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# Species distribution modeling for farmland birds in South Tyrol

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## Introduction

Agricultural biodiversity is rapidly declining due to the intensification of farming practices (Emmerson et al. 2016). In particular, habitat loss due to e.g. reduced crop type variability, the disappearance of structural elements such as hedges, or early and frequent mowing is a major challenge for many species in these ecosystems (Benton et al. 2003). In this context, birds are considered environmental indicators and play a key role in the assessment of agricultural landscapes (Morelli et al. 2014). As birds are sensitive to environmental changes, their condition reflects the health of the ecosystem (Gottschalk et al. 2010), and they are also one of the most monitored taxonomic groups (Engler et al. 2017). Therefore, understanding bird habitats and the environmental factors that shape them is crucial for assessing the impacts on land use in agroecosystems. However, especially farmland bird species are facing severe declines, as shown by recent abundance trends (European Environment Agency 2024).
This study models the habitat of six farmland bird species in South Tyrol: *Alauda arvensis* (Eurasian Skylark), *Emberiza citrinella* (Yellowhammer), *Lanius collurio* (Red-backed Shrike), *Passer montanus* (Eurasian Tree Sparrow), *Saxicola rubetra* (Whinchat) and *Sturnus vulgaris* (European Starling). Using ensemble species distribution models (SDMs), we linked bird occurrences to remotely sensed environmental features including climatic, satellite-derived and and other spatial variables to model the occurrence probability of these species in spatially complex terrain.

## Material and Methods

South Tyrol is the most northern province of Italy within the Alpine region. The region is characterized by highly heterogenous mountainous landscapes and elevation ranges from 194 m to 3893 m, with about 40 % of the land above 2000 m sea level. Although agriculture covers approximately 69.5 % of the total area, only 26.6 % is classified as utilized agricultural area, mainly consisting of permanent meadows and pastures (ASTAT Landesinstitut für Statistik 2025).
Species distribution models (SDMs) are a commonly used modelling tool in ecological applications (Guisan et al. 2017). By combining data on the occurrence of species and environmental characteristics (features), they estimate the relationship between the two data sources and predict the suitability of habitats over space and time. To account for model selection bias and map the main trend and overall variation across several models, we used an ensemble modeling approach (Araújo & New 2007; Roilo et al. 2022). We used five modeling algorithms, namely, generalized linear models, generalized additive models, boosted regression trees, random forest, and maxent. We used breeding bird occurrence data from 2017–2023, provided by the Museum of Nature South Tyrol and the Institute of Alpine Environment at Eurac Research and environmental data accounting for topography, climate, land cover, vegetation and land management. Specifically, we derived spectral indices to characterize vegetation conditions and mapped the timing and frequency of mowing events to indicate land management intensity using freely available high-resolution satellite data from the European Coper-

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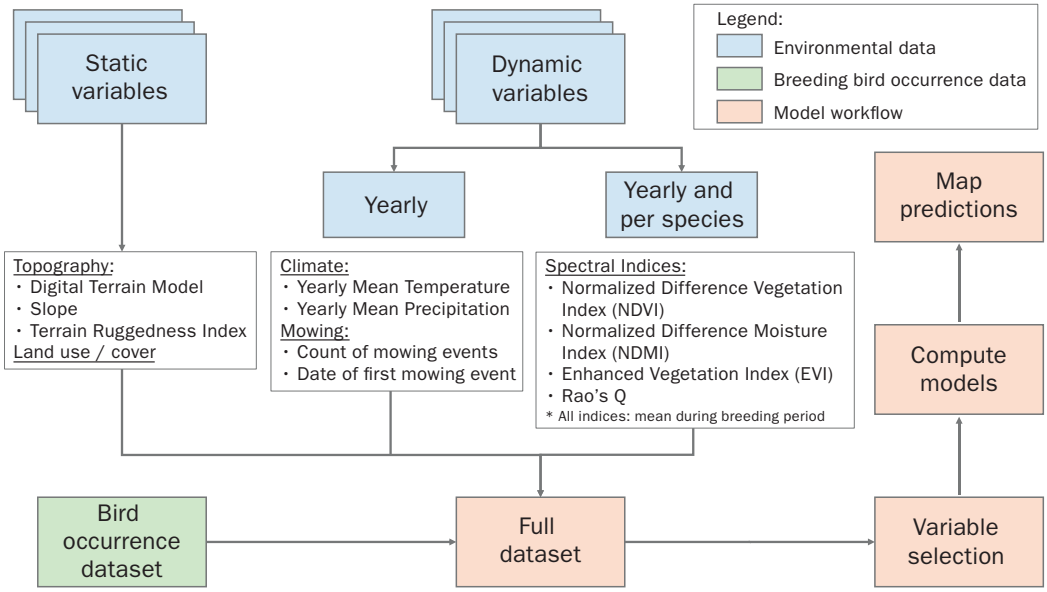


Figure 1: Schematic overview of the preprocessing and modeling workflow.

nicus Program. Milanesi et al. (2019) emphasize the importance of using dynamic environmental variables, to account for changing environmental or land use conditions. Consequently, we categorized our environmental variables as static or dynamic, with dynamic variables further divided into year- and species-specific data (Figure 1) which allowed us to model species-specific habitat suitabilities.

To assess cross correlation among environmental features and to only retain the most meaningful variables in the models, we employed the approach by Roilo et al. (2023) by fitting simple linear models for each variable and ranked them by the corrected Akaike information criterion (AICc) score. In addition, the number of presence points was set to a minimum number of 10 occurrences per variable to avoid overfitting. Final predictions were obtained by calculating the mean, weighted mean and median probabilities for models with a TSS (True Skill Statistic) value higher than 0.7.

## Results

From the ensemble species distribution models, we obtained presence probability maps and variable importance statistics for each of the six modeled bird species across South Tyrol.

The probability maps showed that species-specific habitat preferences based on environmental and land use variables are effectively captured. Figure 2 shows exemplarily the produced maps for the Vinschgau valley with the Mals Heath as area with high predicted probabilities for all six species. *Alauda arvensis* (Skylark) and *Saxicola rubetra* (Whinchat) showed a high presence probability in open meadows and grasslands. In contrast, transition zones with a mixture of landscape features (i.e. hedgerows) and open meadows increased the presence probability of *Emberiza citrinella* (Yellowhammer) and *Lanius collurio* (Red-backed Shrike).

All selected variables in the models included land use and management variables, illustrating their importance for all species (Table 1). In particular, the timing of the first mowing event is a key information that can be accurately captured by remote sensing data. Overall, model accuracy was high for all species, with AUC (Area under ROC curve) values above 0.91 and TSS (True Skill Statistic) values higher than 0.7, indicating strong predictive power.

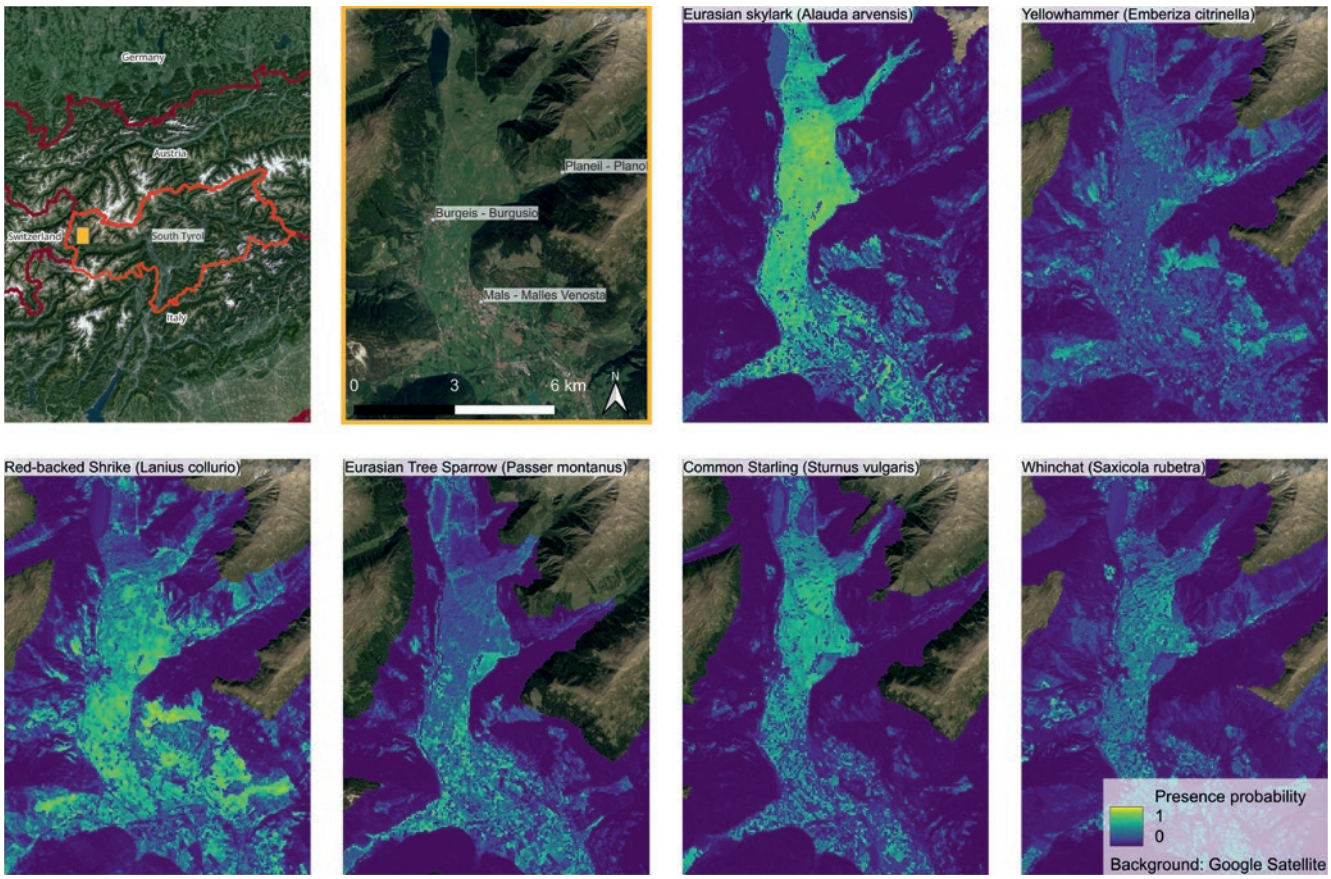


Figure 2: Habitat suitability in the upper Vinschgau valley (South Tyrol, Italy) for six farmland bird species.

Table 1: Selected variables in the models, sorted by importance.

| ***Alauda arvensis*** | ***Emberiza citrinella*** | ***Lanius collurio*** | ***Passer montanus*** | ***Saxicola rubetra*** | ***Sturnus vulgaris*** |
|---|---|---|---|---|---|
| Precipitation | Precipitation | Precipitation | Precipitation | Date of first mowing event | Date of first mowing event |
| Slope | Land use/land cover | Land use/land cover | Slope | Precipitation | Slope |
| Land use/land cover | Slope | Date of first mowing event | Land use/land cover | EVI | Land use/land cover |
| Date of first mowing event | Date of first mowing event | EVI | Digital Terrain Model | Slope | EVI |
| EVI | Digital Terrain Model | Digital Terrain Model | NDMI | Land use/land cover | Precipitation |
| NDMI | NDMI | Slope | Rao'sQ | | Digital Terrain Model |
| Rao'sQ | EVI | NDMI | Count of mowing events | | Temperature |
| | Rao'sQ | Rao'sQ | EVI | | NDVI |
| | | | | | Rao'sQ |
| **occurrences: 83** | **occurrences: 166** | **occurrences: 282** | **occurrences: 212** | **occurrences: 55** | **occurrences: 140** |

## Discussion

Our findings underline the value of high-resolution remote sensing data for habitat suitability assessments. Since land use and land management variables were among the most important parameters, our results reflect that early mowing can destroy the nests and chicks of ground breeding species during their rearing time (Grüebler et al. 2008). This is a strong factor in modeling ecologically realistic habitat probabilities. Furthermore, the contrasting habitat preferences of the different species align with expert knowledge, nicely illustrated by the Mals Heath (Figure 2). The open meadows and

grasslands north of Burgeis show a high probability of occurrence of Skylarks, whereas transition zones with a mix of landscape features and open meadows increase the probability of occurrence of the Yellowhammer. Overall, the Mals Heath stands out with high presence probability of different species. This is partly explained by a relatively late first mowing date of many meadows in the area, incentivized at least partly also by existing political efforts promoting biodiversity protection (Südtiroler Landesverwaltung 2024). This emphasizes the potential of SDMs to critically assess land use and management practices, and to provide support for decision-making regarding biodiversity conservation.

## Summary

This study represents an effective modeling of farmland bird species in South Tyrol, reflecting species-specific ecological requirements. It also shows how remote sensing can significantly improve the quality of SDMs with additional high-resolution data. In particular, land use and management information derived from satellite data can improve our understanding of spatio-temporal land use dynamics and support a more dynamic modeling approach. This further highlights the value of interdisciplinary work between ecologists and remote sensing experts to identify critical areas for biodiversity conservation and targeted conservation measures.

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