geese and waders disappear. The diversity and abundance of farmland birds on grasslands and pastures were high throughout the whole season, mainly represented by species also breeding in such fields. The vegetation structure–the key factor determining the suitability of grasslands for breeding and foraging birds (Wilson et al., 2005)–is kept at moderate levels due to grazing or haying.

The number of individuals steadily declined on abandoned fields and heavily fluctuated on arable fields, and the mean values over the season were similar among the field types. The differential use of arable fields across the whole season, also demonstrated here, stresses the relevance of the mosaic pattern of field use on landscape level (Benton et al., 2003, Tscharntke et al., 2012b). Though the farmland in Gatchina is dominated by grasslands their variety and pockets of arable fields may contribute to the high diversity levels.

Interestingly, was found some apparent shifts in the field-use pattern by the most abundant species as the breeding season progressed. The accessibility of prey was shown to be critical in the use of habitats by birds on farmland (Butler and Gillings, 2004), and may also explain the fact that bird abundance decreased most sharply on abandoned fields. For instance, Skylark numbers were fairly stable on all fields except for abandoned fields, where the species basically disappeared (declined approximately 75%). Some decline in Skylark numbers also happened on grasslands by the end of June. Some of the decline in registrations is likely to be due to a generally cryptic behaviour of the species later into the season. Abandoned fields became more attractive for some species (such as Whinchat, Corncrake, Whitethroat and Marsh Warbler), possibly because haying (usually at the end of June in the region) removes the high vegetation needed for the second breeding attempt (Britschgi et al., 2006). Meadow Pipits were most numerous on arable fields at the spring arrival and very late in the breeding season (the end of July). Our results indicated that Meadow Pipits seemed to explore the arable fields more at the onset of breeding and once the fledglings appeared. For example, it was recently demonstrated that Curlew (*Numenius arquata*) may shift its foraging preference to cereal fields in mid-summer if their prey in non-tilled fields becomes less accessible (de Jong, 2012). The numbers of Starling increase on pastures and grasslands as the season progresses. This may be caused by easier food accessibility and availability (Gibson et al., 1992; Lack, 1992; Tucker et al., 1992; Perkins et al., 2000).

## 4.4. Bird communities among field types (Paper V)

Pastures and multiple-species grasslands were the most preferred field types with some species rarely found elsewhere. Successful breeding of ground-nesting species is, however, possible only under extensive grazing pressure and a single hay harvest, as is currently practiced in North Western Russia. Hay making is usually completed at the end of June but on some fields it extends into July. The early single cut allows ground-nesting birds to lay replacement clutches (Martin, 1995). The practice of rotational pasturing of parcels that allowed for 4 Livestock Units/ha and led to the trampling of virtually all nests was common in parts of the Russian Federation but has largely ceased after the collapse of the collective-farm production system (Sviridova et al., 1999). The preference for such field types is most likely attributable to the structural diversity of their swards and therefore optimal nesting conditions and rich foraging resources (Wilson et al., 2005). Finally, use of such fields was particularly active and prolonged when they were not drained effectively leading to partial flooding in spring and wet patches through the season (Herzon, Marja unpublished data).

A high species diversity and numbers of bird individuals were also documented on the abandoned fields (Paper V), although the effects of land abandonment on birds are complex and may be both positive and negative (Tryjanowski 1999; Tryjanowski et al., 2011). The attractiveness of abandoned fields to some of the true field and edge farmland species increased as the breeding season progressed. Mowing by mid-summer removes high vegetation needed for the second breeding attempt for most such species and therefore some of the pairs are likely to move into abandoned fields (Britschgi et al., 2006). The value of such fields is time-limited, however, due to the rapid vegetation succession. Due to the proximity to Saint Petersburg, the abandonment has been less extensive in the district than elsewhere in North Western Russia. This may explain the sustained utilisation of such fields even by open field species.

Fields under spring and winter cereals and root vegetables were associated with the lowest species richness of breeding birds. This pattern is similar for most European agricultural landscapes (Tucker and Evans, 1997), also in North Eastern Europe (Paper III). Disturbance due to the mechanical working of fields at the onset of breeding, homogeneous sward, chemical treatments and a shortage of weeds and invertebrate groups may all contribute to this pattern (Newton, 2004). The bird community on sown and mono-specific grasslands was not distinguished from that on cereal and root crop fields. It is thus plausible that the effect of the homogeneous sward, which is also indirectly responsible for limited diversity in invertebrate prey, could be the key causal factor in this region because inputs on fields are low. The result of the relatively poor breeding habitat value of arable fields even under extensive production resembles the pattern observed in the Eurasian steppe zone (Oparin, 2008; Kamp et al., 2011).

# 5. CONCLUSIONS AND POLICY RECOMMENDATIONS

Papers I and II clearly established the important role of landscape structure for farmland birds. In Papers III and IV, the research clearly demonstrated that common landscape elements in Northern Europe – open ditches and their margins – can be used as nesting sites, shelter and feeding places for farmland birds. Ditches with high vegetation, containing bushes and trees at their margins, considerably enhance the diversity of farmland birds, especially in a crop-dominated landscape. These results are highly relevant for several of the Eastern and Northern European countries (such as the Baltic countries, Finland and North Western Russia), which have similar structures and levels of production intensity, and thus the results have a direct policy application. The replacement of open ditches with subsurface pipes is an ongoing process (for instance in Estonia, Latvia, Poland and Finland) that is subsidised by governments. The existing national policy in these countries should be changed to retain the remaining open ditches, at least in regions with already prevailing subsurface drainage. This was presented as a more cost-efficient solution for the conservation of farmland bird diversity as compared to the total fallowing of such fields, which is privately and socially a more expensive option (Saikkonen et al., re-submitted manuscript).

The productivity potential of the remaining fields drained with open ditches is likely to be sub-optimal and below the national average (the most productive and best-positioned fields had been sub-drained first). On such fields, a certain level of production could be maintained while supporting farmland bird populations. It is of pressing importance that the continuing homogenization of landscapes across Northern Europe does not lead to the dismantling of the existing open ditch networks, especially in crop-dominated landscapes. The removal of state support for the replacement of ditches is likely to be a sufficient policy measure to retain open ditches. In regions with high agricultural revenues, targeted agri-environmental support may be a necessary additional incentive. All Northern European EU Member States should insure that agri-environmental schemes contain a requirement for sufficiently wide input-free grassy margins and some tree and bush vegetation along the ditches.

An understanding of the relationships between farmland birds, land use (Paper V) and landscape pattern measured by landscape metrics at different scales (Paper II) would be of great value in associating them with agri-environment schemes. Paper V clearly indicates the important role of different land use types and these temporal dynamics. This is clear evidence that agri-environment schemes in all Northern European EU Member States should contain measurements to assure mixed farming, diverse crop production and crop rotation plans as well as grazing. In addition, agri-environmental schemes should preserve ecologically valuable areas (such as ditches, old farmyards, tree groups, shrubs, etc.). These are important ecologically compensating elements of agricultural landscapes that support biological diversity (Papers III and IV). Only in this way will it be possible to retain the agricultural biodiversity of Northern Europe, which is still richer than that of the Central and Western European countries (Sutcliffe et al., submitted manuscript).

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# SUMMARY IN ESTONIAN

## Põllulindude seosed maakasutuse ja maastiku struktuuriga Põhja-Euroopas

Käesolevas doktoritöös hinnatakse maastiku struktuuri ja maakasutuse mõju põllulindude liigirikkusele ja elupaigavalikule. Selleks kasutati erinevaid andmestikke, mis hõlmasid nii Balti riike, Soomet kui ka Loode-Venemaad. Andmed on kogutud aastatel 2002–2011.

Töö sissejuhatavas osas antakse maastikuindeksite näitel ülevaade elurikkuse seostest maastiku struktuuriga (I artikkel). Maastikuindekseid on kasutatud varasemalt peamiselt seepärast, et hinnata keskkonnamuutuse mõju lindude liigirikkusele. Näiteks on uuringud viidanud sellele, et nii lindude liigirikkusele kui ka rohkusele on oluline mitmekesine maakasutus. Lisaks on varasemad uuringud näidanud, et maakasutuse konfiguratsioon pole linnustiku mitmekesisuse või rohkuse näitajate kirjeldamisel eriti oluline. Ainult servatiheduse puhul on ilmnenud statistiliselt olulised positiivsed seosed linnustiku rohkusega.

Detailsemalt uuriti doktoritöös kolme maastikuindeksi (eraldiste tihedus, servatihedus ja Shannoni maastiku mitmekesisuse indeks) mõju lindude liigirikkusele ja mitmekesisusele Eesti uurimisaladel, mis paiknesid kolmes maakonnas: Valga-, Jõgeva- ja Lääne-Virumaal. Igal uurimisalal valiti 10 juhuslikku uurimisruutu (igal uurimisruudul paiknes 4 loenduspunkti), kus teostati punktloenduse metoodikaga kaks (2002. ja 2004. aastal) pesitsusaegset põllulindude loendust. Maastikuindeksid arvutati kolmel erineval tasandil: 100 m ja 200 m puhvritele ümber loenduspunktide ning uurimisruutudele kogu ulatuses. Linnustiku näitajatest kasutati uuringus lindude liigirikkust ning Shannoni indeksit. Lisaks arvutati linnunäitajad põllulindude kohastumuste järgi: avamaastiku, serva-, metsa- ja aialindude liikide arv. Linnustiku näitajate seoseid maastikuindeksitega analüüsiti üldistatud aditiivsete segamudelite abil kolmel erineval tasandil (100 m ja 200 m puhvrid ning uurimisruutude tasand) eraldi.

Saadud tulemused viitasid, et uuritud tasanditel olid linnustiku üldnäitajad (üldine liigirikkus ja lindude Shannoni indeks) kõikide maastikuindeksitega seotud. Praktiliselt kõikidel uuritud juhtudel tuli välja trend, et suurema pindala kohta arvutatud maastikuindeksid korreleerusid lindude muutujatega tugevamini. Mudelite varieeruvus oli madalam 100 m puhvriga loenduspunktide puhul ja kõrgem ruutkilomeetristel uurimisaladel. See viitab sellele, et liiga väike ala ümber loenduspunkti ei pruugi anda piisavalt adekvaatset infot lindude jaoks oluliste maastikustruktuuride kohta, mis osutab skaalast tulenevale efektile.

Seega kinnitab käesoleva uurimistöö maastikuindeksite analüüs (II artikkel) varasemaid tulemusi (ülevaateartikkel 1), et mitmekesisem ja fragmenteerunum maakasutus ja maastiku struktuur võivad suurendada kohalikku liigirikkust. Lindudel on nii rohkem võimalusi erinevaid nišše kasutada ning kasvab ka elupaikade ja mikroelupaikade arv. Näiteks suurendab fragmenteerumine servaelupaikade ulatust, mis on väga oluline mitmetele põllumajandusmaastiku linnuliikidele.

III artiklis uuriti kuivenduskraavide (lagedad kraavid ilma puude ja põõsasteta ning puude ja põõsastega kraavid) mõju üldisele lindude liigirikkusele, rohkusele ning arvukamate liikide asustustihedusele, pidades silmas ka maakasutuse erinevusi. Uurimisalad paiknesid nii Eestis, Lätis kui ka Leedus ning olid valitud sarnase metoodika abil kui II artiklis. Ka nendel aladel teostati punktloenduse metoodikaga 2002. a pesitsusaegsed linnuloendused. Analüüsimisel arvestati järgnevaga: maakasutus (rohumaad, teraviljapõllud, segaelupaik), põõsastega kraavide pikkus, põõsasteta kraavide pikkus, puistu pindala, kaugus põlluservast, kaugus lähimast teest ning kraavide pikkuse ning maakasutuse koosmõju. Andmeid analüüsiti üldistatud lineaarsete mudelite ning liigseid nulle lubavate mudelitega.

III artikli tulemused näitasid, et lindude üldine liigirikkus oli teraviljapõldudel madalam kui rohumaadel või segaelupaikades. See viitab selliste alade intensiivsemale majandamisele, mis muudab ilmselt elupaiga väärtusetumaks. Samuti leiti paljudel juhtudel, et suurematest teedest kaugemal linnunäitajad suurenesid. Järelikult väldivad põllulinnud suuremaid teid. Tehti oluline tähelepanek: mida pikemad olid puude ja põõsastega kraavid teraviljapõldudel, seda kõrgem oli üleüldine lindude liigirikkus, servaliikide liigirikkus ning isendite rohkus neil aladel. Rohumaadel ja segaelupaikades sellist seost ei esinenud. See viitab omakorda sellele, et puude ja põõsastega kraavid on eriti olulised teraviljapõldudel, pakkudes mitmekesisema maastiku struktuuriga elupaika, paremaid varje- ja pesitsuskohti ning ilmselt ka rikkalikumat toiduvalikut. Tulemused näitasid, et ka üksikute liikide (pruunselg-põõsalind *Sylvia communis*, võsa-ritsiklind *Locustella naevia*, kiivitaja *Vanellus vanellus*) arvukus oli teraviljapõldudel suurem, kui seal esinesid puude ja põõsastega kraavid.

IV artikli eesmärgiks oli hinnata kahe tüüpilise põllulinnu (põldlõokese *Alauda arvensis* ja sookiuru *Anthus pratensis*) populatsioonidünaamikat kuivenduskraavidega ning -kraavideta (drenaažkuivendusega) põldudel. Selleks kasutati Soome riiklikku põllumajandusseire andmestikku aastatest 2002–2009. Linnuloendused teostati territooriumite kaardistamise meetodiga ning saadud andmeid analüüsiti üldiste aditiivsete segamudelitega, lähtudes eeldusest, et linnuliikide populatsioonidünaamika ei ole ajas lineaarne. Populatsioonidünaamika väljaselgitamise mudelid sisaldasid järgnevaid tunnuseid: kuivendustüüp (avatud kraavidega või kuivenduskraavideta drenaažkuivendusega põld), maakasutus (teraviljapõld või rohumaa), puistu pindala ja põllu keskkoha koordinaadid. Lisaks eelnevale sisaldasid mudelid aasta ja kuivendustüübi ning kuivendustüübi ja maakasutuse koosmõju.

Tulemused näitasid, et avatud kraavidega põldudel põldlõokese arvukus suurenes. Drenaažkuivendusega põldudel, kus kuivenduskraave ei esinenud, sellist seost ei leitud (IV artikkel). Samuti suurenes sookiuru arvukus põldudel, kus esinesid avatud kuivenduskraavid. Drenaažkuivendusega põldudel taaskord sellist seost ei leitud. Leiti küll langev, kuid statistiliselt mitteoluline trend.

Kraavidel kui inimloodud maastikuelementidel on põllumajandusmaastikus ilmselgelt väga suur roll. Näiteks mitmed kraavide servades pesitsevad värvulised (pruunselg-põõsalind, soo-roolind *Acrocephalus palustris*) on väga olulised “võõrustajad” käole *Cuculus canorus*, kes muneb nende liikide pesadesse ning laseb nendel liikidel oma pojad üles kasvatada. See viitab kraavidele kui olulistele mikroelupaikadele, mis on seotud ka kõrgemate troofiliste tasemetega. Kindlasti ei tohiks avatud kuivenduskraave põllumajandusmaastikust eemaldada. Kraavide servaalad (kuni 10 m laiuselt) peaksid olema väetistest ja taimekaitsevahenditest puutumata, et soodustada elurikkuse säilimist põllumajandusmaastikus.

V artikli eesmärgiks oli analüüsida põllulindude liigirikkust, rohkust ja liikide asustustihedusi erinevates põllukultuurides. Lisaks analüüsiti põllukultuuride kasutust pikema perioodi vältel (aprilli lõpust juuli lõpuni), kuna enamik uurimusi põllulindude kohta on enamasti keskendunud ainult kitsale pesitsusajale (aprilli lõpust juuni keskpaigani). Analüüsiks kasutati Loode-Venemaal kogutud andmestikku ajavahemikul 2006–2011. Linnuloendused teostati neil aladel transektloenduse metoodikaga. Kogutud andmeid analüüsiti üldiste aditiivsete segamudelite abil, lähtudes eeldusest, et linnuliikide populatsioonidünaamika pesitsushooaja jooksul ei ole lineaarne. Mudelid sisaldasid järgnevaid tunnuseid: maakasutus (teraviljapõld, rohumaa, karjamaa, söötis põllumaa) ja maakasutuse ning pesitsushooaja koosmõju. Lisaks võrreldi liikide asustustihedust põllukultuuride kaupa ning uuriti linnuliikide kompositsiooni põllukultuuridest lähtuvalt.

Põllukultuuride analüüs (V artikkel) tõi välja, et nii lindude liigirikkuse ja rohkuse näitajad kui ka kõige tavalisemate põllulindude asustustihedused olid valdavalt kõige suuremad söötis põldudel, karjamaadel ja mitmeliigilistel rohumaadel. Oluliselt madalamad olid samad näitajad juurviljakultuurides, üheliigilistel rohumaadel ja teraviljapõldudel.

Pesitushooajal lindude liigirikkus reeglina langes kõikides uuritud elupaikades, kuid suurim oli see langus teraviljapõldudel, kus liikide arv alates juuni algusest oluliselt vähenes. Isendite arv vähenes silmnähtavalt söötis põllumaadel ning kõikus teraviljapõldudel. Lisaks eelnevale leiti mitmete liikide puhul pesitsushooaja jooksul märkimisväärsed arvukuse kõikumised erinevates põllukultuurides. Näiteks põldlõokese arvukus oli stabiilne kõikides elupaikades, kui välja arvata söötis põllumaad, kus liigi arvukus vähenes ligikaudu 75%. Seevastu sookiuru arvukus oli teraviljapõldudel kõrge nii pesitsussesooni alguses kui ka selle lõpus. Kuldnokkade arvukus kasvas pesitsussesooni lõpus märgatavalt karjamaadel ja rohumaadel.

Seega näitavad antud uurimistöö tulemused selgelt, et lindudele on oluline maastiku mitmekesisus suuremal pindalal (artiklid 1 ja 2). Mikroelupaikadest on väga olulised kraavide servaalad (artiklid 3 ja 4) ning lindudele on väga oluline ka mitmekesine maakasutus, kuna linnud kasutavad pesitsustsükli jooksul erinevate põllukultuuridega põlde (artikkel 5).

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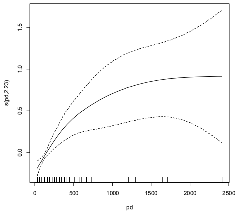
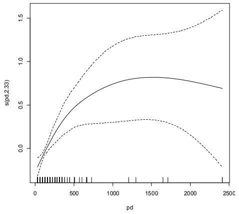
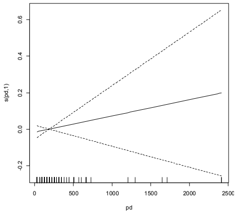
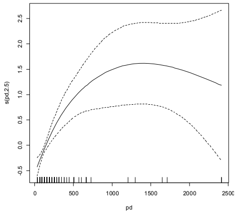
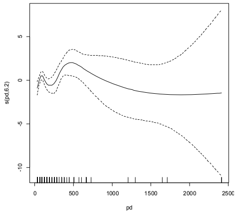
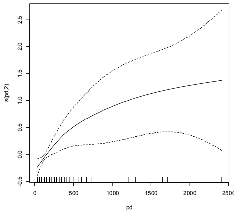
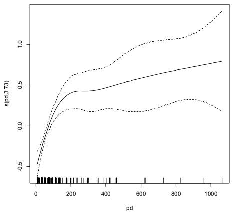
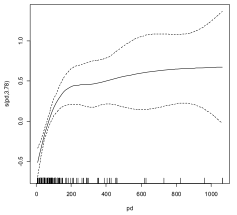
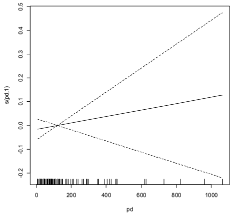
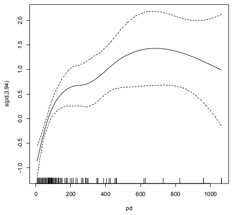
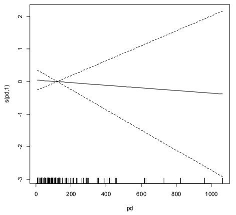
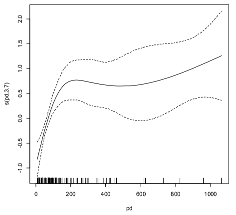
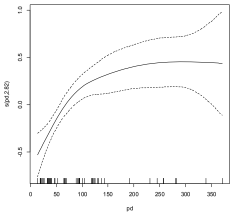
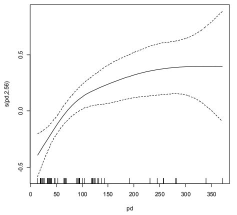
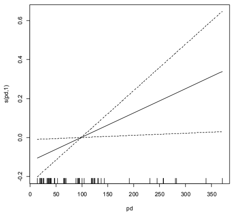
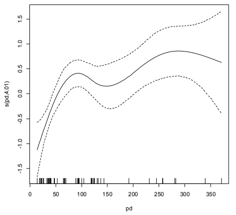
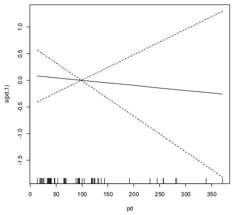
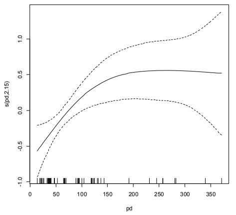
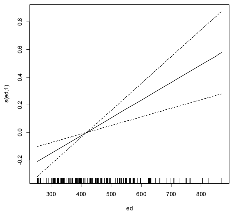
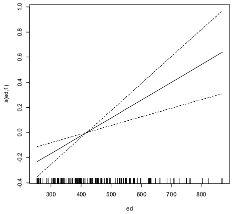
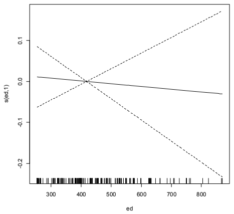
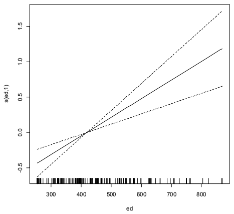
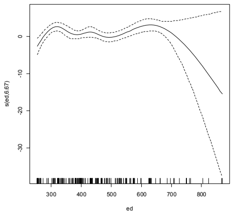
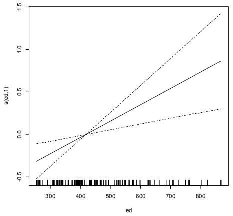
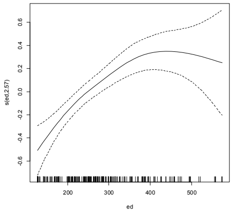
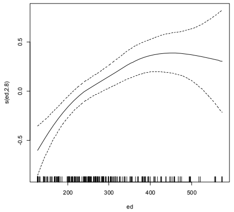
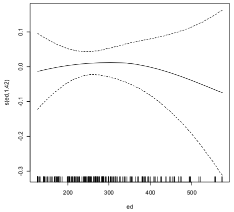
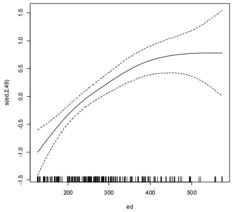
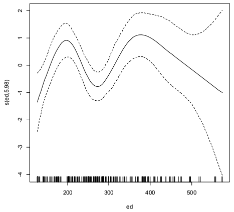
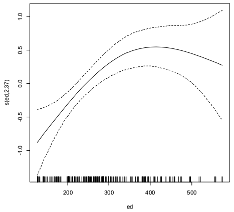
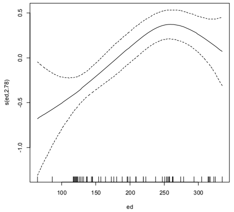
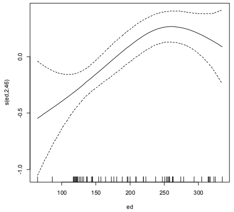
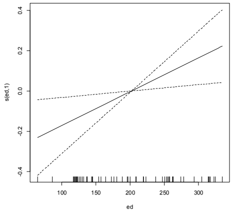
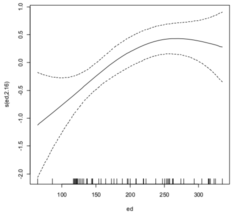
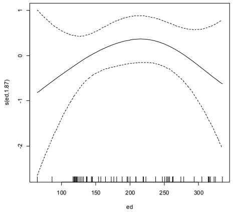
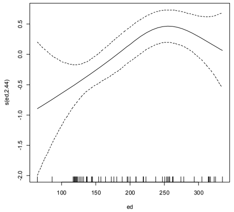
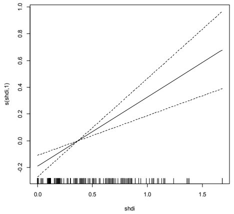
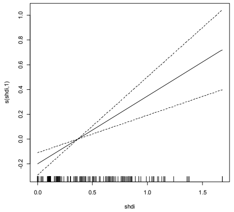
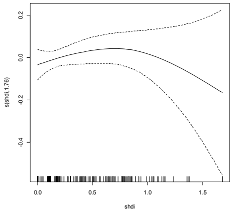
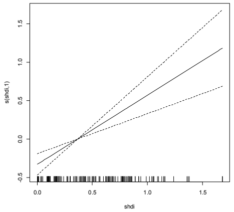
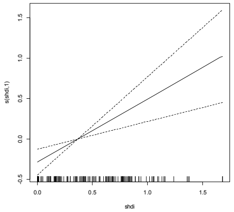
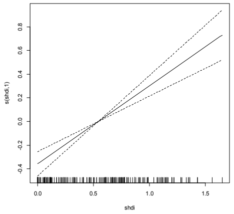
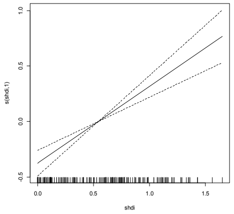
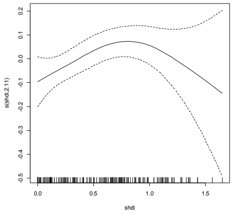
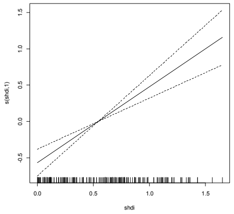
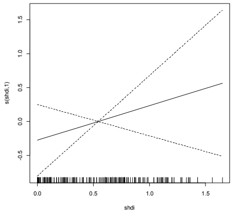
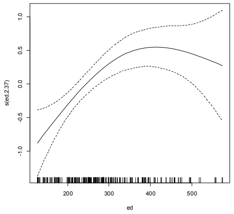
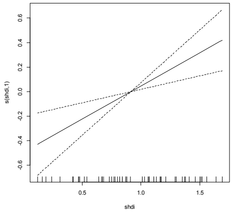
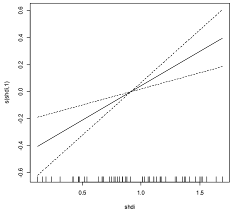
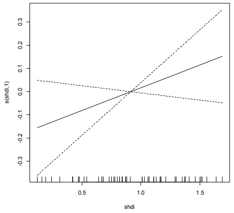
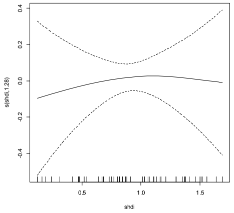
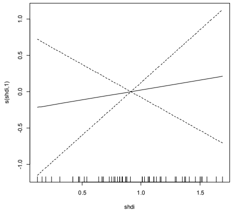
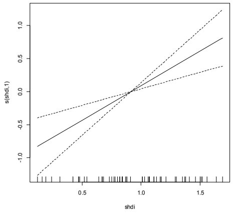
Helsinki – Tartu – Göttingen (2011–2013)

# SUPPLEMENTARY MATERIAL

**Supplementary material, Table 1**. Estimated smoothers trends for the different spatial scales and bird variables of the generalized additive mixed models. The model smoother (solid line) is the estimate of bird variables change (log-scale) with 95% point-wise confidence intervals (dotted line). The smoother is centred at 0. The y-axis shows the contribution of the smoother to the fitted values.

| **Land-scape indices** | **Scale** | **No. of breeding species** | **Shannon's H** | **Number of true field species** | **Number of edge species** | **Number of farmyard species** | **Number of dendrophilous species** |
|---|---|---|---|---|---|---|---|
| PD | 100 m buffer zone |  |  |  |  |  |  |
| PD | 200 m buffer zone |  |  |  |  |  |  |
| PD | 1 km$^2$ research square |  |  |  |  |  |  |

| Land-scape indices | Scale | No. of breeding species | Shannon’s H | Number of true field species | Number of edge species | Number of farmyard species | Number of dendrophilous species |
|---|---|---|---|---|---|---|---|
| ED | 100 m buffer zone |  |  |  |  |  |  |
| ED | 200 m buffer zone |  |  |  |  |  |  |
| ED | 1 km$^2$ research square |  |  |  |  |  |  |

| Land-scape indices | Scale | No. of breeding species | Shannon’s H | Number of true field species | Number of edge species | Number of farmyard species | Number of dendrophilous species |
|---|---|---|---|---|---|---|---|
| SHDI | 100 m buffer zone |  |  |  |  | Model crashed |  |
| SHDI | 200 m buffer zone |  |  |  |  |  |  |
| SHDI | 1 km$^2$ research square |  |  |  |  |  |  |

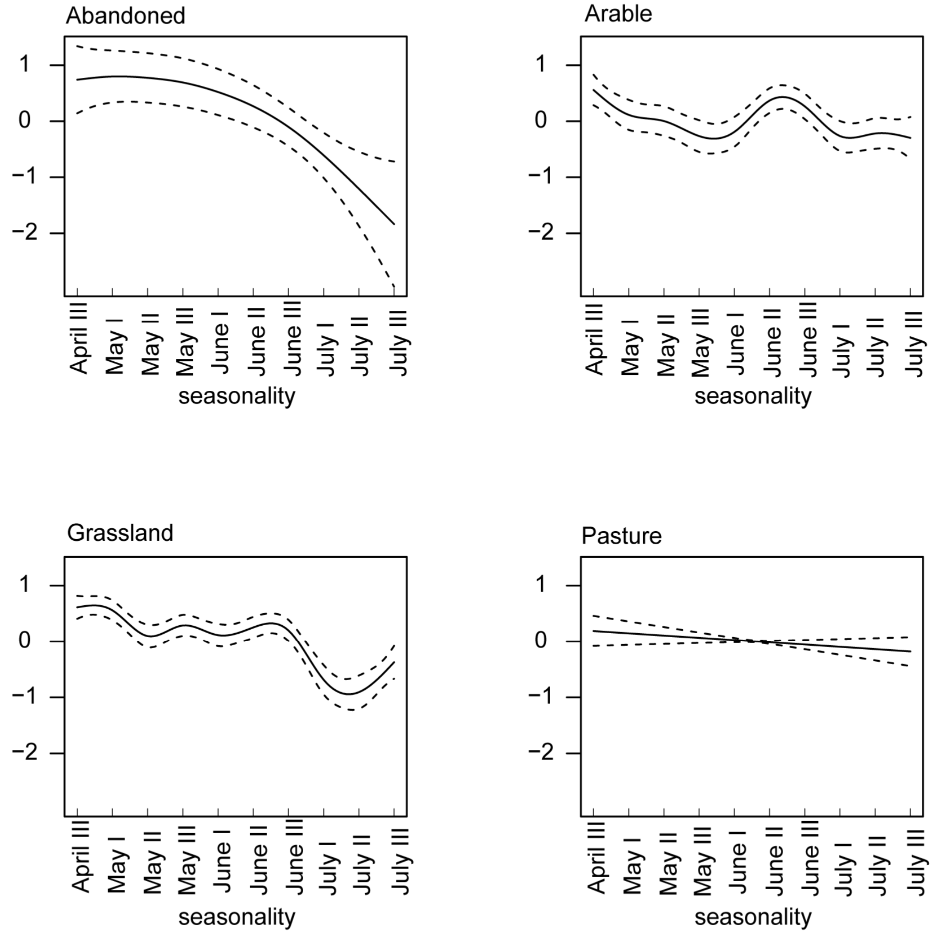
**Supplementary material, Table 2**. Means and standard deviations (SD) over the years of 2008, 2010 and 2011of the farmland bird species standardized by the transect length within each field and by the field types. Field types: root vegetables (RV), spring and winter cereal (SWC), first-year sown grasses (SG), monospecific grassland (MG), multiple-species grassland (MSG), pasture (P), abandoned arable land (AAL) and abandoned grassland (AG). The highest densities (within 75–100 % of the highest count) among the field types are shown in bold. The figure after the species name gives the number of registration.

| **Variable** | | **RV** | **SWC** | **SG** | **MG** | **MSG** | **P** | **AAL** | **AG** |
|---|---|---|---|---|---|---|---|---|---|
| Species richness | mean | 2.98 | 5.91 | 4.46 | 4.93 | 9.64 | 10.75 | 9.65 | **14.09** |
| | SD | 3.32 | 4.89 | 3.49 | 3.92 | 5.08 | 6.86 | 3.17 | 7.45 |
| Number of individuals | mean | 10.9 | 29.9 | 14.16 | 20.34 | 41.05 | **69.66** | 47.23 | 52.54 |
| | SD | 14.28 | 37.25 | 11.67 | 22.09 | 30.62 | 47.92 | 31.36 | 32.35 |
| | | | | | | | | | |
| Acrocephalus dumetorum 208 | mean | 0.05 | 0.09 | 0.05 | 0.1 | 0.4 | 0.21 | 0.35 | **1.55** |
| | SD | 0.33 | 0.55 | 0.18 | 0.48 | 0.9 | 0.65 | 0.58 | 1.94 |
| Acrocephalus palustris 491 | mean | 0 | 0.12 | 0.13 | 0.16 | 0.93 | 0.57 | 1.4 | **4** |
| | SD | 0 | 0.59 | 0.36 | 0.67 | 1.61 | 1.41 | 0.99 | 4.18 |
| Acrocephalus schoenobaenus 134 | mean | 0.03 | 0.06 | 0.16 | 0 | 0.26 | 0.21 | **1.74** | 0.65 |
| | SD | 0.21 | 0.47 | 0.61 | 0 | 1.18 | 0.5 | 1.21 | 1.49 |
| Alauda arvensis 4418 | mean | 1.4 | 5.89 | 4.41 | 4.88 | **7.93** | **9.05** | 7.5 | 6.76 |
| | SD | 4.11 | 6.96 | 3.62 | 5.66 | 6.11 | 6.68 | 6.01 | 7.57 |
| Anthus pratensis 777 | mean | 0.03 | 0.06 | 0.16 | 0.7 | 1.67 | 1.61 | **3.28** | 2.16 |
| | SD | 0.21 | 0.43 | 0.64 | 3.16 | 2.88 | 2.26 | 2.14 | 4.32 |
| Asio flammeus 32 | mean | 0 | 0 | 0 | 0 | 0.06 | 0 | **0.35** | 0.11 |
| | SD | 0 | 0 | 0 | 0 | 0.25 | 0 | 0.58 | 0.34 |
| Buteo buteo 75 | mean | 0 | 0 | 0 | 0.02 | 0.14 | 0.1 | **0.35** | 0.09 |
| | SD | 0 | 0 | 0 | 0.13 | 0.39 | 0.32 | 0.38 | 0.33 |
| Carduelis cannabina 101 | mean | 0 | **0.76** | 0.19 | 0 | 0.11 | 0 | 0 | 0 |
| | SD | 0 | 1.81 | 0.73 | 0 | 0.59 | 0 | 0 | 0 |
| Carduelis carduelis 47 | mean | 0 | 9 | 0 | 0 | 0.1 | 0 | **1.16** | 0 |
| | SD | 0 | 0.65 | 0 | 0 | 0.64 | 0 | 2.18 | 0 |
| Carduelis chloris 66 | mean | 0 | 8 | 0 | 0.08 | 0.1 | **0.18** | 0.12 | 0 |
| | SD | 0 | 0.4 | 0 | 0.49 | 0.71 | 1.04 | 0.29 | 0 |
| Carpodacus erythrinus 210 | mean | 0 | 0.09 | 0.21 | 0.16 | 0.3 | 0.09 | 0.59 | **2.17** |
| | SD | 0 | 0.57 | 0.65 | 0.85 | 0.91 | 0.39 | 0.94 | 3.86 |
| Ciconia ciconia 31 | mean | 0 | 0 | 0 | 0 | **0.08** | 0 | 0 | 0 |
| | SD | 0 | 0 | 0 | 0 | 0.54 | 0 | 0 | 0 |
| Circus aeruginosus 31 | mean | 0 | 0 | 0 | 0.03 | 0.04 | **0.08** | 0.06 | 0.01 |
| | SD | 0 | 0 | 0 | 0.17 | 0.2 | 0.31 | 0.14 | 0.05 |
| Circus cyaneus 91 | mean | 0 | 0.02 | 0 | 0.08 | **0.18** | 0.11 | 0 | 0.02 |
| | SD | 0 | 0.24 | 0 | 0.29 | 0.44 | 0.26 | 0 | 0.1 |
| Circus macrourus 1 | mean | 0 | 0 | 0 | 0 | **0.001** | 0 | 0 | 0 |
| | SD | 0 | 0 | 0 | 0 | 0.04 | 0 | 0 | 0 |
| Circus pygargus 22 | mean | 0 | 0 | 0 | 0 | **0.06** | 0.02 | 0 | 0 |
| | SD | 0 | 0 | 0 | 0 | 0.26 | 0.1 | 0 | 0 |

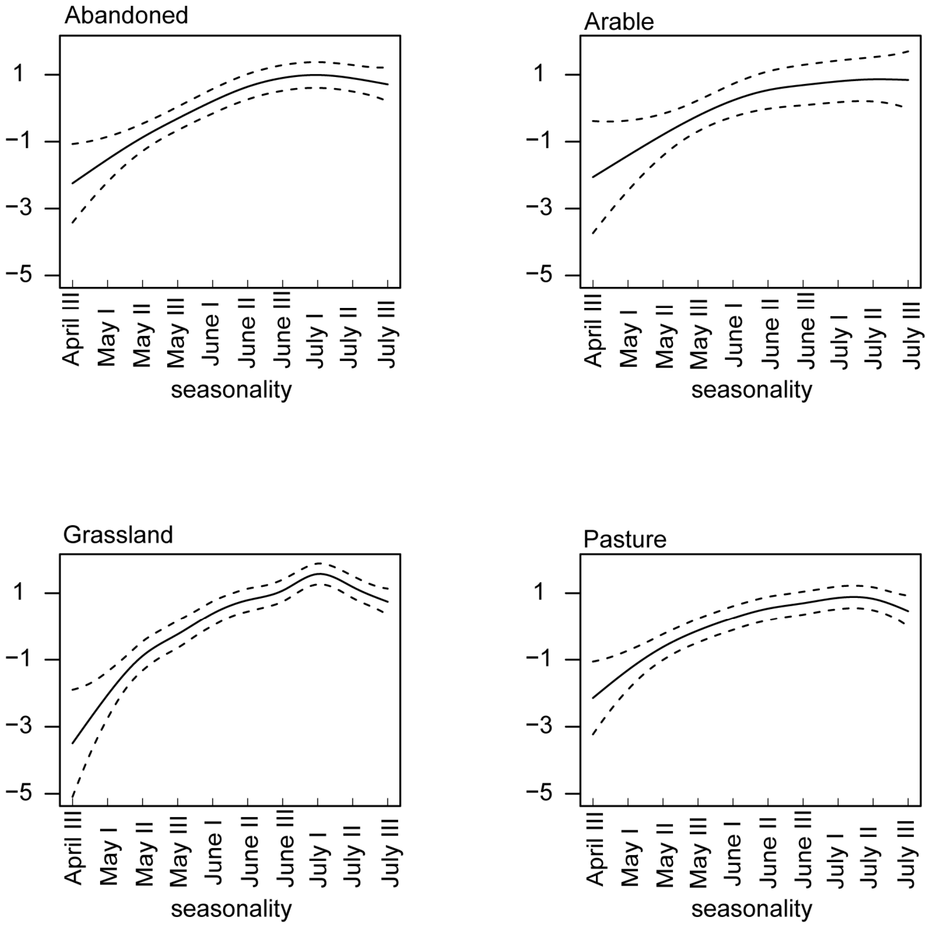
| Variable | | RV | SWC | SG | MG | MSG | P | AAL | AG |
|---|---|---|---|---|---|---|---|---|---|
| Columba livia 180 | mean | 0.19 | **1.07** | 0.16 | 0.61 | 0.18 | **0.86** | 0.57 | 0 |
| | SD | 0.97 | 3.61 | 0.63 | 3.7 | 1.09 | 3.89 | 1.41 | 0 |
| Columba palumbus 363 | mean | 0.08 | 0.8 | 0.24 | 0.44 | 0.55 | 0.22 | **1.75** | **1.39** |
| | SD | 0.45 | 2.29 | 0.92 | 1.37 | 1.5 | 0.98 | 1.97 | 3.73 |
| Corvus corone cornix 514 | mean | 0.36 | 0.62 | 0.52 | 0.18 | 1 | **2.52** | 0.47 | 0.29 |
| | SD | 1.11 | 1.41 | 1.44 | 0.58 | 2.02 | 4.39 | 0.73 | 1.26 |
| Corvus frugilegus 1678 | mean | 0.83 | 2.96 | 1.03 | 0.31 | 1.56 | **9.68** | 5.56 | 0.15 |
| | SD | 2.33 | 9.34 | 3.68 | 1.77 | 4.01 | 16.47 | 9.09 | 0.9 |
| Corvus monedula 899 | mean | 0.76 | 1.92 | 0.6 | 0.46 | 0.76 | **6.36** | 0.24 | 0 |
| | SD | 2 | 3.62 | 1.77 | 1.6 | 2.39 | 13.19 | 0.37 | 0 |
| Coturnix coturnix 10 | mean | 0 | 0 | 0 | 0 | **0.02** | 0 | 0 | 0 |
| | SD | 0 | 0 | 0 | 0 | 0.13 | 0 | 0 | 0 |
| Crex crex 365 | mean | 0 | 0.01 | 0.08 | 0.27 | **0.74** | 0.32 | **0.82** | **0.8** |
| | SD | 0 | 0.11 | 0.31 | 0.6 | 0.95 | 0.61 | 0.72 | 1.16 |
| Emberiza citrinella 98 | mean | 0.13 | 0.2 | 0.39 | 0 | 0.16 | 2 | 0.35 | **0.88** |
| | SD | 0.74 | 1.11 | 0.92 | 0 | 0.61 | 0.18 | 0.58 | 1.56 |
| Emberiza schoeniclus 78 | mean | 0.03 | 0.01 | 0 | 0 | 0.08 | 0.09 | **1.5** | 1.12 |
| | SD | 0.21 | 0.14 | 0 | 0 | 0.54 | 0.33 | 2.7 | 2.53 |
| Falco tinnunculus 67 | mean | 0 | 0 | 0 | 0.1 | 0.13 | 0.17 | **0.58** | 0 |
| | SD | 0 | 0 | 0 | 0.53 | 0.48 | 0.51 | 0.92 | 0 |
| Gallinago gallinago 50 | mean | 0 | 0 | 0 | 0 | 0.09 | 0.07 | 0 | **0.24** |
| | SD | 0 | 0 | 0 | 0 | 0.62 | 0.34 | 0 | 0.66 |
| Gallinago media 1 | mean | 0 | 0 | 0 | 0 | **0.002** | 0 | 0 | 0 |
| | SD | 0 | 0 | 0 | 0 | 0.03 | 0 | 0 | 0 |
| Lanius collurio100 | mean | 0 | 0 | 0 | 0.07 | 0.17 | 0 | 0.23 | **1.33** |
| | SD | 0 | 0 | 0 | 0.44 | 0.63 | 0 | 0.57 | 2.88 |
| Limosa limosa 24 | mean | 0 | 0 | 0 | 0 | **0.05** | 0.01 | 0 | 0.03 |
| | SD | 0 | 0 | 0 | 0 | 0.38 | 0.07 | 0 | 0.2 |
| Locustella naevia 451 | mean | 0 | 0.14 | 0 | 0.33 | 0.85 | 0.64 | 1.87 | **3.45** |
| | SD | 0 | 0.71 | 0 | 1.49 | 1.5 | 1.3 | 1.5 | 4.36 |
| Motacilla flava 490 | mean | 0 | 0.02 | 0 | 0.48 | 0.95 | **1.71** | 0.46 | 0.2 |
| | SD | 0 | 0.12 | 0 | 1.61 | 2.41 | 3.11 | 0.72 | 0.86 |
| Numenius arquata 458 | mean | 0.03 | 0.19 | 0.16 | 0.14 | 0.72 | **1.24** | 0.24 | 0.37 |
| | SD | 0.21 | 1.06 | 0.43 | 0.42 | 1.15 | 1.25 | 0.37 | 0.99 |
| Numenius phaeopus 11 | mean | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | **0.1** |
| | SD | 0 | 0 | 0 | 0 | 0.1 | 0.04 | 0 | 0.37 |
| Oenanthe oenanthe 48 | mean | 0 | 0.06 | 0.16 | 0 | 0.07 | **0.21** | 0 | 0.16 |
| | SD | 0 | 0.47 | 0.61 | 0 | 0.41 | 0.68 | 0 | 0.72 |
| Passer domesticus 166 | mean | 1.09 | 0.36 | 0 | 0.72 | 0.1 | 0.44 | 0 | **1.66** |
| | SD | 3.02 | 2.02 | 0 | 5.26 | 0.89 | 2.94 | 0 | 6.01 |
| Passer montanus 153 | mean | **1.06** | 0.29 | 0 | 0.1 | 0.26 | 0.59 | 0 | 0.68 |
| | SD | 4.07 | 1.12 | 0 | 0.83 | 1.63 | 3.08 | 0 | 2.53 |
| Perdix perdix 4 | mean | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | **0.02** |
| | SD | 0 | 0 | 0 | 0 | 0.07 | 0 | 0 | 0.1 |
| Pica pica 111 | mean | 0.01 | 0.08 | 0 | 0.03 | 0.2 | 0.24 | 0.24 | **0.62** |
| | SD | 9 | 0.71 | 0 | 0.15 | 0.97 | 0.72 | 0.37 | 2.14 |
| Saxicola rubetra 2289 | mean | 0.06 | 0.25 | 0.74 | 1.57 | **4.94** | 3.51 | **5.97** | **5.92** |
| | SD | 0.41 | 0.96 | 1.3 | 4.33 | 4.52 | 3.63 | 4.45 | 4.05 |
| Sturnus vulgaris 1155 | mean | 0.4 | 0.47 | 0 | 0.92 | 1.64 | **9.66** | 0.59 | 0.95 |
| | SD | 1.7 | 2.51 | 0 | 5.49 | 4.93 | 15.07 | 1.45 | 4.33 |

| **Variable** | | **RV** | **SWC** | **SG** | **MG** | **MSG** | **P** | **AAL** | **AG** |
|---|---|---|---|---|---|---|---|---|---|
| Sylvia communis 1042 | mean | 0.12 | 0.33 | 0.66 | 0.97 | 2.25 | 1.22 | 2.58 | **5.2** |
| | SD | 0.72 | 1.13 | 1.51 | 3.73 | 2.91 | 1.77 | 2.09 | 5.73 |
| Tetrao tetrix 16 | mean | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | **0.35** |
| | SD | 0 | 0 | 0 | 0 | 0.16 | 0 | 0 | 1.26 |
| Tringa totanus 43 | mean | 0 | 0 | 0 | 0 | 0.08 | **0.34** | 0 | 0.02 |
| | SD | 0 | 0 | 0 | 0 | 0.46 | 1.17 | 0 | 0.1 |
| Turdus pilaris 2527 | mean | 0.62 | 2.3 | 1.24 | 2.11 | 4.7 | **9.08** | 3.97 | 6.33 |
| | SD | 2.32 | 4.89 | 2.98 | 4.62 | 6.37 | 17.38 | 3.8 | 7.68 |
| Vanellus vanellus 2353 | mean | 1.97 | 4.83 | 2.7 | 1.91 | 3.33 | **7.44** | 0.71 | 1.69 |
| | SD | 3.52 | 6.23 | 2.88 | 3.06 | 4.28 | 8.01 | 1.1 | 3.65 |

**Supplementary material, Figure 1**. Estimated changes in Skylark registration trends according to the timing of the count on abandoned fields, arable fields, grassland and pastures during the period from 26 April to 28 July 2006. The model smoother (solid line) is the estimate of log-scale population change with 95% point-wise confidence intervals (dotted line). The smoother is centred at 0. The y-axis shows the contribution of the smoother to the fitted values.



**Supplementary material, Figure 2**. Estimated changes in Whinchat registration trends according to the timing of the count on abandoned fields, arable fields, grassland and pastures during the period from 26 April to 28 July 2006. The model smoother (solid line) is the estimate of log-scale population change with 95% point-wise confidence intervals (dotted line). The smoother is centred at 0. The y-axis shows the contribution of the smoother to the fitted values.



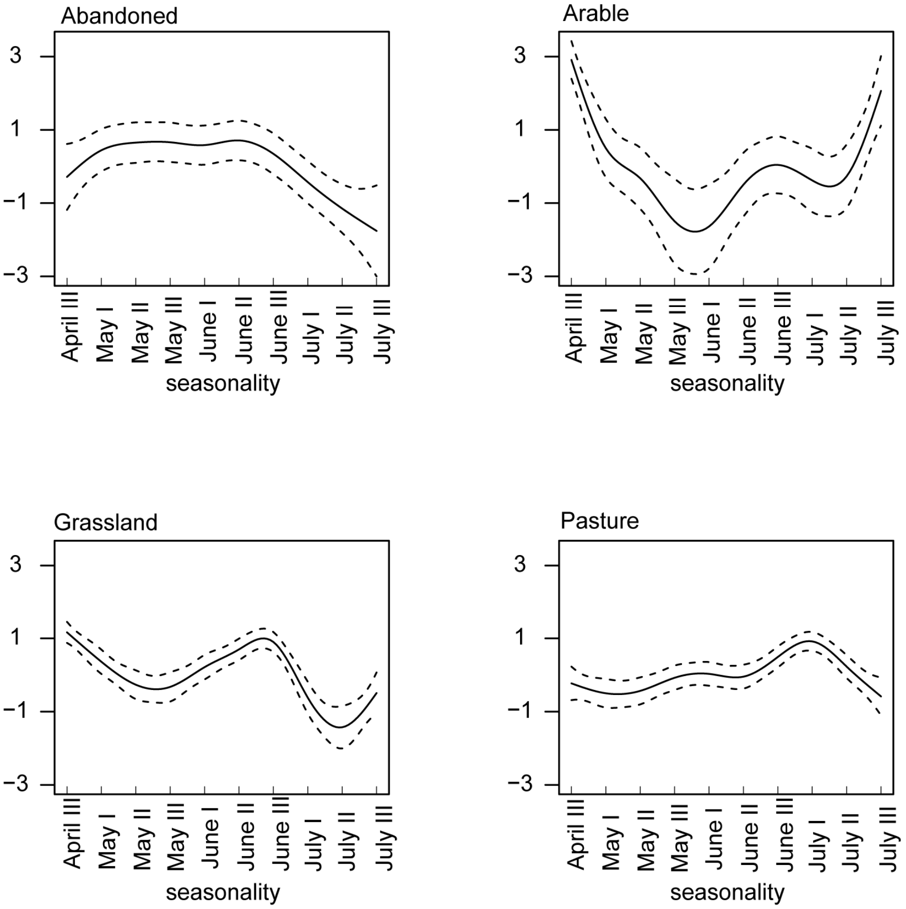
Abandoned

Arable

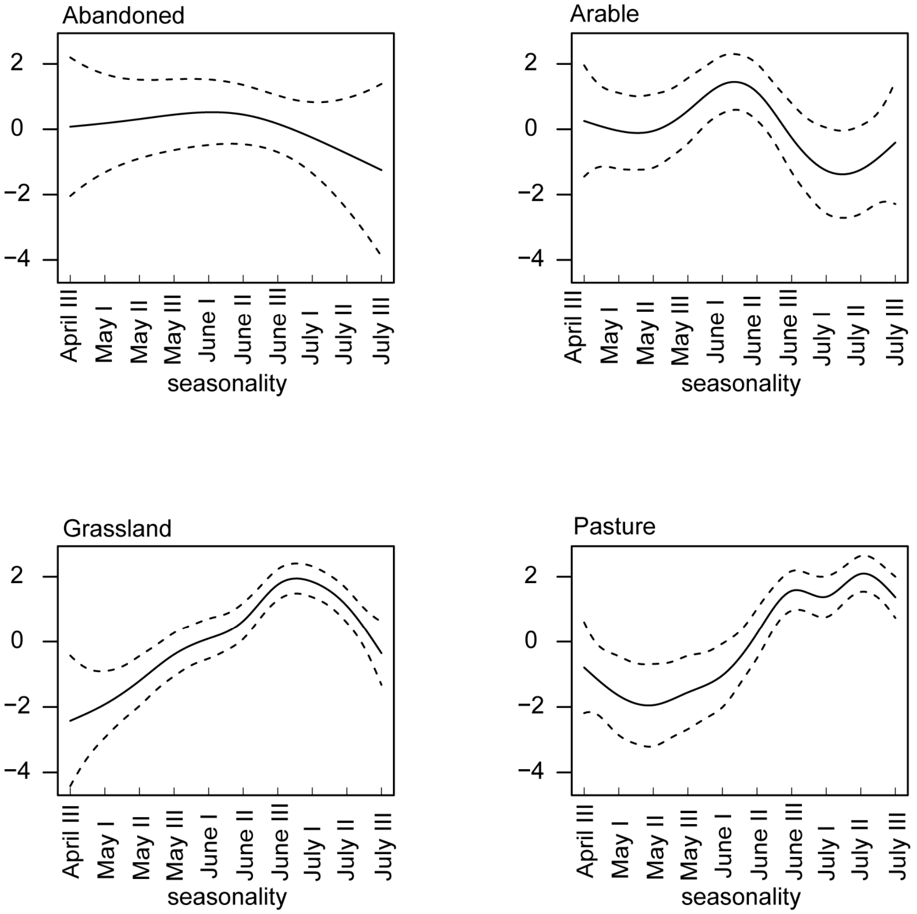
Grassland

Pasture

**Supplementary material, Figure 3**. Estimated changes in Meadow Pipit registration trends according to the timing of the count on abandoned fields, arable fields, grassland, and pastures during the period from 26 April to 28 July 2006. The model smoother (solid line) is the estimate of log-scale population change with 95% point-wise confidence intervals (dotted line). The smoother is centred at 0. The y-axis shows the contribution of the smoother to the fitted values.



**Supplementary material, Figure 4**. Estimated changes in Starling registration trends according to the timing of the count on abandoned fields, arable fields, grassland and pastures during the period from 26 April to 28 July 2006. The model smoother (solid line) is the estimate of log-scale population change with 95% point-wise confidence intervals (dotted line). The smoother is centred at 0. The y-axis shows the contribution of the smoother to the fitted values.



# PUBLICATIONS

# CURRICULUM VITAE

**Name:** Riho Marja
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**Education:**

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| 1989–1991 | Tartu 14. Secondary School |
| 1991–1998 | Tartu Forseliuse Gymnasium |
| 1998–2001 | Hugo Treffneri Gymnasium |
| 2001–2005 | University of Tartu (BSc. in landscape ecology) |
| 2005–2007 | University of Tartu (MSc. in landscape ecology) |
| 2008–2013 | University of Tartu (Ph.D. student in landscape ecology) |

**Professional employment:**

2006–2012 Agricultural Research Centre.

January 2011–April 2011 visitor student in University of Helsinki (Finland). European Social Fund's Doctoral Studies and Internationalisation Programme DoRa (Sihtasutus Archimedes).

February 2012–April 2012 visitor student in University of Helsinki (Finland). European Social Fund's Doctoral Studies and Internationalisation Programme DoRa (Sihtasutus Archimedes).

February 2013–… visitor student in University of Göttingen (Georg-August-Universität Göttingen; Germany). Deutsche Bundesstiftung Umwelt scholarship.

**Research interests:**

Farmland biodiversity relationships with landscape structure, land use and agri-environment schemes

**Publications**

***1. Scientific publications***

Uuemaa, E., Antrop, M., Roosaare, J., Marja, R., Mander, Ü. 2009. Landscape Metrics and Indices: An Overview of Their Use in Landscape Research. Living Reviews in Landscape Research, 3(1), [Online Article].

Muljar, R., Viik, E., Marja, R., Svilponis, E., Jõgar, K., Karise, R., Mänd, M. 2010. The effect of field size on the number of bumble bees. Agronomy Research 8: 357–360.

Marja, R., Herzon, I. 2012. The importance of drainage ditches for farmland birds in agricultural landscapes in the Baltic countries: does field type matter? Ornis Fennica 89: 170–181.

Uuemaa, E., Mander, Ü., Marja, R. 2013. Trends in the use of landscape spatial metrics as landscape indicators: a review. Ecological Indicators 28: 100–106.

Marja, R., Uuemaa, E., Mander, Ü., Elts, J., Truu, J. 2013. Landscape pattern and census area as determinants of the diversity of farmland avifauna in Estonia. Regional Environmental Change 13: 1013–1020.

Marja, R., Herzon, I., Rintala, J.N., Tiainen, J., Seimola, T. 2013. Drainage type in agriculture modifies habitat value of fields for farmland birds. Agriculture, Ecosystems and Environment 165: 184–189.

Herzon, I., Marja, R., Menshikova, S., Kondratyev, A. 201X. Farmland bird communities in an agricultural landscape in Northwest Russia: seasonal and spatial patterns. Agriculture, Ecosystems and Environment (In press).

Sutcliffe, L., Batáry, P., Kormann, U., Báldi, A., Dicks, L., Herzon, I., Kleijn, D., Tryjanowski, P., Apostolova, I., Arlettaz, R., Aunins, A., Aviron, S., Balezentiene, L., Čierna-Plassmann, M., Fischer, C., Gabrielová, J., Halada, L., Hartel, T., Helm, A., Hristov, I., Jelaska, S., Jones, G., Kaligarič, M., Kamp, J., Klimek, S., Koorberg, P., Kovács-Hostyánszki, A., Kuemmerle, T., Leuschner, C., Lindborg, R., Loos, J., Maccherini, S., Marja, R., Máthé, O., Paulini, I., Proença, V., Rey-Benayas, J., Sans, F.X., Seifert, C., Stalenga, J., Štrbenac, A., Timaeus, J., Török, P., van Swaay, C., Viik, E., Tscharntke, T., East meets west – overcoming the divide in European farmland conservation. Biological Conservation (submitted manuscript).

Marja, R., Herzon, I., Viik, E., Elts, J., Mänd, M., Tscharntke, T., Batáry, P. Effectiveness of agri-environment schemes and landscape structure for plants, bumblebee and farmland bird communities in North East of EU (manuscript).

**2. Articles in scientific conference proceedings with no referee practice**

Marja, R., Uuemaa, E., Mander, Ü., Elts, J., Truu, J. 2010. Relationships between bird fauna diversity and landscape metrics in agricultural landscape at different levels. 8th International Conference of the EBCC Bird Numbers 2010. Caceres, Spain. 22–26 March 2010.

Marja, R., Elts, J. 2010. Farmland birds and agri-environment schemes in Estonia: bird monitoring results from 2006–2009. Seminar on European Learning Network on Functional AgroBiodiversity (ELN-FAB) in Baltic Sea Region. Rakvere, Estonia. 25–26 August 2010.

Marja, R., Herzon, I. 2011. Farmland birds and drainage ditches in agricultural landscapes in Baltic countries: does a field type matter? Next generation insights into geosciences and ecology. Tartu, Estonia. 12–13 May 2011.

Elts, J., Marja, R. 2011. Advancement of arrival of the Woodcock (Scolopax rusticola) and Common Snipe (Gallinago gallinago) to Estonia, 1923–2009: does weather play a role? 7th Woodcock & Snipe workshop. Saint Petersburg, Russia. 16–18 May 2011.

Marja, R., Herzon, I., Rintala, J.N., Tiainen, J., Seimola, T. 2013. The importance of agricultural drainage ditches for farmland birds in the North-East of the EU: results of two studies „East meets West–transferring Conservation approaches between Eastern and Westen European landscapes“. Göttingen, Germany. 13–15 February 2013.

### 3. Estonian scientific journals with referee practice

Elts, J., Marja, R. 2007. Counts of singing male corncrakes (Crex crex) in Karula National Park during 2003 and 2004 and the effect of song playbacks on counting efficiency. Hirundo 20: 54–65. In Estonian with English summary

Marja, R. 2008. Farmland birds species richness relationships with landscape indices. Hirundo 21: 29–50. In Estonian with English summary

### 4. Other publications (popular)

Marja, R., Elts, J. 2010. Stonewalls–Cultural heritage and habitat. Eesti Loodus. 11: 50–52. In Estonian

# ELULOOKIRJELDUS

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**Sünniaeg:** 22. september, 1982
**Kodakondsus:** Eesti
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**Haridus:**

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| 1989–1991 | Tartu 14. Keskkool |
| 1991–1998 | Tartu Forseliuse Gümnaasium |
| 1998–2001 | Hugo Treffneri Gümnaasium |
| 2001–2005 | Tartu Ülikool (BSc. maastikuökoloogias) |
| 2005–2007 | Tartu Ülikool (MSc. maastikuökoloogias) |
| 2008–2013 | Tartu Ülikool (doktoriõpingud maastikuökoloogias) |

**Teenistuskäik:**

2006–2012 Põllumajandusuuringute Keskus

Jaanuar 2011–Aprill 2011 külalisüliõpilane Helsinki Ülikoolis (Soome). Rahvusvaheliste koostöövõrgustike arendamine läbi Eesti doktorantide õpirände. Sihtasutus Archimedes stipendium.

Veebruar 2012–Aprill 2012 külalisüliõpilane Helsinki Ülikoolis (Soome). Rahvusvaheliste koostöövõrgustike arendamine läbi Eesti doktorantide õpirände. Sihtasutus Archimedes stipendium.

Veebruar 2013–… külalisüliõpilane Göttingeni Ülikoolis (Georg-August-Universität Göttingen; Saksamaa). Deutsche Bundesstiftung Umwelt (Saksa Keskkonnafond) stipendium.

**Uurimisvaldkond:**

Põllumajandusmaastiku elurikkuse seosed maastiku struktuuri, maakasutuse ja põllumajandus-keskkonna skeemidega

**Publikatsioonide loetelu**

***1. Teadusartiklid***

Uuemaa, E., Antrop, M., Roosaare, J., Marja, R., Mander, Ü. 2009. Landscape Metrics and Indices: An Overview of Their Use in Landscape Research. Living Reviews in Landscape Research, 3(1), [Online Article].

Muljar, R., Viik, E., Marja, R., Svilponis, E., Jõgar, K., Karise, R., Mänd, M. 2010. The effect of field size on the number of bumble bees. Agronomy Research 8: 357–360.

Marja, R., Herzon, I. 2012. The importance of drainage ditches for farmland birds in agricultural landscapes in the Baltic countries: does field type matter? Ornis Fennica 89: 170–181.

Uuemaa, E., Mander, Ü., Marja, R. 2013. Trends in the use of landscape spatial metrics as landscape indicators: a review. Ecological Indicators 28: 100–106.

Marja, R., Uuemaa, E., Mander, Ü., Elts, J., Truu, J. 2013. Landscape pattern and census area as determinants of the diversity of farmland avifauna in Estonia. Regional Environmental Change 13: 1013–1020.

Marja, R., Herzon, I., Rintala, J.N., Tiainen, J., Seimola, T. 2013. Drainage type in agriculture modifies habitat value of fields for farmland birds. Agriculture, Ecosystems and Environment 165: 184–189.

Herzon, I., Marja, R., Menshikova, S., Kondratyev, A. 201X. Farmland bird communities in an agricultural landscape in Northwest Russia: seasonal and spatial patterns. Agriculture, Ecosystems and Environment (trükis).

Sutcliffe, L., Batáry, P., Kormann, U., Báldi, A., Dicks, L., Herzon, I., Kleijn, D., Tryjanowski, P., Apostolova, I., Arlettaz, R., Aunins, A., Aviron, S., Balezentiene, L., Čierna-Plassmann, M., Fischer, C., Gabrielová, J., Halada, L., Hartel, T., Helm, A., Hristov, I., Jelaska, S., Jones, G., Kaligarič, M., Kamp, J., Klimek, S., Koorberg, P., Kovács-Hostyánszki, A., Kuemmerle, T., Leuschner, C., Lindborg, R., Loos, J., Maccherini, S., Marja, R., Máthé, O., Paulini, I., Proença, V., Rey-Benayas, J., Sans, F.X., Seifert, C., Stalenga, J., Štrbenac, A., Timaeus, J., Török, P., van Swaay, C., Viik, E., Tscharntke, T., East meets west – overcoming the divide in European farmland conservation. Biological Conservation (esitatud käsikiri).

Marja, R., Herzon, I., Viik, E., Elts, J., Mänd, M., Tscharntke, T., Batáry, P. Effectiveness of agri-environment schemes and landscape structure for plants, bumblebee and farmland bird communities in North East of EU (käsikiri).

***2. Konverentsiettekanded ja konverentsi teesidena avaldatud artiklid:***

Marja, R., Uuemaa, E., Mander, Ü., Elts, J., Truu, J. 2010. Relationships between bird fauna diversity and landscape metrics in agricultural landscape at different levels. 8th International Conference of the EBCC Bird Numbers 2010. Caceres, Hispaania. 22–26. märts 2010.

Marja, R., Elts, J. 2010. Farmland birds and agri-environment schemes in Estonia: bird monitoring results from 2006–2009. Seminar on European Learning Network on Functional AgroBiodiversity (ELN-FAB) in Baltic Sea Region. Rakvere, Eesti. 25–26. august 2010.

Marja, R., Herzon, I. 2011. Farmland birds and drainage ditches in agricultural landscapes in Baltic countries: does a field type matter? Next generation insights into geosciences and ecology. Tartu, Eesti. 12–13. mai 2011.

Elts, J., Marja, R. 2011. Advancement of arrival of the Woodcock (Scolopax rusticola) and Common Snipe (Gallinago gallinago) to Estonia, 1923–2009: does weather play a role? 7th Woodcock & Snipe workshop. Saint Petersburg, Venemaa. 16–18. mai 2011.

Marja, R., Herzon, I., Rintala, J.N., Tiainen, J., Seimola, T. 2013. The importance of agricultural drainage ditches for farmland birds in the North-East of the EU: results of two studies „East meets West–transferring Conservation approaches between Eastern and Westen European landscapes". Göttingen, Saksamaa. 13–15. veebruar 2013.

### *3. Teadusartiklid eesti keeles:*

Elts, J., Marja, R. 2007. Rukkiräägu (Crex crex) loendused Karula rahvuspargis aastatel 2003 ja 2004 ning helisalvestisega peibutamise mõjust loendustulemustele. Hirundo 20: 54–65.

Marja, R. 2008. Põllumajandusmaastiku linnustiku mitmekesisuse seosed maastikuindeksitega. Hirundo 21: 29–50.

### *4. Populaarteaduslikud artiklid:*

Marja, R., Elts, J. 2010. Kiviaiad – kultuuripärand ja elupaik. Eesti Loodus. 11: 50–52.

# DISSERTATIONES GEOGRAPHICAE UNIVERSITATIS TARTUENSIS

1. **Вийви Руссак.** Солнечная радиация в Тыравере. Тарту, 1991.
2. **Urmas Peterson.** Studies on Reflectance Factor Dynamics of Forest Communities in Estonia. Tartu, 1993.
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23. **Anto Aasa.** Changes in phenological time series in Estonia and Central and Eastern Europe 1951–1998. Relationships with air temperature and atmospheric circulation. Tartu, 2005.
24. **Anneli Palo.** Relationships between landscape factors and vegetation site types: case study from Saare county, Estonia. Tartu, 2005.
25. **Mait Sepp.** Influence of atmospheric circulation on environmental variables in Estonia. Tartu, 2005.
26. **Helen Alumäe.** Landscape preferences of local people: considerations for landscape planning in rural areas of Estonia. Tartu, 2006.
27. **Aarne Luud.** Evaluation of moose habitats and forest reclamation in Estonian oil shale mining areas. Tartu, 2006.
28. **Taavi Pae.** Formation of cultural traits in Estonia resulting from historical administrative division. Tartu, 2006.
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31. **Üllas Ehrlich.** Ecological economics as a tool for resource based nature conservation management in Estonia. Tartu, 2007.
32. **Evelyn Uuemaa.** Indicatory value of landscape metrics for river water quality and landscape pattern. Tartu, 2007.
33. **Raivo Aunap.** The applicability of gis data in detecting and representing changes in landscape: three case studies in Estonia. Tartu, 2007.
34. **Kai Treier.** Trends of air pollutants in precipitation at Estonian monitoring stations. Tartu, 2008.
35. **Kadri Leetmaa.** Residential suburbanisation in the Tallinn metropolitan area. Tartu, 2008.
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37. **Alar Teemusk.** Temperature and water regime, and runoff water quality of planted roofs. Tartu, 2009.
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39. **Merje Lesta.** Evaluation of regulation functions of rural landscapes for the optimal siting of treatment wetlands and mitigation of greenhouse gas emissions. Tartu, 2009.
40. **Siiri Silm.** The seasonality of social phenomena in Estonia: the location of the population, alcohol consumption and births. Tartu, 2009.
41. **Ene Intermitte.** Exposure to fluorides in drinking water and dental fluorosis risk among the population of Estonia. Tartu, 2010.

42. **Kaido Soosaar.** Greenhouse gas fluxes in rural landscapes of Estonia. Tartu, 2010.
43. **Jaan Pärn.** Landscape factors in material transport from rural catchments in Estonia. Tartu, 2010.
44. **Triin Saue.** Simulated potato crop yield as an indicator of climate variability in Estonia. Tartu, 2011.
45. **Katrin Rosenvald.** Factors affecting EcM roots and rhizosphere in silver birch stands. Tartu, 2011.
46. **Ülle Marksoo.** Long-term unemployment and its regional disparities in Estonia. Tartu, 2011, 163 p.
47. **Hando Hain.** The role of voluntary certification in promoting sustainable natural resource use in transitional economies. Tartu, 2012, 180 p.
48. **Jüri-Ott Salm**. Emission of greenhouse gases $CO_2$, $CH_4$, and $N_2O$ from Estonian transitional fens and ombrotrophic bogs: the impact of different land-use practices. Tartu, 2012, 125 p.
49. **Valentina Sagris.** Land Parcel Identification System conceptual model: development of geoinfo community conceptual model. Tartu, 2013, 161 p.
50. **Kristina Sohar**. Oak dendrochronology and climatic signal in Finland and the Baltic States. Tartu, 2013, 129 p.