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Habitat selection of farmland birds in southeastern Norway: Is spring sown cereal preferred over autumn sown cereal?

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Abstract

The switch from spring sown cereals to autumn sown cereals is one of several modern agricultural practices causing declines in farmland bird populations. Autumn sown cereals grow too tall and dense as nesting habitats during the breeding season, and grain leftovers consumed by seed-eating species in stubble fields are lost for autumn sown cereals. The habitat selection of farmland birds, with a focus on whether they prefer spring sown cereal or autumn sown cereal, was investigated by monitoring a total of 107 farmlands in southeastern Norway during the breeding season of 2024. Out of 20 species, 10 species avoided autumn sown cereals for other farmland types, and 14 species preferred short vegetation. The Eurasian skylark *Alauda arvensis* was the only species preferring autumn sown cereal over spring sown cereal, but they selected short vegetation. The other ground-nesting species in this study with a significant result was the northern lapwing *Vanellus vanellus*, which indicated an avoidance of autumn sown cereal and tall vegetation. Autumn sown cereals would protect more nests from destruction by agricultural practices than spring sown cereals. However, based on the results of the other species than Eurasian skylarks in this study, a switch from spring sown cereals to autumn sown cereals is not recommended. Skylark plots and lapwing plots in autumn sown cereals are possible management practices for providing better habitats for Eurasian skylarks and northern lapwings, if autumn sown cereals have been selected for nest placement.

Acknowledgements

I want to thank my supervisor, Svein Dale, for the regular and constructive guidance during my work on my master's thesis, and for the help with some of my fieldwork. The consistent availability and support have been very appreciated during the development of my master's thesis. I also want to express my gratitude for the help I got with the statistical analyses in RStudio from the R Club at the university. Lastly, I want to thank my boyfriend for his encouraging words and driving me to the first study site of some of my bicycle routes when it was too early to take the bus.

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1 Introduction

The intensification of agricultural practices in recent decades has drastically reduced the biodiversity in farmlands (Raven & Wagner, 2021; Donald et al., 2001; Tsiafouli et al., 2014; Richner et al., 2014). Birds are one of the groups of species affected, where farmland birds are among the bird species experiencing most of the declines in populations (Rigal et al., 2023). In both Europe and Norway, several farmland birds such as the Eurasian skylark *Alauda arvensis*, the yellowhammer *Emberiza citrinella*, and the northern lapwing *Vanellus vanellus* are declining in numbers (PECBMS, 2023; Kålås et al., 2022). The Eurasian skylark has been classified as near threatened (NT), the yellowhammer as vulnerable (VU), and the northern lapwing as critically endangered (CR) in the 2021 version of the Norwegian Red List, due to various factors linked to agricultural practices. The house sparrow *Passer domesticus* was previously not red-listed, but is now classified as NT in the last version of the Norwegian Red List (Artsdatabanken, 2021). The habitat preferences among once common farmland birds need to be addressed, to implement measures which will stop the negative trend in population numbers.

Since the 1950s, the Norwegian agricultural practices have been intensified to promote economic growth and better life standards after World War II, as shown by the shift from many smallholdings to fewer industrial farms (Almås, 2002). There was also a sharp increase in the use of synthetic fertilizers and pesticides in the post-war period, but the insecticide dichloro-diphenyl-trichloroethane (DDT) was forbidden in 1970, which thinned the eggshells of birds of prey, like the peregrine falcon *Falco peregrinus* (Almås, 2002; Ratcliffe, 1970). Cultivated pastures have mostly replaced outfield pastures, and intensive driven hay meadows are harvested several times during one season (Almås, 2002). The more frequent harvests are negatively affecting farmland birds, such as the corn crake *Crex crex* and the common quail *Coturnix coturnix* (Artsdatabanken, 2021). Wetlands have also been drained, streams have been laid in pipes, and forests have been cleared away for developing the modern agricultural landscape (Almås, 2002). Especially waders *Charadriiformes*, such as the Eurasian curlew *Numenius arquata*, are negatively affected by the drainage of wetlands (Newton, 2004; Artsdatabanken, 2021). The modern agricultural practices show how the preferred habitats of several farmland bird species are no longer compatible with the present landscape.

Along with the intensification of agricultural practices, there has been a switch from spring sown cereals to autumn sown cereals, which has proven to be negative for the bird diversity in farmlands (Chamberlain et al., 2001; Newton, 2004). During the breeding season, avoidance of autumn sown cereals in favor of spring sown cereals has been detected among a group of common ground-foraging species in farmlands (Eggers et al., 2011). In the wintertime, seed-eating birds are negatively affected, since they are dependent on the grain leftovers in the stubble fields for the food supply, which are lost when fields become autumn sown cereals (Newton, 2004, Moorcroft et al., 2002). The use of pesticides on autumn sown cereals during winters extends the period of the decreased food supply for herbivores and insectivores compared to spring sown cereals, which are treated in the summer (Moreby & Southway, 1999; Henderson et al., 2009). However, autumn sown cereals have fewer farming operations during spring than spring sown cereals, which can decrease the risk of nest destruction of ground-nesting bird species breeding in autumn sown cereals. Additionally, climate change has created an ecological trap in spring sown cereals, since ground-nesters like Eurasian curlews and northern lapwings have shown to advance more rapidly with their timing of egg laying than the farmers with their farming operations, resulting in more nest destruction (Santangeli et al., 2018). Nest destruction during farming operations is one of the biggest contributors to the declines among ground-nesting farmland birds, which show how autumn sown cereals can provide protection for nests, even though the switch from spring sown cereals to autumn sown cereals has decreased the diversity of farmland birds (Artsdatabanken, 2018; Santangeli et al., 2018; Chamberlain et al., 2001; Newton, 2004).

The vegetation height and structure in autumn sown cereals, as well as other farmland types, can determine which habitat is suitable for farmland birds. In general, tall and dense vegetation can reduce the food availability for ground-foraging birds, as well as increasing the predation risk with the decreased detection of predators in the agricultural landscape (Atkinson et al., 2004; Douglas et al., 2009; Whittingham & Evans, 2004). High diversity of sward heights and structure can also provide more invertebrates and seed-rich habitats, like complex structured grasslands (Vickery et al., 2001; Vickery et al., 2009). However, the intensification has led to a monocultural agricultural landscape with little variation in the sward structure, as well as tall and dense vegetation to maximize the output of the agricultural production (Almås, 2002). Autumn sown cereals, which are among the tallest and densest farmland types, are preferred by Eurasian skylarks early in the breeding season, but eventually they shift to spring sown cereals, because of the taller swards in autumn sown cereals (Hiron et al., 2012; Eggers et al., 2011). Northern lapwings avoid autumn sown cereals and prefer breeding in farmland types with low vegetation and patchy bare ground (Wilson et al., 2001;

Sheldon et al., 2005; Sakseide & Dale, 2023). The studies mentioned indicate that tall swards, as well as autumn sown cereals are avoided among several farmland birds for other farmland types with shorter vegetation, but more studies are needed since the habitat selection between autumn sown cereals and spring sown cereals has mostly been studied in Eurasian skylarks and northern lapwings (Atkinson et al., 2004; Douglas et al., 2009; Sheldon et al., 2005; Sakseide & Dale, 2023; Hiron et al., 2012; Eggers et al., 2011).

The switch from spring sown cereals to autumn sown cereals, has mainly been proven to be negative for the farmland bird populations in England (Chamberlain et al., 2001; Newton, 2004). In Norway, the use of autumn sown cereals decreased in the post-war period and has fluctuated the last decade, with a low in 2018 with 4 % of the total cereals and oil crops, but peaked in 2019 with 17.1 % percent, which is more than spring sown cereals the same year (Strand, 1984; SSB, 2025). The fluctuations create uncertainty about whether a similar correlation between the switch from spring sown cereals to autumn sown cereals and the declines in farmland bird populations in England is applicable to the negative trends among farmland birds in Norway. Studies in Denmark and Sweden have not found the correlation between the switch from spring sown cereals to autumn sown cereals for the declines in their farmland bird populations, since the declines in Danish populations have not corresponded with the increased use of autumn sown cereals, while the Swedish populations have experienced similar trends as in England, even though the use of autumn sown cereals have remained stable (Fox, 2004; Wretenberg et al., 2006).

This study aims to investigate the use of farmlands by birds in the Norwegian agricultural landscape, which can provide new knowledge about species not previously investigated and information for the future management of the declining farmland bird populations. The main objectives are to investigate the use of: (1) autumn sown cereal relative to other farmland types (especially autumn sown cereal versus spring sown cereal, since autumn sown cereals with fewer farming operations during spring, can provide a safer habitat for ground-nesting species) and (2) the selection of vegetation height. Finally, relevant management practices are suggested for conserving the farmland birds.

2 Methods

2.1 Study area

The study area was located in southeastern Norway, in Akershus county, within the municipalities Nordre Follo, Ås, Vestby and Frogn (Fig. 1). Agricultural landscape constitutes a major part of the study area, which surrounds human settlements and infrastructures. The agricultural landscape is dominated by cereal production, which includes barley *Hordeum vulgare,* common wheat *Triticum aestivum*, oats *Avena sativa* and rye *Secale cereale*. A smaller portion of the agricultural landscape consists of vegetable, fruit and berry production, as well as meadows and pastures. Grazing animals on the pastures are mostly cows *Bos taurus*, horses *Equus ferus caballus* or sheeps *Ovis aries*. Smaller forest areas and water bodies of varying sizes are found as a mosaic within the agricultural landscape. Some farmlands have non-crop islands, which can have rocks of varying sizes, grasses, shrubs, deciduous and coniferous trees, or bare bedrock.

A total of 107 study sites were visited during field work, of which 27 were autumn sown cereal, 52 were spring sown cereal, 44 were fields with exposed soil, 12 were meadows, 11 were pastures and 28 were stubble fields (Fig. 1, Table 1). Most of the fields with exposed soil or stubble fields, turned into spring sown cereal later and have been added to the total number of spring sown cereal (Fig. 1, Table 1). Exposed soil is defined as a broader category for harrowed, deeply ploughed and shallowly ploughed fields, because there were few farmlands of each of those types. Five of the fields with exposed soil turned into other irrelevant farmland types for the present study, such as vegetable fields, and are marked in the map of the study area (Fig. 1, Table 1).

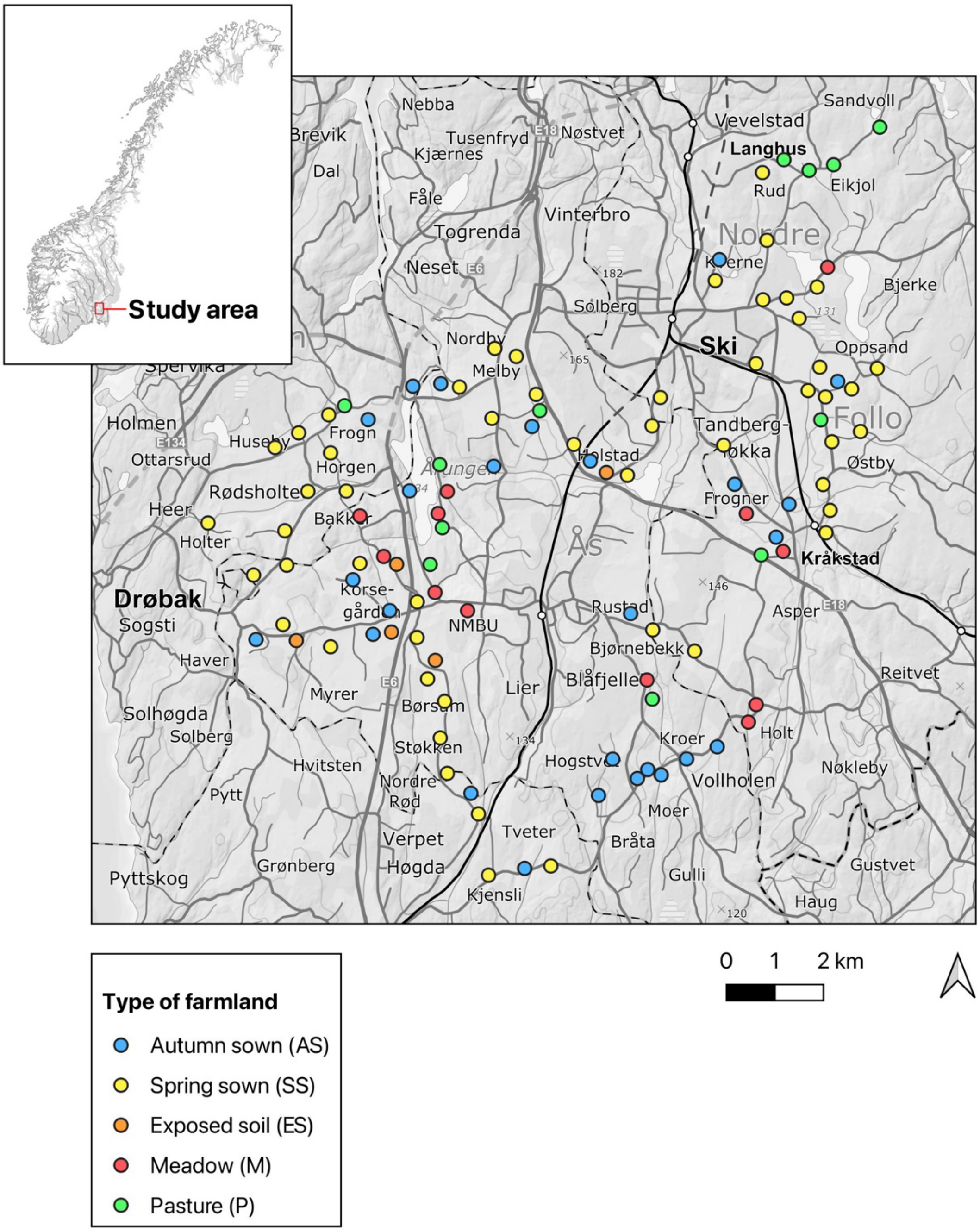


Fig. 1 Map of the study area with all of the study locations visited during field work. Spring sown includes stubble fields and fields with exposed soil, which turned into spring sown cereal later. Harrowed, ploughed and shallowly ploughed are defined as exposed soil. Exposed soil (orange dots) as a type of farmland shows five study sites with exposed soil, which turned into other irrelevant types of farmlands, such as vegetable fields, during the period of fieldwork.

Table 1 Total number of study sites categorized according to farmland types during field work, number of visits, area measured in square kilometers and vegetation height measured in centimeters. Subcategories for the type of farmlands show what the different types of farmlands turned into later during the period of field work. Fields with exposed soil and stubble fields, which turned into spring sown cereal later, are included in the total number of spring sown cereals (*n* farmlands = 52). Five fields with exposed soil turned into irrelevant farmland types, such as vegetable fields, and are listed in the table. The main categories of all types of farmlands are summed up in the total at the bottom line (*n* farmlands = 174). All study sites were visited up to five times during the period of field work, and the total number of visits is shown at the bottom line (*n* visits = 499). The total area has excluded exposed soil and stubble fields, which turned into spring sown cereal later.

Type of farmland	*n* farmlands	*n* visits	Km^2	Vegetation height
Autumn sown (AS)	**27**	**124**	**1.48**	**5-100 cm**
Spring sown (SS)	**52**	**169**	**2.56**	**0-100 cm**
Exposed soil (ES)	**44**	**61**	**1.96**	**0 cm**
Turned into spring sown later	38			
Turned into irrelevant habitats later	5			
Meadow (M)	**12**	**55**	**0.38**	**5-110 cm**
Pasture (P)	**11**	**53**	**0.16**	**0-110 cm**
Turned into exposed soil later	1			
Stubble field (SF)	**28**	**37**	**1.62**	**10-30 cm**
Turned into spring sown later	28			
Total	**174**	**499**	**4.58**	**0-110 cm**

2.2 Data collection

Field work started April 9th, 2024, and ended July 2nd, 2024, with a total of 41 days of field work. The week before the study was conducted, 10 bicycle routes created with Google Maps were visited to gather information about farmland types in the study area. The collected information was used to select 7-13 study sites along each bicycle route. Study sites with similar farmland types had 200 meters between the sites to avoid recording the same individuals of bird species. Each bicycle route and study site got a unique ID, but some study sites have been divided into smaller units with the same ID, because they had different vegetation height or another farmland type. All study sites were visited up to five times at the same observation spot, resulting in a total of 499 visits during the period of field work (Table 1).

The first study site along a bicycle route was visited around one hour after sunrise, and the last study site was visited before 12 PM. One or two routes were surveyed per day. At a study site, bird species were registered with 10x50 binoculars, eyesight or hearing during a period of 10 minutes. After 10 minutes, the vegetation height of the study site was measured with a ruler or a measure tape and noted down on a field scheme. Observer ID, bicycle route ID, study site ID, number of individuals of bird species, bird activity, type of farmland (i.e., autumn sown, spring sown, exposed soil, meadow, pasture and stubble field), date, time for the 10-minute registration period and cloud cover were also noted. The categories of observed bird activity were mostly birds on the ground (G), birds flying over the study site (OF), birds sitting in the edge zone of the study site (EZ) or birds sitting on a non-crop island in the study site (I). The area measure of a study site was done by using QGIS 3.34.13 (QGIS Project, 2023).

2.3 Statistical analyses

Observations of a bird species on at least six study sites were used as a criterion to select a bird species for further analysis. Further, birds observed on the ground (G) were the preferred bird activity category since there is more uncertainty about the habitat preference among birds which were observed in the edge zone (EZ), flying over study sites (OF) or sitting on islands (I). Other bird activity categories were included when there were fewer than six study sites with observations of birds on the ground (G).

Out of the 20 species included in the final analyses, 14 migrating species only include data material from the first day they were recorded until the end of the field season (Appendix A). The meadow pipit *Anthus pratensis* is another migrating species, which could only include data from the first day it was recorded until the last day it was recorded, since it is not breeding in the study area (Appendix A). However, the meadow pipit was excluded from the final analyses, since the subset of data did not include data from the period when the study sites became spring sown cereals. The version of R used for the analyses was R 4.4.2 (R Core Team, 2024). The significance level for all analyses was set to $P < 0.05$.

2.3.1 GLMM with a Zero-inflated Poisson regression

Generalized Linear Mixed Models (GLMM) with a Zero-Inflated Poisson Regression (hereafter GLMM-ZIP) were used to analyze habitat preferences or vegetation height preferences of eight species (Eurasian skylark *Alauda arvensis*, yellowhammer *Emberiza citrinella*, hooded crow *Corvus cornix*, Eurasian magpie *Pica pica*, barn swallow *Hirundo rustica*, white wagtail *Motacilla alba*, common whitethroat *Sylvia communis* and common blackbird *Turdus merula*). The use of the R package "glmmTMB" package, allowed for to include a Zero-Inflated Poisson Regression with the GLMM (Brooks et al., 2025). All models had the same structure to compare the species on the same basis and the coefficients from the models' results were returned on a log-scale.

The number of observed individuals at a study site (count), presence or absence and number of observed individuals per square kilometer of a study site (density) were used as possible options for the response variable. Density as a response variable was not used since it was a continuous variable, which gave issues with the Zero-Inflated Poisson Regression in the GLMM. Presence or absence as a response variable provided the least detailed information about habitat preference. Count was therefore used as the response variable in the final model.

The set of predictor variables included in the GLMM-ZIP was farmland type (i.e., autumn sown, spring sown, exposed soil, meadow, pasture and stubble field) or vegetation height measured in centimeters, start time of the 10-minute registration period at a study site and study site size measured in square kilometers. Two different GLMM-ZIP were used for each species when analyzing habitat selection or selection of vegetation height, since the inclusion of farmland type and vegetation height as predictor variables in the same model created model issues. Some study sites had vegetation height set as an interval, especially pastures. At these study sites, we used the lowest recorded height for birds observed on the ground, since we assumed they would prefer the lowest vegetation height. An exception was made for birds only flying over study sites, where we instead used the mean of the vegetation height interval. To take into consideration that individual sites were sampled multiple times, study site IDs were included as a random effect. Only additive effects between the variables were included in the final models.

Bicycle route ID and observer ID were excluded as random effects, since they had little to no effect and to simplify the model. Multicollinearity issues between vegetation height and date did not allow for an analysis of the interaction between the variables. Interaction between farmland type and date, as well as date as an additive effect, were also excluded, since exposed soil and stubble fields had fewer days with observations than the other farmland types. Cloud cover as a predictor variable was not included in the final model, because of little to no effect on the species.

2.3.2 Fisher's exact test and Spearman's rank correlation

Many species could not be analyzed with the GLMM-ZIP, since they had too few observations, too many zero-values in the dataset or many observations of individuals of a species at few study sites. The Fisher's exact test used in contingency analyses was therefore used when analyzing habitat selection among 12 of the species (common wood pigeon *Columba palumbus*, starling *Sturnus vulgaris*, fieldfare *Turdus pilaris*, Eurasian jackdaw *Corvus monedula*, redwing *Turdus iliacus*, lesser black-backed gull *Larus fuscus*, Eurasian tree sparrow *Passer montanus*, common gull *Larus canus*, black-headed gull *Chroicocephalus ridibundus*, northern lapwing *Vanellus vanellus,* Eurasian chaffinch *Fringilla coelebs* and common linnet *Linaria cannabina*). The presence or absence of a species at a study site and the type of farmland (i.e., autumn sown, spring sown, exposed soil, meadow, pasture and stubble field) were used as the variables in Fisher's exact test.

Selection of vegetation height was analyzed with a Spearman's Rank correlation for the 12 species, which did not provide results with the GLMM-ZIP. Density based on the number of observed individuals per square kilometer at a study site and the vegetation height measured in centimeters were used as the variables.

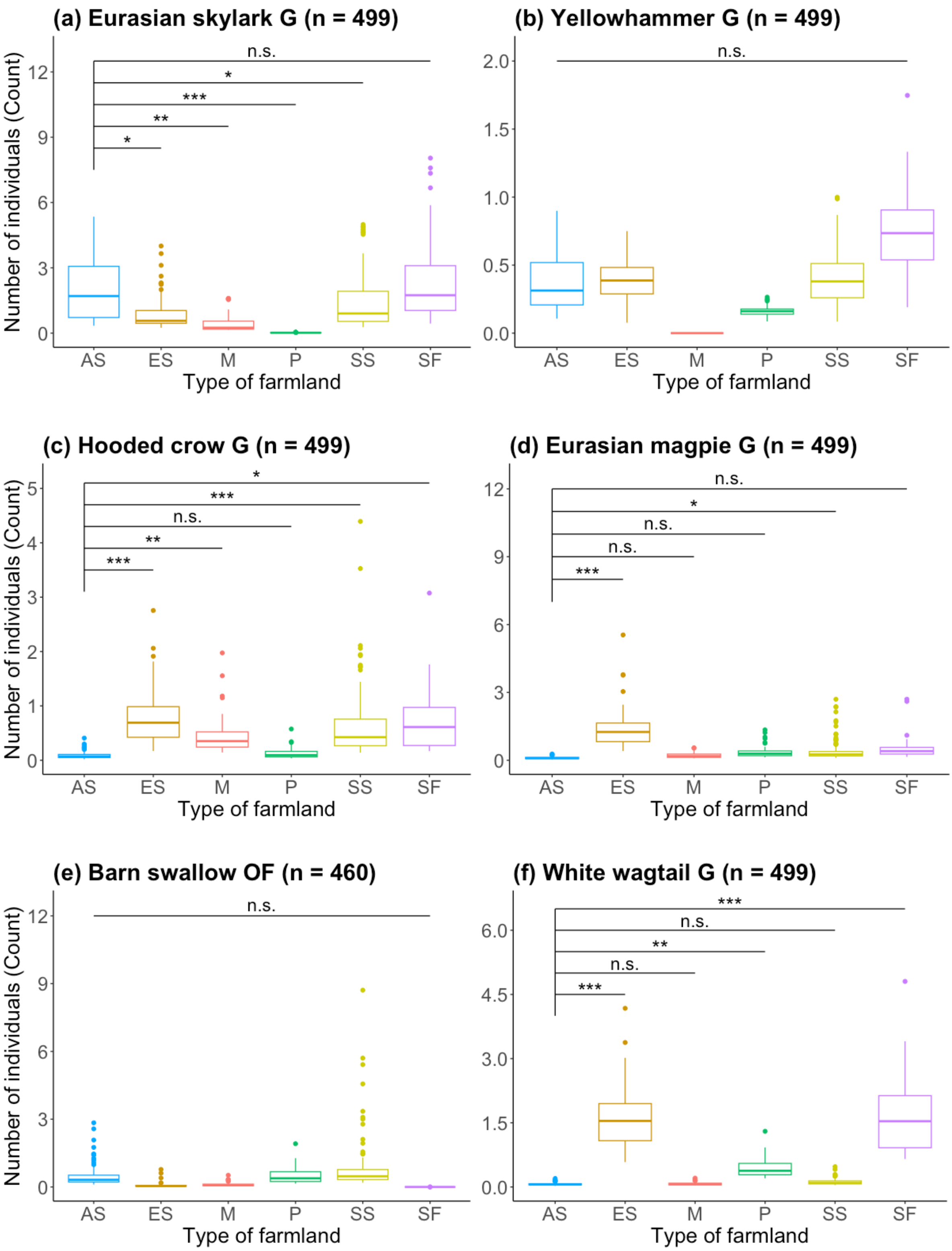
3 Results

In total, we observed 44 bird species at the study sites during field work, of which 20 species provided enough material for further analysis (Appendix A). Eurasian skylark and yellowhammer, which are included in the analyses, had the highest number of individuals observed, with a total of 658 individuals and 263 individuals, during the total of 499 visits (Appendix A, Table 1). See Appendix B for detailed results from the GLMM-ZIP (Appendix B1-B16).

3.1 Habitat selection

The GLMM-ZIP only provided significant preference for autumn sown cereal (AS) over spring sown cereal (SS) among Eurasian skylarks on the ground (Eurasian skylark G; Fig. 2a). Selection of SS over AS were significant for hooded crows on the ground (Hooded crow G; Fig. 2c) and Eurasian magpie on the ground (Eurasian magpie G; Fig. 2d). The six other species analyzed with the GLMM-ZIP, did not show a significant preference between AS and SS (Fig. 2b & 2e-2h). Seven of the 12 species analyzed with Fisher´s exact test had a significant relationship between the variables, where all species indicated preference for other farmland types over AS (Fig. 3a, 3d, 3e, 3h-3j & 3l).

Regarding other farmland types than SS, Eurasian skylark G had a significant preference for AS compared to exposed soil (ES), meadow (M) and pasture (P; Fig. 2a). Hooded crow G had a significant preference for ES, M and stubble field (SF) over AS (Fig. 2c). White wagtails on the ground (White wagtail G), had a significant selection of ES, P and SF over AS (Fig. 2f). Eurasian magpie on the ground (Eurasian magpie G) had a significant preference of ES over AS (Fig. 2d). The four other species analyzed with the GLMM-ZIP, did not have a significant difference in their habitat preference regarding other farmland types than SS (Fig. 2b, 2e & 2g-2h).


(a) Eurasian skylark G (n = 499)
(b) Yellowhammer G (n = 499)
(c) Hooded crow G (n = 499)
(d) Eurasian magpie G (n = 499)
(e) Barn swallow OF (n = 460)
(f) White wagtail G (n = 499)
Number of individuals (Count)
Type of farmland
AS
ES
M
P
SS
SF
n.s.
*
**
***

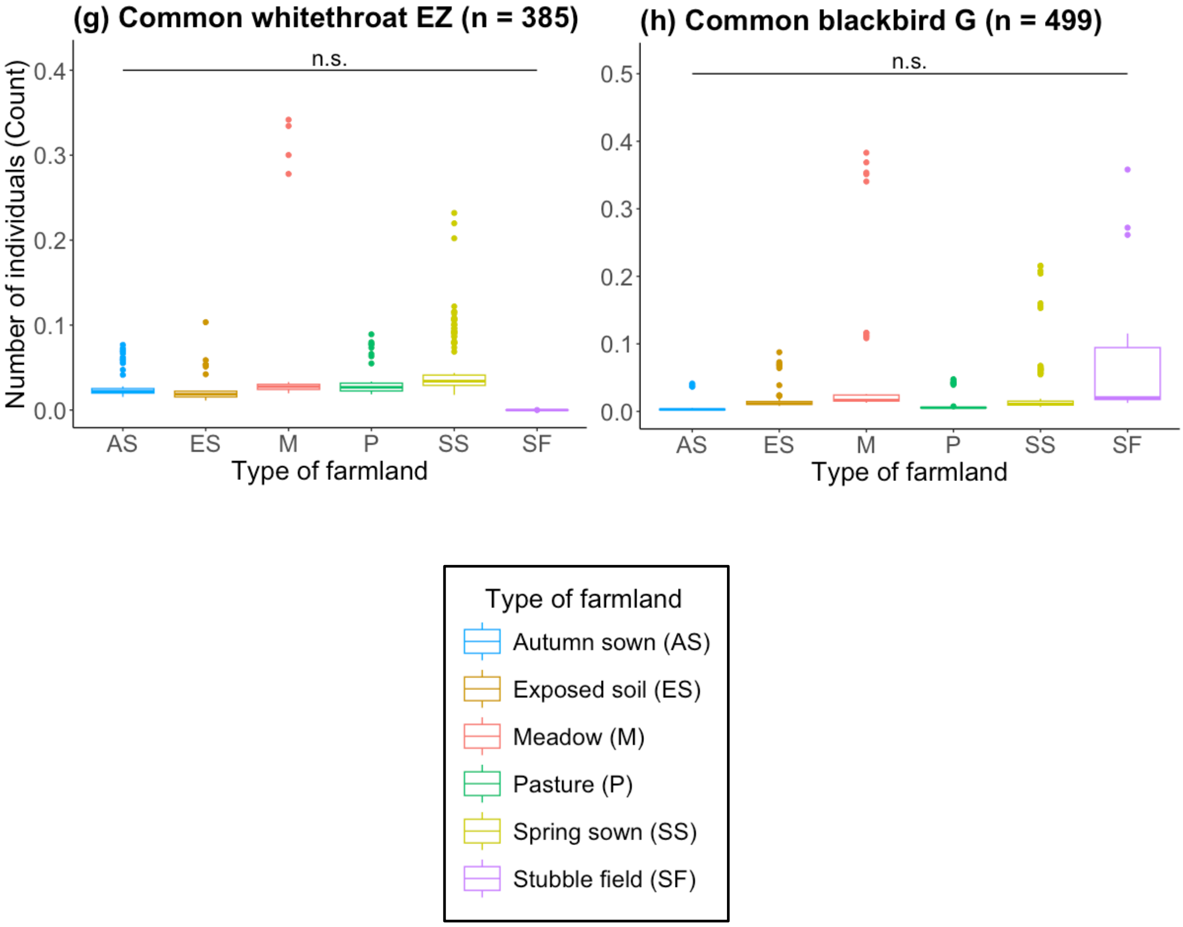
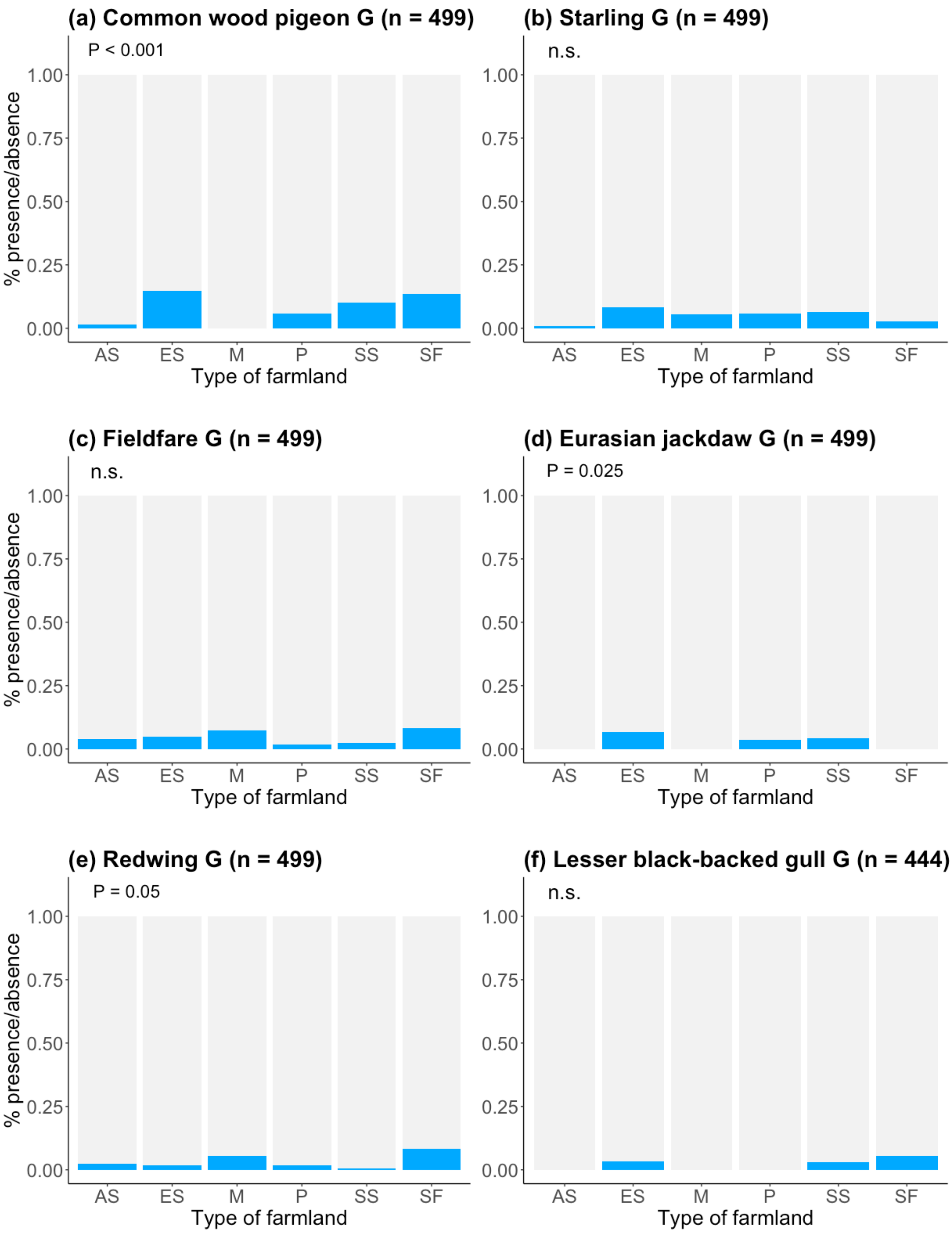
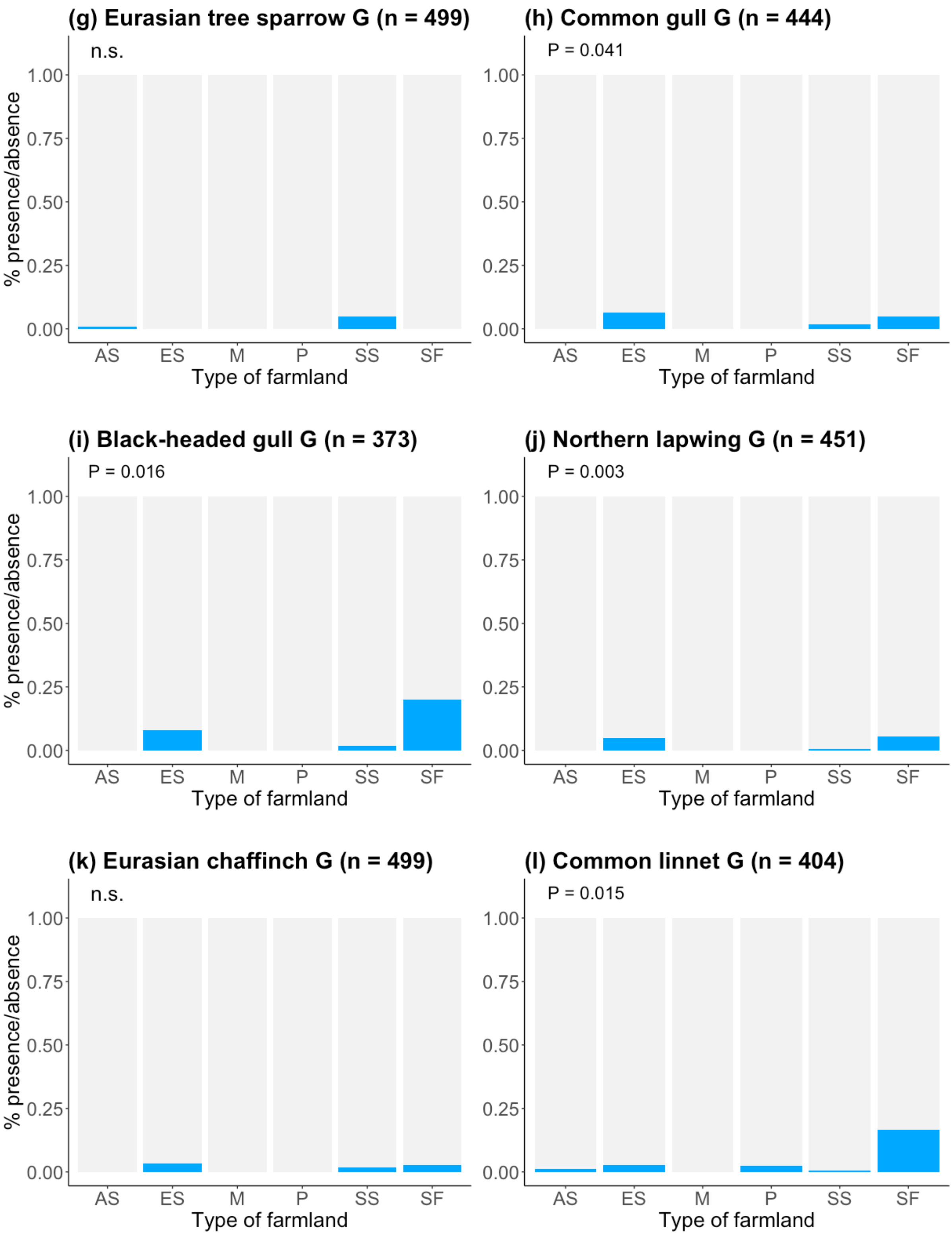


Fig. 2 Results from the Generalized Linear Mixed Models with Zero-inflated Poisson regression of how the type of farmland influenced the abundance of eight farmland birds in southeastern Norway. Log count has been transformed to actual count. **n** = the sample size for a species as the total visits to study sites (based on the first day the species was observed for migrating species). ******* = $P \leq 0.001$, ****** = $P \leq 0.01$, ***** = $P \leq 0.05$ and **n.s.** = $P > 0.05$. **(a)** Eurasian skylark *Alauda arvensis* on the ground (Eurasian skylark G), **(b)** yellowhammer *Emberiza citrinella* on the ground (Yellowhammer G), **(c)** hooded crow *Corvus cornix* on the ground (Hooded crow G), **(d)** Eurasian magpie *Pica pica* on the ground (Eurasian magpie G), **(e)** barn swallow *Hirundo rustica* flying over study sites (Barn swallow OF), **(f)** white wagtail *Motacilla alba* on the ground (White wagtail G), **(g)** common whitethroat *Sylvia communis* in the edge zone of study sites (Common whitethroat EZ) and **(h)** common blackbird *Turdus merula* on the ground (Common blackbird G).


(a) Common wood pigeon G (n = 499)
P < 0.001
(b) Starling G (n = 499)
n.s.
(c) Fieldfare G (n = 499)
n.s.
(d) Eurasian jackdaw G (n = 499)
P = 0.025
(e) Redwing G (n = 499)
P = 0.05
(f) Lesser black-backed gull G (n = 444)
n.s.
% presence/absence
1.00
0.75
0.50
0.25
0.00
AS
ES
M
P
SS
SF
Type of farmland


(g) Eurasian tree sparrow G (n = 499)
n.s.
(h) Common gull G (n = 444)
P = 0.041
(i) Black-headed gull G (n = 373)
P = 0.016
(j) Northern lapwing G (n = 451)
P = 0.003
(k) Eurasian chaffinch G (n = 499)
n.s.
(l) Common linnet G (n = 404)
P = 0.015
% presence/absence
1.00
0.75
0.50
0.25
0.00
AS
ES
M
P
SS
SF
Type of farmland

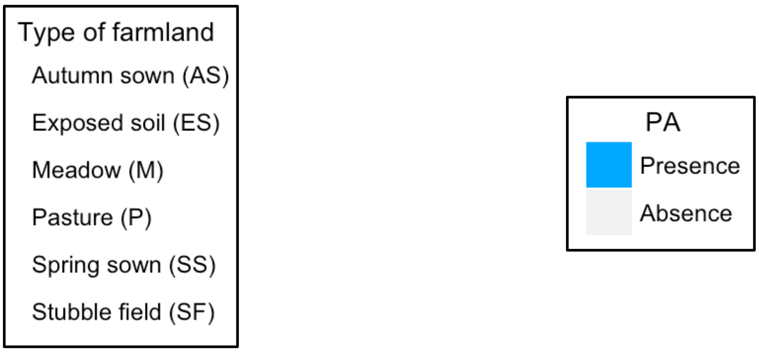
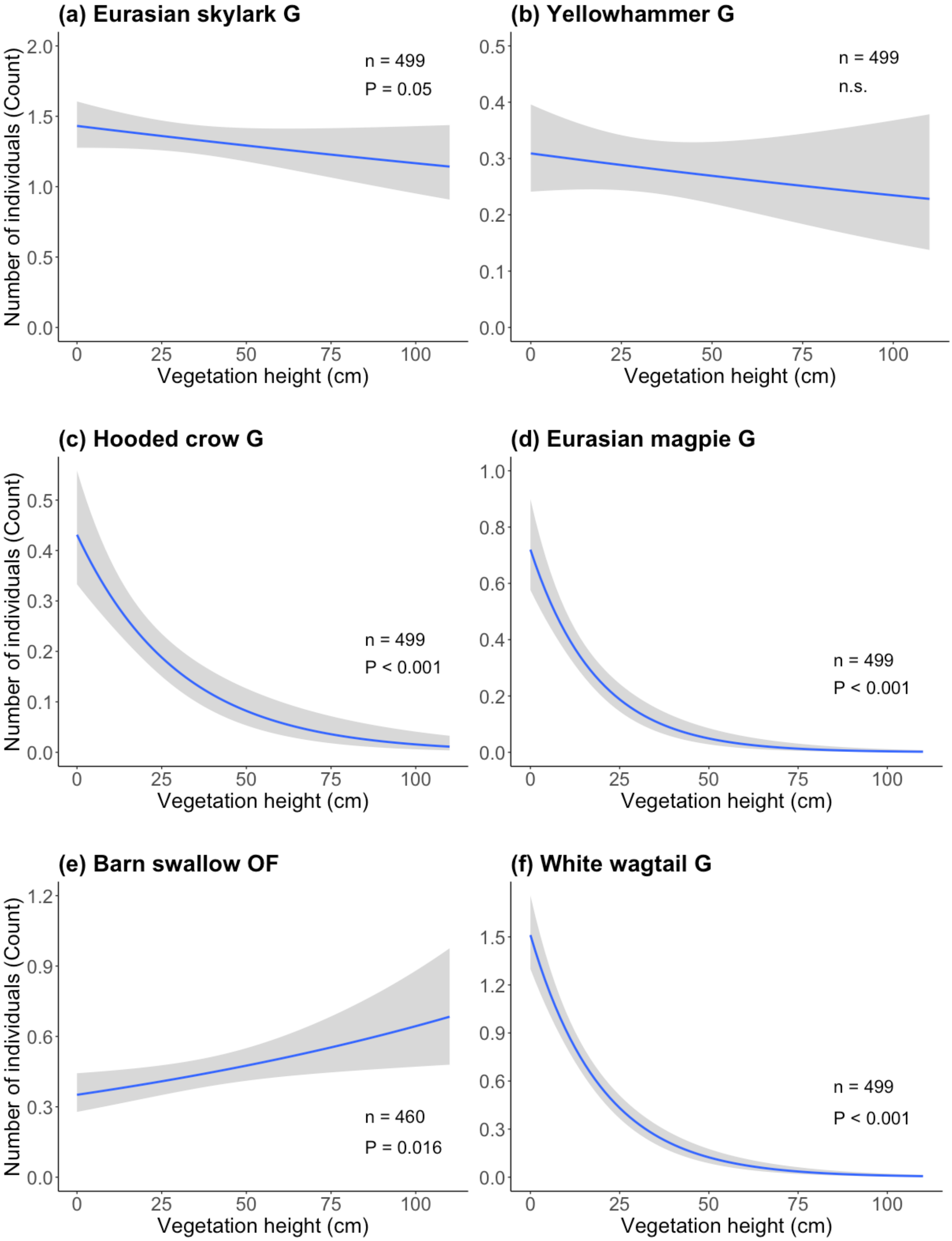


Fig. 3 Results from the Fisher's exact test of how the type of farmland influenced the presence or absence of 12 farmland birds in southeastern Norway. **n** = the sample size for a species as the total visits to study sites (based on the first day the species was observed for migrating species). **n.s.** = $P > 0.05$. **(a)** Common wood pigeon *Columba palumbus* on the ground (Common wood pigeon G), **(b)** starling *Sturnus vulgaris* on the ground (Starling G), **(c)** fieldfare *Turdus pilaris* on the ground (Fieldfare G), **(d)** Eurasian jackdaw *Corvus monedula* on the ground (Eurasian jackdaw G), **(e)** redwing *Turdus iliacus* on the ground (Redwing G), **(f)** lesser black-backed gull *Larus fuscus* on the ground (Lesser black-backed gull G), **(g)** Eurasian tree sparrow *Passer montanus* on the ground (Eurasian tree sparrow G), **(h)** common gull *Larus canus* on the ground (Common gull G), **(i)** black-headed gull *Chroicocephalus ridibundus* on the ground (Black-headed gull G), **(j)** northern lapwing *Vanellus vanellus* on the ground (Northern lapwing G) and **(k)** Eurasian chaffinch *Fringilla coelebs* on the ground (Eurasian chaffinch G) and **(i)** common linnet *Linaria cannabina* in the edge zone of study sites (Common linnet EZ).

3.2 Selection of vegetation height

The number of observed individuals at a farmland significantly decreased with higher vegetation among five of the species analyzed with the GLMM-ZIP (Fig. 4a, 4c, 4d, 4f & 4h). Only barn swallows flying over study sites preferred higher vegetation (Barn swallow OF; Fig. 4e). The remaining two species analyzed with the GLMM-ZIP, did not have a significant effect of vegetation height on the number of observed individuals of a species (Fig. 4b & 4g). Nine of the 12 species analyzed with Spearman's rank correlation showed significant, but weak negative correlations between observed individuals per square kilometer (density) and vegetation height (Fig. 5a-5f & 5h-5j). Three of the last species analyzed with Spearman's rank correlation did not show a significant correlation between density and vegetation height (Fig. 5g, 5k & 5l).


(a) Eurasian skylark G
n = 499
P = 0.05
(b) Yellowhammer G
n = 499
n.s.
(c) Hooded crow G
n = 499
P < 0.001
(d) Eurasian magpie G
n = 499
P < 0.001
(e) Barn swallow OF
n = 460
P = 0.016
(f) White wagtail G
n = 499
P < 0.001
Number of individuals (Count)
Vegetation height (cm)

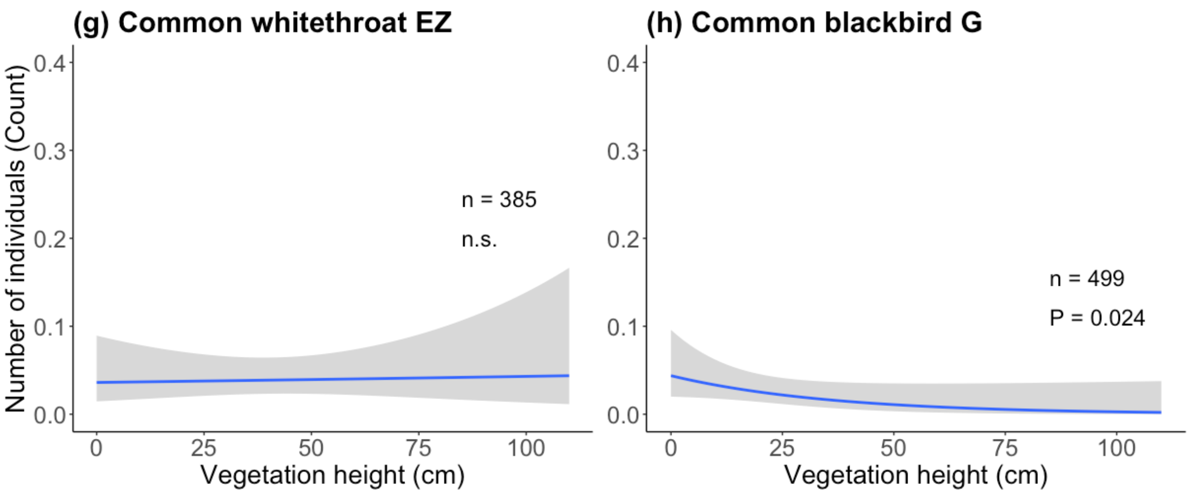
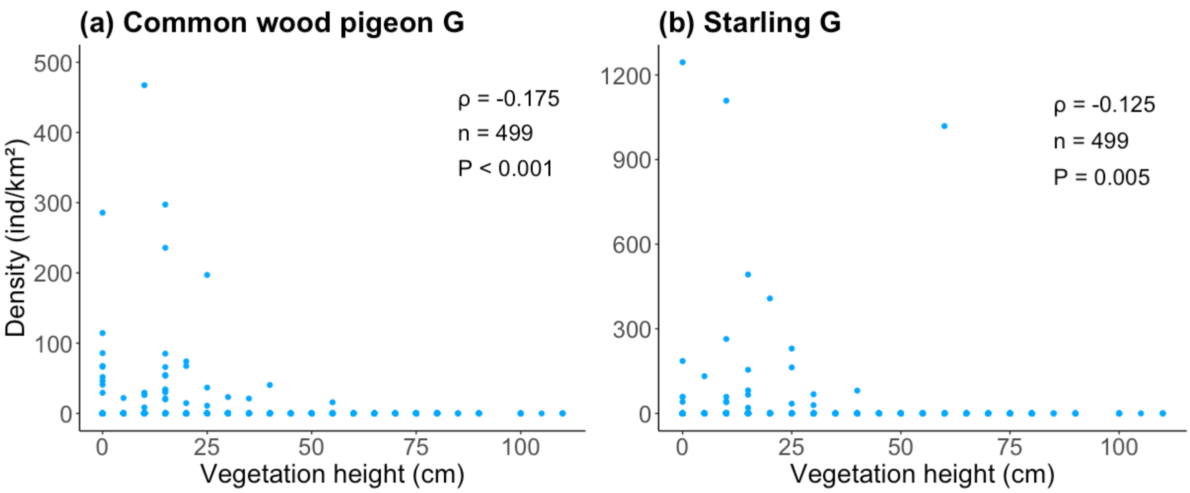
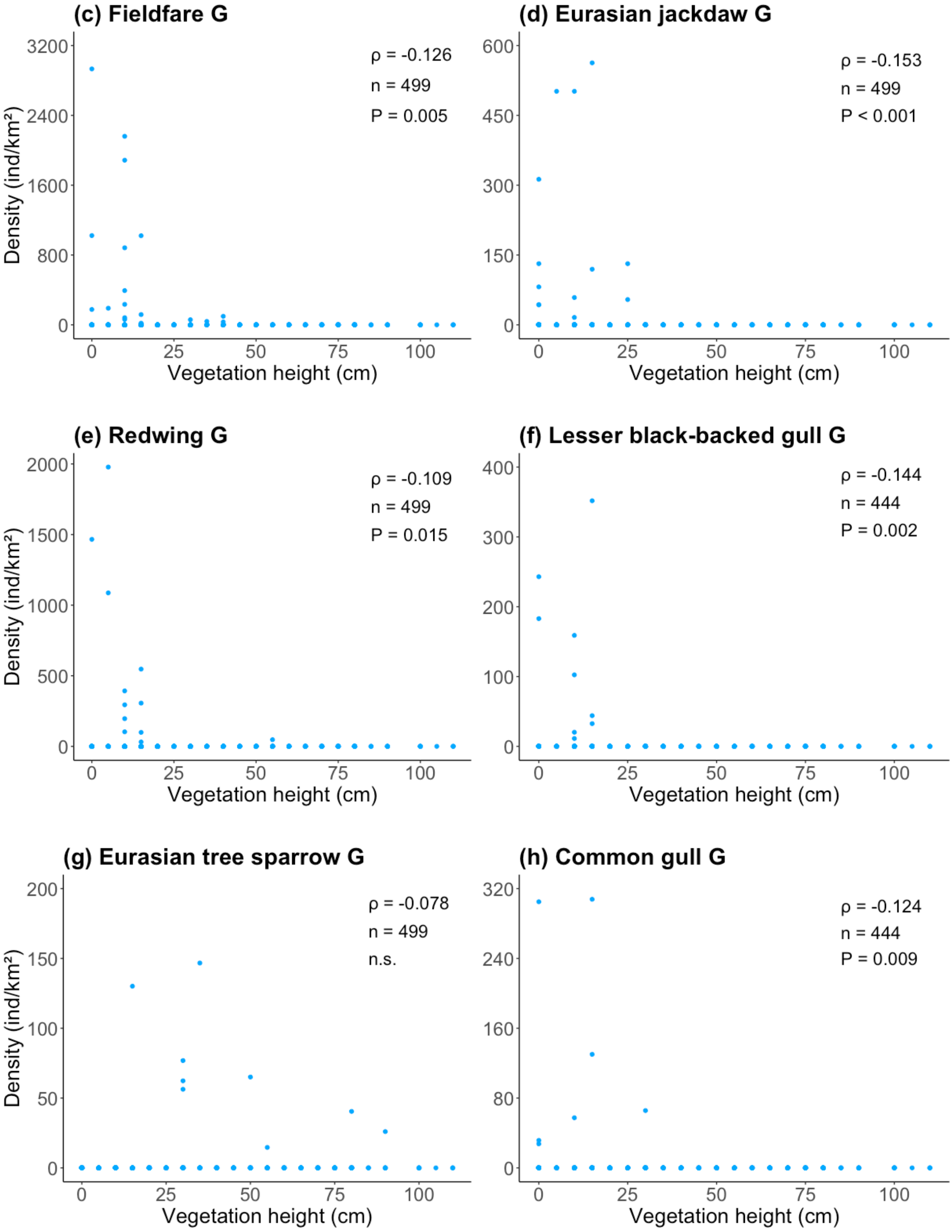


Fig. 4 Results from Generalized Linear Mixed Models with Zero-inflated Poisson regression of how the vegetation height influenced the abundance of eight farmland birds in southeastern Norway. Log count has been transformed to actual count. **n** = the sample size for a species as the total visits to study sites (based on the first day the species was observed for migrating species). **n.s.** = $P > 0.05$. **(a)** Eurasian skylark *Alauda arvensis* on the ground (Eurasian skylark G), **(b)** yellowhammer *Emberiza citrinella* on the ground (Yellowhammer G), **(c)** hooded crow *Corvus cornix* on the ground (Hooded crow G), **(d)** Eurasian magpie *Pica pica* on the ground (Eurasian magpie G), **(e)** barn swallow *Hirundo rustica* flying over study sites (Barn swallow OF), **(f)** white wagtail *Motacilla alba* on the ground (White wagtail G), **(g)** common whitethroat *Sylvia communis* in the edge zone of study sites (Common whitethroat EZ) and **(h)** common blackbird *Turdus merula* on the ground (Common blackbird G).




(c) Fieldfare G
ρ = -0.126
n = 499
P = 0.005
Density (ind/km²)
Vegetation height (cm)
(d) Eurasian jackdaw G
ρ = -0.153
n = 499
P < 0.001
Vegetation height (cm)
(e) Redwing G
ρ = -0.109
n = 499
P = 0.015
Density (ind/km²)
Vegetation height (cm)
(f) Lesser black-backed gull G
ρ = -0.144
n = 444
P = 0.002
Vegetation height (cm)
(g) Eurasian tree sparrow G
ρ = -0.078
n = 499
n.s.
Density (ind/km²)
Vegetation height (cm)
(h) Common gull G
ρ = -0.124
n = 444
P = 0.009
Vegetation height (cm)

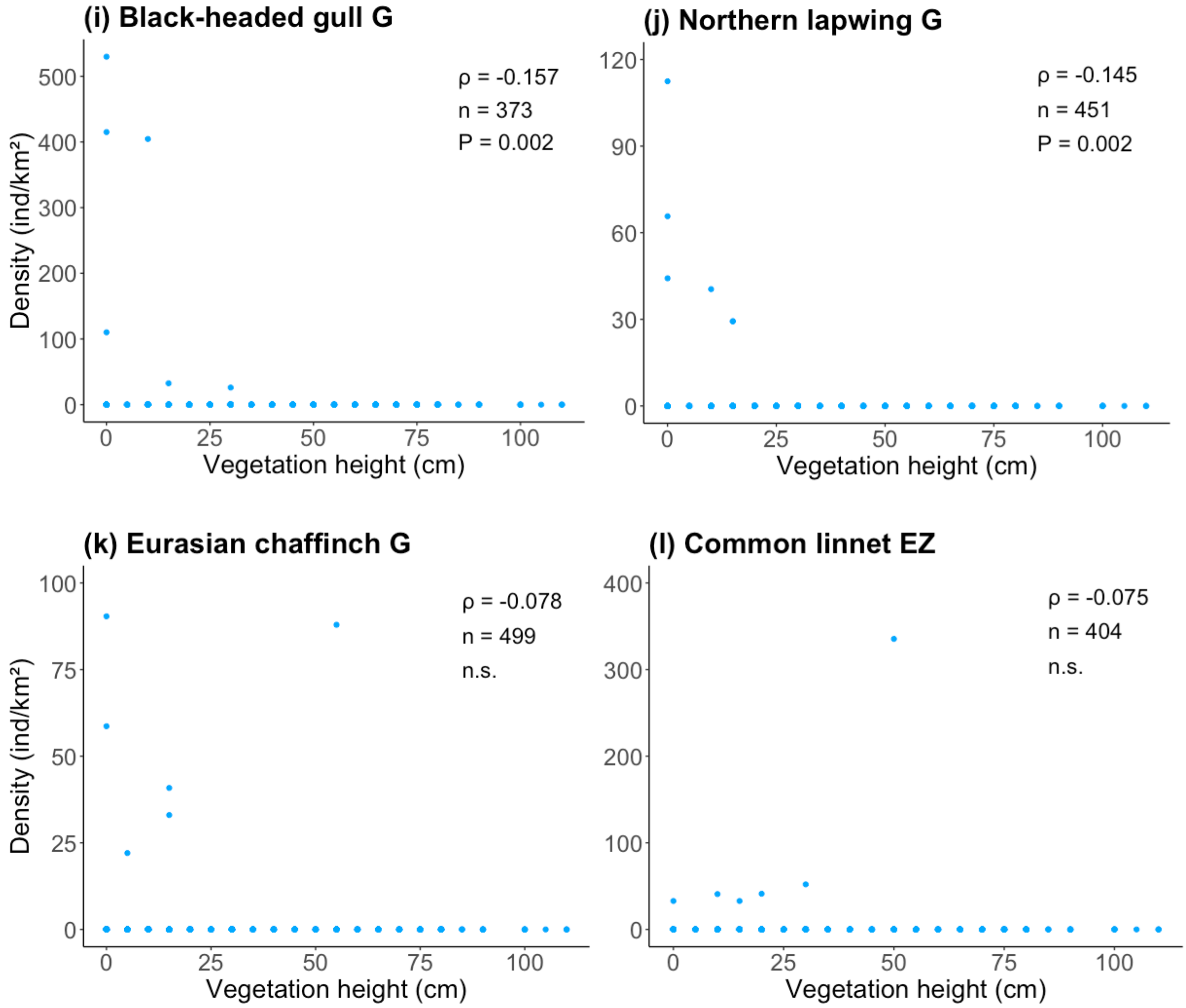


Fig. 5 Results from Spearman's rank correlation of how the vegetation height influenced the density of 12 farmland birds in southeastern Norway. Density is measured as the number of observed individuals per square kilometer at a study site. **ρ** = Spearman's rank correlation coefficient. **n** = the sample size for a species as the total visits to study sites (based on the first day the species was observed for migrating species). n**.s.** = $P > 0.05$. **(a)** Common wood pigeon *Columba palumbus* on the ground (Common wood pigeon G), **(b)** starling *Sturnus vulgaris* on the ground (Starling G), **(c)** fieldfare *Turdus pilaris* on the ground (Fieldfare G), **(d)** Eurasian jackdaw *Corvus monedula* on the ground (Eurasian jackdaw G), **(e)** redwing *Turdus iliacus* on the ground (Redwing G), **(f)** lesser black-backed gull *Larus fuscus* on the ground (Lesser black-backed gull G), **(g)** Eurasian tree sparrow *Passer montanus* on the ground (Eurasian tree sparrow G), **(h)** common gull *Larus canus* on the ground (Common gull G), **(i)** black-headed gull *Chroicocephalus ridibundus* on the ground (Black-headed gull G), **(j)** northern lapwing *Vanellus vanellus* on the ground (Northern lapwing G), **(k)** Eurasian chaffinch *Fringilla coelebs* on the ground (Eurasian chaffinch G) and **(l)** common linnet *Linaria cannabina* in the edge zone of study sites (Common linnet EZ).

4 Discussion

4.1 Habitat selection

Among the 20 bird species analyzed, only Eurasian skylarks, hooded crows and Eurasian magpies showed a significant preference between autumn sown cereals (AS) or spring sown cereals (SS). Interestingly, Eurasian skylarks preferred AS over SS, which could be a result of AS providing habitats with the preferred sward height early in the breeding season, when SS were less available. AS have generally been preferred over SS in another European study (Hiron et al., 2012). However, a switch from AS to SS during the breeding season was not found for Eurasian skylarks in this study, which has been the case in other studies (Hiron et al., 2012; Eggers et al., 2011). In contrast, hooded crows and Eurasian magpies favored SS over AS, which most likely were selected when SS had shorter sward heights than AS, providing easier access to food and better predator detection.

The Eurasian skylark was the only species preferring AS over exposed soil (ES), meadows (M) and pastures (P), among the four species showing a significant selection between AS and other farmland types than SS. The selection of AS over the other farmland types could be explained by AS providing the optimal sward heights as explained with SS, but also the difference in sward structures. Intensive driven meadows have denser sward structure and more rapid growth than AS, which were likely reasons for AS being favored over M. Previous studies have shown that Eurasian skylarks avoid nesting or foraging in farmland types with too dense structures and rapid growth, because of decreased accessibility (Wilson et al., 1997; Morris et al., 2004; Odderskær et al., 1997). On the other hand, too short swards and sparse vegetation is not preferred among Eurasian skylarks when building and protecting nests, which can probably explain why AS was preferred over P, if P had too high grazing intensity by grazing animals (Wilson et al., 1997; Báldi et al., 2005). Both M and P, especially the latter, were much smaller in size than AS and had forest areas in the edge zones, which leads to more enclosed habitats, whereas Eurasian skylarks favor open landscapes (Wilson et al., 1997; Donald, 2004). The avoidance of M and P could be a cause of decreased detection of predators in the smaller areas, since Eurasian skylarks nesting along field margins experience higher nest loss by predators, such as mammals, which mostly occur along the boundaries (Morris & Gilroy, 2008).

Hooded crows, Eurasian magpies and white wagtails preferred ES over AS. In general, ploughing has been shown in other studies (but with some contradicting results) to reduce the abundance of invertebrates used as food sources by farmland birds, as well as negatively affecting seed-eaters consuming residual grains from post-harvests in stubble fields (Wilson et al., 1999; Cunningham et al., 2004; Newton, 2004). However, many individuals of the invertebrate-eaters were observed at ES right after ploughing, probably because of the instant access to invertebrates, which were otherwise concealed under the soil.

One of the species preferring stubble fields (SF) over AS was the hooded crow. SF are generally an important foraging habitat for seed-eating species, which can also include the hooded crow with its broad diet of different food items such as cereal grains in farmlands (Newton, 2004; Cramp et al., 1994). The selection of SF over AS among white wagtails, M over AS by hooded crows, and P over AS by white wagtails, were most likely selected because of the short vegetation or when the swards were short, since lower vegetation can provide better foraging efficiency and predator detection (Atkinson et al., 2004; Douglas et al., 2009; Whittingham & Evans, 2004). Another explanation of why white wagtails preferred P over AS could be that grazing animals on pastures flush or attract insects. A similar relationship has been detected in previous studies, where several invertebrate-eating bird species, like the white wagtail, preferred pastures with grazing activity, even though other farmland types with longer swards had a higher abundance of invertebrates. These studies concluded that shorter sward heights providing higher foraging efficiency are prioritized over food abundance when foraging (Romanowski & Żmihorski, 2008; Danyłow et al., 2010).

Seven of the 12 species analyzed with Fisher's exact test indicated an avoidance of AS for other farmland types. This is in line with previous studies for the ground-nesting northern lapwing, which was one of the species analyzed (Wilson et al., 2001; Sheldon et al., 2005; Sakseide & Dale, 2023). The six other species (common wood pigeons, Eurasian jackdaws, redwings, common gulls, black-headed gulls and common linnets), most likely selected other farmland types for better foraging efficiency and predator detection, as the other ground-foraging species in this study.

4.2 Selection of vegetation height

The Eurasian skylark and the northern lapwing were the only ground-nesting species selecting low vegetation. The selection of short swards by Eurasian skylarks contradicts the result of the preference of AS over SS, since AS were mostly taller than SS during the breeding season. However, AS with shorter vegetation could have been preferred over AS with taller swards in this study, since Eurasian skylarks have shown in other studies to avoid tall vegetation (Hiron et al., 2012; Eggers et al., 2011; Wilson et al., 1997; Morris et al., 2004; Odderskær et al., 1997). The selection of low vegetation by northern lapwings is in line with previous studies (Sheldon et al., 2005; Sakseide & Dale, 2023). Low vegetation with a varied sward structure, as well as patches with bare ground, are known to be preferred among northern lapwings for nest placement, predator detection by parents and foraging efficiency among foraging chicks (Devereux et al., 2004; Shrubb, 2010).

The 12 other species selecting low vegetation are not ground-nesters in farmlands, but can use the farmlands as foraging sites. Several studies indicate that farmland types with lower vegetation are preferred among 11 of the 12 species when foraging, because of increased food accessibility and better detection of predators. However, mainly species feeding on invertebrates selected shorter vegetation in these studies, while granivores had more variation in their selection and could prefer taller swards (Atkinson et al., 2005; Buckingham et al., 2006; Isaksson et al., 2016). Little research has been made about the selection of vegetation heights by hooded crows, but since hooded crows have a similar diet to Eurasian magpies and Eurasian jackdaws, foraging efficiency is most likely the reason for the selection of shorter swards.

Only barn swallows selected high vegetation. The selection of taller vegetation could be linked to prey abundance, since taller swards generally have a higher abundance of insects (Milberg et al., 2016; Atkinson et al, 2004; Mccracken & Tallowin, 2004). This could further be confirmed by a study from England, which showed a decreased occurrence of foraging barn swallows a few days after cutting in grasslands (Peggie et al., 2011).

Several species did not show significant results when analyzing habitat selection and selection of vegetation height, which could be attributed to many zero-values in the dataset and observations of many individuals at few study sites. Other reasons could be that they selected other farmland types to the same degree as AS, or preferred a selection of different vegetation heights based on different activities like nesting or foraging. One could argue that fewer birds were detected in farmland types with higher vegetation, but most birds were detected after 2-3 minutes during the 10 minutes by hearing birds calling and seeing birds flying up or landing on the ground at the study site. Thus, the selection of short vegetation by several farmland birds in this study seems to be the real preference for vegetation height. It is important to note that the 12 species analyzed with Fisher's exact test or Spearman's rank correlation have more uncertainty in their results, since they could not include study site ID as a random effect like the species analyzed with the GLMM-ZIP. However, each study site changed character for each visit due to the change of vegetation heights and often changing farmland types. Pseudoreplication caused by including the same study sites several times in Fisher's exact test and Spearman's rank correlation should therefore have had little to no effect on the results.

4.3 Conservation recommendations

A switch from spring sown cereals to autumn sown cereals should be preferred according to the study by Santangeli et al., (2018), since climate change has created an increased mismatch of the timing of farming practices and egg laying by ground-nesting species in spring sown cereals. However, our results indicate that autumn sown cereals, as well as tall swards are for the most part not preferred among the farmlands birds included in this study. Autumn sown cereals would provide a safer habitat for the ground-nesting species, but since the northern lapwing indicated an avoidance of autumn sown cereals, a switch from spring sown cereals to autumn sown cereals is generally not recommended in the future management of farmland bird populations. In this study, Eurasian skylarks seem to be the only species benefiting from the use of autumn sown cereals, if the swards are not too tall.

Skylark plots (called "lerkeruter" in Norway) and lapwing plots (called "vipestriper" in Norway) can increase the quality of autumn sown cereals as a nesting habitat, if they are selected by Eurasian skylark and northern lapwings for breeding. The plots are made by letting unsown patches be fallow during the breeding season and they are used for foraging and nest placement (BirdLife Norge & Norges Bondelag, 2022). However, Eurasian skylarks mainly use the skylark plots when foraging, since the Skylark plots have greater food abundance and food accessibility than the rest of a cultivated field (Morris et al., 2004, Roualet & Skjetne, 2020) A study in Sweden has also shown that the use of skylark plots in an area can increase the number of skylarks with 60% (Wärnbäck et al., 2018). Other species, such as yellowhammers and common wood pigeons, can also use the plots which were found in a study with lapwing plots (Chamberlain et al., 2008). To decrease the risk of predation and disturbance, the placement of skylark plots should be 50 meters away from field margins and 100 meters away from tall vegetation and human-made structures for the lapwing plots (BirdLife Norge & Norges Bondelag, 2022). Both skylark plots and lapwing plots can be financially aided by the Special Environment Measures in Agriculture (SMIL), which is a Norwegian grant scheme to encourage farmers to increase the biological diversity in the agricultural landscape (Forskrift om spesielle miljøtiltak i jordbruket, 2004).

4.4 Conclusion

This study has provided new knowledge about species previously not investigated, regarding the selection of autumn sown cereal or spring sown cereal, as well as other farmland types and the selection of vegetation heights. Only Eurasian skylarks selected autumn sown cereals over several other farmland types, but they favored short vegetation. Remaining species showing significant results selected other farmland types than AS and mostly selected low vegetation, which could generally be explained by better foraging efficiency and predator detection in fields with shorter swards. Based on the results of the other species than Eurasian skylarks in this study, a switch from spring sown cereals to autumn sown cereals is not recommended for the future management of the farmland bird populations. Skylark plots and lapwing plots can improve autumn sown cereals as nesting habitats, if fields with autumn sown cereal have been selected for breeding.

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Appendix A

Table A1 List of species with the total number of observed individuals in different types of farmlands and the total number of farmlands with observed individuals. **G**= on the ground. **EZ** = in the edge zone of the farmland. **I** = on an island in the farmland. **OF** = flying over the farmland. **PC** = sitting on a power cord over the farmland. Species which provided enough data material for further data analysis are marked in yellow and green. These species had a minimum criterion of being observed on ≥ 6 farmlands. Generalized Linear Mixed Models with Zero-inflated Poisson regression (GLMM-ZIP) were used for the species marked in yellow. Fisher's exact test and Spearman's rank correlation were used for the species marked in green, since the GLMM-ZIP would not provide results for those species. **1st day** includes the first day a migrating bird species was observed after the first day of field work (April 9th, 2024), which is only noted for the marked species. **Last day** is only noted for the marked species, and includes the last day a migrating bird species was observed, before it traveled to its breeding ground which was not located in the study area. ***n* visits** = the sample size for a species as the total visits to study sites (based on the first day the species was observed for migrating species). **AS** = autumn sown cereal. **ES** = exposed soil, **M** = meadow, **P** = pasture, **SS** = spring sown cereal and **SF** = stubble field.

Species	Activity	1st day	Last day	*n* visits	AS	ES	M	P	SS	SF	Total
Eurasian skylark *Alauda arvensis*					***n* observed individuals in different farmlands**						
	G	1		499	237	50	21	1	193	95	597
	OF				23	7	7	0	19	5	61
					***n* farmlands with observed individuals**						
	G				74	23	9	1	77	31	215
	OF				20	6	3	0	16	4	49
Yellowhammer *Emberiza citrinella*					***n* observed individuals in different farmlands**						
	G			499	17	9	0	3	22	12	63
	EZ				51	16	12	19	71	12	181
	I				3	0	3	0	12	1	19
					***n* farmlands with observed individuals**						
	G				12	8	0	2	16	7	45
	EZ				38	12	12	15	44	8	129
	I				3	0	3	0	10	1	17
Hooded crow *Corvus cornix*					***n* observed individuals in different farmlands**						
	G			499	3	16	7	2	31	8	67
	EZ				0	1	0	1	0	0	2
					***n* farmlands with observed individuals**						
	G				2	11	3	2	21	4	43
	EZ				0	1	0	1	0	0	2
Eurasian magpie *Pica pica*					***n* observed individuals in different farmlands**						
	G			499	4	28	4	6	20	4	66
	EZ				0	0	0	0	0	6	6
					***n* farmlands with observed individuals**						
	G				4	13	3	3	11	2	36
	EZ				0	0	0	0	0	2	2

Barn swallow *Hirundo rustica*					***n* observed individuals in different farmlands**					
	OF	11		460	15	1	2	6	42	0	66
	PC				0	0	0	0	0	1	1
					***n* farmlands with observed individuals**					
	OF				9	1	2	3	20	0	35
	PC				0	0	0	0	0	1	1
White wagtail *Motacilla alba*					***n* observed individuals in different farmlands**					
	G	1		499	2	26	1	7	5	12	53
					***n* farmlands with observed individuals**					
	G				2	12	1	5	5	6	31
Common whitethroat *Sylvia communis*					***n* observed individuals in different farmlands**					
	EZ	26		385	3	1	3	2	12	0	21
					***n* farmlands with observed individuals**					
	EZ				3	1	3	2	12	0	21
Common blackbird *Turdus merula*					***n* observed individuals in different farmlands**					
	G			499	1	2	4	1	6	3	17
					***n* farmlands with observed individuals**					
	G				1	2	3	1	6	3	16
Common linnet *Linaria cannabina*					***n* observed individuals in different farmlands**					
	G				0	2	0	0	6	2	10
	EZ	23		404	2	1	0	1	2	3	9
					***n* farmlands with observed individuals**					
	G				0	1	0	0	1	1	3
	EZ				1	1	0	1	1	2	6
Common wood pigeon *Columba palumbus*					***n* observed individuals in different farmlands**					
	G	1		499	9	23	0	4	49	21	106
	EZ				0	9	0	0	0	4	13
					***n* farmlands with observed individuals**					
	G				1	9	0	3	17	5	35
	EZ				0	3	0	0	0	3	6
Starling *Sturnidae*					***n* observed individuals in different farmlands**					
	G	1		499	3	34	14	19	140	4	214
	EZ				0	2	0	1	0	0	3
	I				0	0	0	3	0	0	3
					***n* farmlands with observed individuals**					
	G				1	5	3	3	11	1	24
	EZ				0	1	0	1	0	0	2
	I				0	0	0	1	0	0	1
					***n* observed individuals in different farmlands**					

Fieldfare *Turdus pilaris*	G	1		499	75	156	17	1	15	52	316
	EZ				0	1	2	2	1	0	6
					***n* farmlands with observed individuals**						
	G				5	3	4	1	4	3	20
	EZ				0	1	1	1	1	0	4
Eurasian jackdaw *Corvus monedula*					***n* observed individuals in different farmlands**						
	G			499	0	23	0	8	40	0	71
					***n* farmlands with observed individuals**						
	G				0	4	0	2	7	0	13
Redwing *Turdus iliacus*					***n* observed individuals in different farmlands**						
	G	1		499	20	50	35	10	3	20	138
	EZ				0	0	2	2	0	0	4
					***n* farmlands with observed individuals**						
	G				3	1	3	1	1	3	12
	EZ				0	0	1	2	0	0	3
Lesser black-backed gull *Larus fuscus*					***n* observed individuals in different farmlands**						
	G	14		444	0	46	0	0	28	27	101
					***n* farmlands with observed individuals**						
	G				0	2	0	0	5	2	9
Eurasian tree sparrow *Passer montanus*					***n* observed individuals in different farmlands**						
	G			499	1	0	0	0	18	0	19
					***n* farmlands with observed individuals**						
	G				1	0	0	0	8	0	9
Common gull *Larus canus*					***n* observed individuals in different farmlands**						
	G	14		444	0	33	0	0	13	21	67
	OF				0	0	0	2	1	0	3
					***n* farmlands with observed individuals**						
	G				0	3	0	0	3	1	7
	OF				0	0	0	1	1	0	2
Meadow pipit *Anthus pratensis*					***n* observed individuals in different farmlands**						
	G	1	18	83	0	16	0	2	0	1	19
	I				0	1	0	0	0	0	1
					***n* farmlands with observed individuals**						
	G				0	5	0	1	0	1	7
	I				0	1	0	0	0	0	1
Black-headed gull *Chroicocephalus ridibundus*					***n* observed individuals in different farmlands**						
	G	28		373	0	12	0	0	73	1	86
					***n* farmlands with observed individuals**						
	G				0	2	0	0	3	1	6

Northern lapwing *Vanellus vanellus*					***n* observed individuals in different farmlands**						
	G	13		451	0	9	0	0	2	4	15
					***n* farmlands with observed individuals**						
	G				0	3	0	0	1	2	6
Eurasian chaffinch *Fringilla coelebs*					***n* observed individuals in different farmlands**						
	G	1		499	0	3	0	0	8	2	13
	EZ				1	1	0	0	0	0	2
					***n* farmlands with observed individuals**						
	G				0	2	0	0	3	1	6
	EZ				1	1	0	0	0	0	2
Song trush *Turdus philomelos*					***n* observed individuals in different farmlands**						
	G				0	0	2	6	1	2	11
					***n* farmlands with observed individuals**						
	G				0	0	1	2	1	1	5
House sparrow *Passer domesticus*					***n* observed individuals in different farmlands**						
	G				0	0	0	0	10	0	10
					***n* farmlands with observed individuals**						
	G				0	0	0	0	5	0	5
Brambling *Fringilla montifringilla*					***n* observed individuals in different farmlands**						
	G				2	5	0	0	0	4	11
	EZ				0	0	0	2	0	0	2
	I				0	0	0	0	0	24	24
					***n* farmlands with observed individuals**						
	G				1	1	0	0	0	2	4
	EZ				0	0	0	1	0	0	1
	I				0	0	0	0	0	1	1
House martin *Delichon urbicum*					***n* observed individuals in different farmlands**						
	OF				1	0	0	0	7	0	8
					***n* farmlands with observed individuals**						
	OF				1	0	0	0	3	0	4
Marsh warbler *Acrocephalus palustris*					***n* observed individuals in different farmlands**						
	EZ				2	0	0	0	2	0	4
					***n* farmlands with observed individuals**						
	EZ				2	0	0	0	2	0	4
Western marsh harrier *Circus aeruginosus*					***n* observed individuals in different farmlands**						
	OF				3	0	0	0	1	0	4
					***n* farmlands with observed individuals**						
	OF				3	0	0	0	1	0	4
					***n* observed individuals in different farmlands**						

Common reed bunting *Emberiza schoeniclus*	G				0	0	0	0	0	4	4
Common reed bunting *Emberiza schoeniclus*	EZ				1	0	0	0	2	0	3
Common reed bunting *Emberiza schoeniclus*					***n* farmlands with observed individuals**						
Common reed bunting *Emberiza schoeniclus*	G				0	0	0	0	0	2	2
Common reed bunting *Emberiza schoeniclus*	EZ				1	0	0	0	2	0	3
Common quail *Coturnix coturnix*					***n* observed individuals in different farmlands**						
Common quail *Coturnix coturnix*	G				1	0	0	0	3	0	4
Common quail *Coturnix coturnix*					***n* farmlands with observed individuals**						
Common quail *Coturnix coturnix*	G				1	0	0	0	2	0	3
Common buzzard *Buteo buteo*					***n* observed individuals in different farmlands**						
Common buzzard *Buteo buteo*	EZ				0	0	1	0	1	0	2
Common buzzard *Buteo buteo*	OF				0	0	0	0	1	0	1
Common buzzard *Buteo buteo*					***n* farmlands with observed individuals**						
Common buzzard *Buteo buteo*	EZ				0	0	1	0	1	0	2
Common buzzard *Buteo buteo*	OF				0	0	0	0	1	0	1
Ring ouzel *Turdus torquatus*					***n* observed individuals in different farmlands**						
Ring ouzel *Turdus torquatus*	G				2	0	0	0	0	0	2
Ring ouzel *Turdus torquatus*	I				0	0	0	0	0	1	1
Ring ouzel *Turdus torquatus*					***n* farmlands with observed individuals**						
Ring ouzel *Turdus torquatus*	G				2	0	0	0	0	0	2
Ring ouzel *Turdus torquatus*	I				0	0	0	0	0	1	1
Herring gull *Larus argentatus*					***n* observed individuals in different farmlands**						
Herring gull *Larus argentatus*	G				0	8	0	0	0	0	8
Herring gull *Larus argentatus*					***n* farmlands with observed individuals**						
Herring gull *Larus argentatus*	G				0	2	0	0	0	0	2
Northern wheatear *Oenanthe oenanthe*					***n* observed individuals in different farmlands**						
Northern wheatear *Oenanthe oenanthe*	G				0	7	0	0	0	0	7
Northern wheatear *Oenanthe oenanthe*					***n* farmlands with observed individuals**						
Northern wheatear *Oenanthe oenanthe*	G				0	2	0	0	0	0	2
Common kestrel *Falco tinnunculus*					***n* observed individuals in different farmlands**						
Common kestrel *Falco tinnunculus*	EZ				2	0	0	0	0	1	3
Common kestrel *Falco tinnunculus*					***n* farmlands with observed individuals**						
Common kestrel *Falco tinnunculus*	EZ				1	0	0	0	0	1	2
Domestic pigeon *Columba livia domestica*					***n* observed individuals in different farmlands**						
Domestic pigeon *Columba livia domestica*	G				0	1	0	0	2	0	3
Domestic pigeon *Columba livia domestica*					***n* farmlands with observed individuals**						
Domestic pigeon *Columba livia domestica*	G				0	1	0	0	1	0	2
Great tit *Parus major*					***n* observed individuals in different farmlands**						
Great tit *Parus major*	G				0	0	0	1	1	0	2

					***n* farmlands with observed individuals**					
	G				0	0	0	1	1	0	2
Golden plover *Pluvialis apricaria*					***n* observed individuals in different farmlands**						
	G				0	0	0	0	0	16	16
					***n* farmlands with observed individuals**						
	G				0	0	0	0	0	1	1
Icterine warbler *Hippolais icterina*					***n* observed individuals in different farmlands**						
	EZ				0	0	0	0	3	0	3
					***n* farmlands with observed individuals**						
	EZ				0	0	0	0	1	0	1
Common shelduck *Tadorna tadorna*					***n* observed individuals in different farmlands**						
	G				0	0	0	0	2	0	2
					***n* farmlands with observed individuals**						
	G				0	0	0	0	1	0	1
Mistle trush *Turdus viscivorus*					***n* observed individuals in different farmlands**						
	G				0	0	0	1	0	0	1
					***n* farmlands with observed individuals**						
	G				0	0	0	1	0	0	1
Blue tit *Cyanistes caeruleus*					***n* observed individuals in different farmlands**						
	G				0	0	0	0	1	0	1
					***n* farmlands with observed individuals**						
	G				0	0	0	0	1	0	1
Whinchat *Saxicola rubetra*					***n* observed individuals in different farmlands**						
	EZ				0	0	0	1	0	0	1
					***n* farmlands with observed individuals**						
	EZ				0	0	0	1	0	0	1
European goldfinch *Carduelis carduelis*					***n* observed individuals in different farmlands**						
	EZ				0	0	0	1	0	0	1
					***n* farmlands with observed individuals**						
	EZ				0	0	0	1	0	0	1
Green sandpiper *Tringa ochropus*					***n* observed individuals in different farmlands**						
	EZ				0	0	0	1	0	0	1
					***n* farmlands with observed individuals**						
	EZ				0	0	0	1	0	0	1

Appendix B

Table B1 Result from the Generalized Linear Mixed Models with a Zero-inflated Poisson regression for the habitat selection by Eurasian skylarks (*Alauda arvensis*) on the ground (Euorpean skylark G). Coefficients are on a log scale. **AS** = autumn sown cereal, **ES** = exposed soil, **M** = meadow, **P** = pasture, **SS** = spring sown cereal and **SF** = stubble field. **Start** = start time for the 10-minute registration period at a study site. **Area (km2)** = study site size measured in square kilometers. Autumn sown cereal is used as reference for significant differences between farmland types. Significant results are marked in bold.

Eurasian skylark G

Random effect	**σ2**	**SD**		
Study site ID (Intercept)	0.292	0.541		
Fixed effect	**Estimate**	**SE**	**z-value**	***P***
AS (Intercept)	-0.619	0.444	-1.396	0.163
ES	-0.554	0.221	-2.501	**0.012**
M	-1.107	0.339	-3.262	**0.001**
P	-3.521	1.035	-3.401	**< 0.001**
SS	-0.455	0.177	-2.574	**0.010**
SF	0.062	0.195	0.317	0.752
Start	-0.019	0.048	-0.407	0.684
Area (km2)	23.945	2.900	8.267	**< 0.001**
Zero-inflation model	**Estimate**	**SE**	**z-value**	***P***
Intercept	-1.582	0.308	-5.131	**< 0.001**

Table B2 Result from the Generalized Linear Mixed Models with a Zero-inflated Poisson regression for the selection of vegetation height by Eurasian skylarks (*Alauda arvensis*) on the ground (Eurasian skylark G). Coefficients are on a log scale. **Start** = start time for the 10-minute registration period at a study site. **Vegetation height (cm)** = height of the vegetation at a study site. **Area (km2)** = study site size measured in square kilometers. Significant results are marked in bold.

Eurasian skylark G

Random effect	**σ2**	**SD**		
Study site ID (Intercept)	0.495	0.703		
Fixed effect	**Estimate**	**SE**	**z-value**	***P***
(Intercept)	-1.609	0.434	-3.710	**< 0.001**
Vegetation height (cm)	-0.004	0.002	-1.960	**0.050**
Start	-0.017	0.048	0.358	0.720
Area (km2)	30.806	3.036	10.148	**< 0.001**
Zero-inflation model	**Estimate**	**SE**	**z-value**	***P***
Intercept	-1.615	0.330	-4.900	**< 0.001**

Table B3 Result from the Generalized Linear Mixed Models with a Zero-inflated Poisson regression for the habitat selection by yellowhammers (*Emberiza citrinella*) on the ground (Yellowhammer G). Coefficients are on a log scale. **AS** = autumn sown cereal, **ES** = exposed soil, **M** = meadow, **P** = pasture, **SS** = spring sown cereal and **SF** = stubble field. **Start** = start time for the 10-minute registration period at a study site. **Area (km2)** = study site size measured in square kilometers. Autumn sown cereal is used as reference for significant differences between farmland types. Significant results are marked in bold.

Yellowhammer G				
Random effect	**σ2**	**SD**		
ID (Intercept)	0.234	0.484		
Fixed effect	**Estimate**	**SE**	**z-value**	***P***
AS (Intercept)	-0.553	1.262	-0.438	0.661
ES	-0.182	0.508	-0.359	0.720
M	-14.347	407.850	-0.035	0.972
P	-1.477	0.759	-1.946	0.052
SS	0.049	0.422	0.115	0.908
SF	0.723	0.494	1.465	0.143
Start	0.059	0.128	0.461	0.645
Area (km2)	-19.136	7.791	-2.456	**0.014**
Zero-inflation model	**Estimate**	**SE**	**z-value**	***P***
Intercept	0.763	0.549	1.391	0.164

Table B4 Result from the Generalized Linear Mixed Models with a Zero-inflated Poisson regression for the selection of vegetation height by yellowhammers (*Emberiza citrinella*) on the ground (Yellowhammer G). Coefficients are on a log scale. **Start** = start time for the 10-minute registration period at a study site. **Vegetation height (cm)** = height of the vegetation at a study site. **Area (km2)** = study site size measured in square kilometers. Significant results are marked in bold.

Yellowhammer G				
Random effect	**σ2**	**SD**		
ID (Intercept)	0.809	0.900		
Fixed effect	**Estimate**	**SE**	**z-value**	***P***
(Intercept)	-1.884	1.483	-1.270	0.204
Vegetation height (cm)	-0.001	0.005	-0.261	0.794
Start	0.112	0.132	0.846	0.397
Area (km2)	-8.894	7.409	-1.200	0.230
Zero-inflation model	**Estimate**	**SE**	**z-value**	***P***
Intercept	0.616	0.732	0.842	0.400

Table B5 Result from the Generalized Linear Mixed Models with a Zero-inflated Poisson regression for the habitat selection by hooded crows (*Corvus cornix*) on the ground (Hooded crow G). Coefficients are on a log scale. **AS** = autumn sown cereal, **ES** = exposed soil, **M** = meadow, **P** = pasture, **SS** = spring sown cereal and **SF** = stubble field. Start = start time for the 10-minute registration period at a study site. **Area (km2)** = study site size measured in square kilometers. Autumn sown cereal is used as reference for significant differences between farmland types. Significant results are marked in bold.

Hooded crow G

Random effect	**σ2**	**SD**		
ID (Intercept)	0.000	0.000		
Fixed effect	**Estimate**	**SE**	**z-value**	***P***
AS (Intercept)	-6.114	1.844	-5.582	**< 0.001**
ES	2.380	0.679	3.505	**< 0.001**
M	2.177	0.760	2.862	**0.004**
P	1.224	0.992	1.233	0.217
SS	2.188	0.647	3.380	**< 0.001**
SF	1.757	0.751	2.338	**0.019**
Start	0.393	0.111	3.534	**< 0.001**
Area (km2)	18.428	4.986	3.696	**< 0.001**
Zero-inflation model	**Estimate**	**SE**	**z-value**	***P***
Intercept	0.903	0.301	3.001	**0.003**

Table B6 Result from the Generalized Linear Mixed Models with a Zero-inflated Poisson regression for the selection of vegetation height by hooded crows (*Corvus cornix*) on the ground (Hooded crow G). Coefficients are on a log scale. **Start** = start time for the 10-minute registration period at a study site. Vegetation height (cm) = height of the vegetation at a study site. **Area (km2)** = study site size measured in square kilometers. Significant results are marked in bold.

Hooded crow G

Random effect	**σ2**	**SD**		
ID (Intercept)	0.960	0.980		
Fixed effect	**Estimate**	**SE**	**z-value**	***P***
(Intercept)	-3.662	1.197	-3.059	**0.002**
Vegetation height (cm)	-0.033	0.008	-4.004	**< 0.001**
Start	0.155	0.140	1.111	0.267
Area (km2)	24.718	6.453	3.831	**< 0.001**
Zero-inflation model	**Estimate**	**SE**	**z-value**	***P***
Intercept	-0.128	0.705	-0.181	0.856

Table B7 Result from the Generalized Linear Mixed Models with a Zero-inflated Poisson regression for the habitat selection by Eurasian magpies (*Pica pica*) on the ground (Eurasian magpie G). Coefficients are on a log scale. **AS** = autumn sown cereal, **ES** = exposed soil, **M** = meadow, **P** = pasture, **SS** = spring sown cereal and **SF** = stubble field. **Start** = start time for the 10-minute registration period at a study site. **Vegetation height (cm)** = height of the vegetation at a study site. **Area (km2)** = study site size measured in square kilometers. Autumn sown cereal is used as reference for significant differences between farmland types. Significant results are marked in bold.

Eurasian magpie G				
Random effect	**σ2**	**SD**		
ID (Intercept)	1.167	1.080		
Fixed effect	**Estimate**	**SE**	**z-value**	***P***
AS (Intercept)	-5.026	1.566	-3.209	**0.001**
ES	2.796	0.762	3.671	**< 0.001**
M	1.120	0.887	1.263	0.207
P	1.842	0.968	1.903	0.057
SS	1.372	0.675	2.033	**0.042**
SF	1.289	0.920	1.401	0.161
Start	0.242	0.144	1.679	0.093
Area (km2)	14.620	8.837	1.654	0.099
Zero-inflation model	**Estimate**	**SE**	**z-value**	***P***
Intercept	1.159	0.548	2.115	**0.034**

Table B8 Result from the Generalized Linear Mixed Models with a Zero-inflated Poisson regression for the selection of vegetation height by Eurasian magpies (*Pica pica*) on the ground (Eurasian magpie G). Coefficients are on a log scale. **Start** = start time for the 10-minute registration period at a study site. **Vegetation height (cm)** = height of the vegetation at a study site. **Area (km2)** = study site size measured in square kilometers. Significant results are marked in bold.

Eurasian magpie G				
Random effect	**σ2**	**SD**		
ID (Intercept)	2.085	1.444		
Fixed effect	**Estimate**	**SE**	**z-value**	***P***
Intercept	-2.078	1.832	-1.134	0.257
Vegetation height (cm)	-0.058	0.014	-4.095	**< 0.001**
Start	0.078	0.174	0.452	0.651
Area (km2)	9.338	8.236	1.134	0.257
Zero-inflation model	**Estimate**	**SE**	**z-value**	***P***
Intercept	0.387	0.711	0.545	0.586

Table B9 Result from the Generalized Linear Mixed Models with a Zero-inflated Poisson regression for the habitat selection by barn swallows (*Hirundo rustica*) flying over study sites (Barn swallow OF). Coefficients are on a log scale. **AS** = autumn sown cereal, **ES** = exposed soil, **M** = meadow, **P** = pasture, **SS** = spring sown cereal and **SF** = stubble field. **Start** = start time for the 10-minute registration period at a study site. **Vegetation height (cm)** = height of the vegetation at a study site. **Area (km2)** = study site size measured in square kilometers. Autumn sown cereal is used as reference for significant differences between farmland types. Significant results are marked in bold.

Barn swallow OF

Random effect	**σ2**	**SD**		
ID (Intercept)	0.850	0.922		
Fixed effect	**Estimate**	**SE**	**z-value**	***P***
AS (Intercept)	-4.120	1.659	-2.484	**0.013**
ES	-1.967	1.204	-1.634	0.102
M	-1.190	0.956	-1.124	0.214
P	0.314	0.850	0.369	0.712
SS	0.646	0.500	1.291	0.197
SF	-19.290	7301.350	-0.003	0.998
Start	0.396	0.173	2.295	**0.022**
Area (km2)	0.989	9.001	0.110	0.913
Zero-inflation model	**Estimate**	**SE**	**z-value**	***P***
Intercept	1.189	0.385	3.088	**0.002**

Table B10 Result from the Generalized Linear Mixed Models with a Zero-inflated Poisson regression regression for the selection of vegetation height by barn swallows (*Hirundo rustica*) flying over study sites (Barn swallow OF). Coefficients are on a log scale. **Start** = start time for the 10-minute registration period at a study site. **Vegetation height (cm)** = height of the vegetation at a study site. **Area (km2)** = study site size measured in square kilometers. Significant results are marked in bold.

Barn swallow OF

Random effect	**σ2**	**SD**		
ID (Intercept)	1.577	1.256		
Fixed effect	**Estimate**	**SE**	**z-value**	***P***
Intercept	-4.858	1.607	-3.023	**0.003**
Vegetation height (cm)	0.018	0.007	2.414	**0.016**
Start	0.319	0.165	1.936	0.053
Area (km2)	3.720	8.682	0.428	0.668
Zero-inflation model	**Estimate**	**SE**	**z-value**	***P***
Intercept	0.893	0.438	2.042	**0.041**

Table B11 Result from the Generalized Linear Mixed Models with a Zero-inflated Poisson regression for the habitat selection by white wagtails (*Motacilla alba*) on the ground (White wagtail G). Coefficients are on a log scale. **AS** = autumn sown cereal, **ES** = exposed soil, **M** = meadow, **P** = pasture, **SS** = spring sown cereal and **SF** = stubble field. **Start** = start time for the 10-minute registration period at a study site. **Vegetation height (cm)** = height of the vegetation at a study site. **Area (km2)** = study site size measured in square kilometers. Autumn sown cereal is used as reference for significant differences between farmland types. Significant results are marked in bold.

White wagtail G				
Random effect	**σ2**	**SD**		
ID (Intercept)	0.000	0.000		
Fixed effect	**Estimate**	**SE**	**z-value**	***P***
AS (Intercept)	-5.510	1.506	-3.659	**< 0.001**
ES	3.348	0.780	4.294	**< 0.001**
M	0.501	1.273	0.393	0.694
P	2.541	0.884	2.874	**0.004**
SS	0.762	0.870	0.875	0.381
SF	3.028	0.827	3.662	**< 0.001**
Start	0.258	0.143	1.802	0.020
Area (km2)	13.371	5.766	2.319	**0.020**
Zero-inflation model	**Estimate**	**SE**	**z-value**	***P***
Intercept	1.083	0.287	3.776	**< 0.001**

Table B12 Result from the Generalized Linear Mixed Models with a Zero-inflated Poisson regression the selection of vegetation height by white wagtails (*Motacilla alba*) on the ground (White wagtail G). Coefficients are on a log scale. **Start** = start time for the 10-minute registration period at a study site. **Vegetation height (cm)** = height of the vegetation at a study site. **Area (km2)** = study site size measured in square kilometers. Significant results are marked in bold.

White wagtail G				
Random effect	**σ2**	**SD**		
ID (Intercept)	0.000	0.000		
Fixed effect	**Estimate**	**SE**	**z-value**	***P***
Intercept	-2.000	1.408	-1.420	0.156
Vegetation height (cm)	-0.048	0.012	-3.942	**< 0.001**
Start	0.226	0.153	1.472	0.141
Area (km2)	12.864	5.442	2.364	**0.018**
Zero-inflation model	**Estimate**	**SE**	**z-value**	***P***
Intercept	1.531	0.275	5.574	**< 0.001**

Table B13 Result from the Generalized Linear Mixed Models with a Zero-inflated Poisson regression for the habitat selection by common whitethroats (*Sylvia communis*) in the edge zone of study sites (Common whitethroat EZ). Coefficients are on a log scale. **AS** = autumn sown cereal, **ES** = exposed soil, **M** = meadow, **P** = pasture, **SS** = spring sown cereal and **SF** = stubble field. **Start** = start time for the 10-minute registration period at a study site. **Area (km2)** = study site size measured in square kilometers. Autumn sown cereal is used as reference for significant differences between farmland types. Significant results are marked in bold.

Common whitethroat EZ

Random effect	**σ2**	**SD**		
ID (Intercept)	1.296	1.138		
Fixed effect	**Estimate**	**SE**	**z-value**	***P***
AS (Intercept)	-2.579	1.864	-1.384	0.166
ES	-0.204	1.191	-0.171	0.864
M	0.153	0.991	0.154	0.877
P	0.010	1.120	0.009	0.993
SS	0.395	0.683	0.578	0.563
SF	-9.333	196.763	-0.047	0.962
Start	-0.135	0.212	-0.639	0.523
Area (km2)	-3.290	11.108	-0.296	0.767
Zero-inflation model	**Estimate**	**SE**	**z-value**	***P***
Intercept	-12.58	346.26	-0.036	0.971

Table B14 Result from the Generalized Linear Mixed Models with a Zero-inflated Poisson regression for the selection of vegetation height by common whitethroats (*Sylvia communis*) in the edge zone of study sites (Common whitethroat EZ). Coefficients are on a log scale. **Start** = start time for the 10-minute registration period at a study site. **Vegetation height (cm)** = height of the vegetation at a study site. **Area (km2)** = study site size measured in square kilometers. Significant results are marked in bold.

Common whitethroat EZ

Random effect	**σ2**	**SD**		
ID (Intercept)	1.317	1.147		
Fixed effect	**Estimate**	**SE**	**z-value**	***P***
Intercept	-2.269	1.715	-1.323	0.186
Vegetation height (cm)	-0.001	0.008	0.128	0.898
Start	-0.163	0.212	-0.769	0.442
Area (km2)	-2.920	9.721	-0.300	0.764
Zero-inflation model	**Estimate**	**SE**	**z-value**	***P***
Intercept	-19.65	12051.01	-0.002	0.999

Table B15 Result from the Generalized Linear Mixed Models with a Zero-inflated Poisson regression for the habitat selection by common blackbirds (*Turdus merula*) on the ground (Common blackbird G). Coefficients are on a log scale. **AS** = autumn sown cereal, **ES** = exposed soil, **M** = meadow, **P** = pasture, **SS** = spring sown cereal and **SF** = stubble field. **Start** = start time for the 10-minute registration period at a study site. **Area (km2)** = study site size measured in square kilometers. Autumn sown cereal is used as reference for significant differences between farmland types. Significant results are marked in bold.

Common blackbird G				
Random effect	**σ2**	**SD**		
ID (Intercept)	2.524	1.589		
Fixed effect	**Estimate**	**SE**	**z-value**	***P***
AS (Intercept)	-6.099	2.403	-2.538	**0.011**
ES	1.687	1.363	0.238	0.216
M	2.221	1.413	1.571	0.116
P	1.125	1.721	0.650	0.516
SS	1.501	1.224	1.226	0.220
SF	2.104	1.308	1.609	0.108
Start	-0.042	0.234	-0.181	0.857
Area (km2)	10.887	12.705	0.857	0.392
Zero-inflation model	**Estimate**	**SE**	**z-value**	***P***
Intercept	-18.09	11293.02	-0.002	0.999

Table B16 Result from the Generalized Linear Mixed Models with a Zero-inflated Poisson regression for the selection of vegetation height by common blackbirds (*Turdus merula*) on the ground (Common blackbird G). Coefficients are on a log scale. **Start** = start time for the 10-minute registration period at a study site. **Vegetation height (cm)** = height of the vegetation at a study site. **Area (km2)** = study site size measured in square kilometers. Significant results are marked in bold.

Common blackbird G				
Random effect	**σ2**	**SD**		
ID (Intercept)	3.410	1.847		
Fixed effect	**Estimate**	**SE**	**z-value**	***P***
Intercept	-2.474	2.209	-1.120	0.263
Vegetation height (cm)	-0.037	0.016	-2.255	**0.024**
Start	-0.255	0.255	-0.998	0.318
Area (km2)	10.097	11.730	0.861	0.389
Zero-inflation model	**Estimate**	**SE**	**z-value**	***P***
Intercept	-9.421	104.165	-0.09	0.928

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