# ANALYSIS OF THE RELATIONSHIP BETWEEN LAND COVER CHANGE AND ABUNDANCE DATA OF EURASIAN SKYLARK *(ALAUDA ARVENSIS)*

*Summary of PhD thesis*

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## Introduction and aims

In my thesis, I analysed the changes of the landscape, such as land cover, land use and landscape structure, in Hungary, Schleswig-Holstein Federal State and Europe, and their impact on a farmland bird (Eurasian skylark) abundance. These changes were driven by different causes in Western and Central-Eastern Europe, as the energy landscapes caused transformation (in Germany) or the reforestation of abandonment lands (in Hungary). I have analysed the impact of these changes on the abundance data of Eurasian skylark, because this bird is the indicator species of the agricultural landscapes. Based on these analyses, I was able to estimate the effect of the recent and long-term landscape changes on the fauna of agricultural lands, which is the main land cover category in Europe. I have drawn conclusions based on regional and local scale land cover and land use datasets.
Therefore, I would like to answer the following questions in my thesis:

- Based on the regional land cover dataset, what changes have occurred in the land cover categories in Hungary over the last 30 years?
- Which LULC categories are preferred or non-preferred by the Eurasian skylark in Hungary; and how they changed during the last decades and what are the possible future directions of landscape change?
- What are the hot spots of the transformation of traditional agricultural landscapes into energy landscapes in Western-Europe (Schleswig-Holstein)? How can we delineate the most transformed landscape units?
- What are the impacts of this transformation to energy landscape, analysed via size- and shape related landscape metrics as well as LULC diversity indices?
- What are the effects of the energy landscapes on the population of Eurasian skylark, based on the land cover categories, land use (crop types) and LULC heterogeneity?

- How does the landscape structure (shape and size related metrics, proportion of land cover categories) influence the population of Eurasian skylark based on a local scale land cover dataset?
- What precision can be achieved in the estimation of the Eurasian skylark density based on a local scale land cover dataset?
- What changes have occurred in the European landscape over the last few decades, and how have these changes affected the Eurasian skylark population?

## Applied methods

In my thesis I used different scale land cover and land use dataset (Corine Land Cover, Hungarian Ecosystem Basemap, Agricultural survey dataset), and around the skylark survey points (Hungary and Schleswig-Holstein) I applied different size buffer zones. The pre-processes and the analysis of the spatially distributed datasets have been done by ESRI ArcGis geoinformatics software. Throughout my thesis, I use the R Statistics software for statistical analyses. I use variance inflation factors (VIFs) to identify a group of correlated land cover and landscape index variables, and the explanatory variables were not linearly related. The impact of land cover and landscape structure (composition) on skylark population will be investigated using generalized linear models (GLM). I apply negative binomial models (link=log) to account the overdispersion of skylark abundance data (tested by overdispersiontest function of AER package in R). I created models with all possible combinations of explanatory variables and used the "dredge" function from the MuMin package in R to rank them using Akaike's information criterion. To account for uncertainty arising from the large number of candidate models, I used model averaging for competitive models (delta AICc 2). The significance of the variables will be estimated by the LmerTest package. Since the variables were in different dimensions, I used R to create a range function that converted the values into a number between 0 and 1. The predicted marginal effects of the preferred land cover types and their landscape metrics on the skylark population will be calculated using the ggeffects package in R. On the basis of my dataset in R statistics software, I set up a training and a testing group (2/3 and 1/3, respectively) with random sampling (sample.split function from caTools 1.17 package). The estimated skylark population data will be calculated using the predict function from the car package.

## New scientific results

### T1 *Changes in land cover in the last 30 years (Hungary) and their impact on the population of Eurasian Skylark*

According to my results, the permanent crops (vineyards, fruit trees and berry plantations) and arable land CLC categories had a significant positive effect on the skylark population. Arable land and pastures are well-known habitat type for this farmland bird species. Pastures are grazed, but moderate grazing intensity does not disturb ground-nesting farmland birds like the Eurasian Skylark, and it keeps the vegetation low and the habitat structure simple. The recent abandonment of grasslands and the increasing land cover of dense bushes decrease the visual landscape openness, which could lead to a decrease in skylark populations. The most severe reduction in Skylark habitat occurred in Hungary's central and western regions, where land abandonment and urban sprawl were the leading processes of recent land use change.

According to my findings, the skylark population negatively correlated with the extension of scrub and/or herbaceous vegetation associations CLC category, I only found them inside 300 m and 600 m grain size (circle radius around the bird observation points). Urban fabric and heterogeneous agricultural areas LULC categories showed a negative significant statistical relationship with skylark population inside all investigated buffer zones. According to my results the negative impact of forest land cover on the skylark’s occurrence can be explained by the dense and relatively high vegetation structure of forests, which reduces landscape openness and visibility.

Recent afforestation and abandonment of poor-quality agricultural fields, urban sprawl, decline in grazing, and increasing landscape heterogeneity have resulted an increase in land cover types that Skylarks do not prefer, which can be the cause of the species' recent decline in population.

## T2 *Landscape transformation into energy landscape in Schleswig-Holstein*

In Schleswig-Holstein, I have delineated those areas (energy landscape units) where the bioenergy generated landscape change happened. From the early 2000s, the proportion of silage maize increased in the entire study area, increasing by around 90,000 ha, while pastures decreased by around 70,000 ha. The municipalities with the highest increases reached the 66% proportion of silage maize areas. Silage maize is, without a doubt, the most important indicator of the bioenergy-driven transformation of the agricultural landscape. The area of silage maize has the strongest positive correlation ($r = 0.572$; $p<0.01$) with biogas power plants. The decrease in pasture area coincides with the start of increased silage maize growing. Other crop and land use types did not increase to the same proportion as silage maize, according to the land use dataset.

## T3 *Impacts of the energy landscapes on the landscape structure change in Schleswig-Holstein*

Comparing the two CLC data sets from 2000 and 2012 reveals that the arable land LULC patches became larger and complex, while the LULC patches covered with pasture became more compact shape characteristics, including a reduced length of their margins/edges. This is particularly true in areas with a high density of installed biogas power plants. These findings suggest that a greater proportion of arable fields are becoming larger, and more complex in shape, while fewer isolated patches of pasture remain. A decreasing trend in agricultural land cover diversity were demonstrated by comparing the land use data from 2003 and 2010. Considering crop diversity, a negative change in the Shannon diversity index, Shannon evenness index and Richness index were observed for the entire study area. This indicates that the increase in silage maize production subsequently replaces other crops that were originally grown in these landscapes, which contributes to a loss of crop diversity and a depletion of landscape diversity.

## T4 *Effects of the energy landscapes on the population of Eurasian skylark in Schleswig-Holstein*

I also investigated the Eurasian skylark abundance relationship with energy landscape driven changes in Schleswig-Holstein. The GLM results show a significant correlation with four land cover categories between the recent LULC changes and skylark abundance data across the entire study area. The area of pastures has been drastically reduced as a result of the introduction of biogas plants. The results of the landscape change are the aggregation of small parcels into homogeneous large silage maize fields without shrubs and natural grassland corridors and the decrease of landscape heterogeneity. I have discovered a negative significant correlation between the Shannon Diversity Index (SDI) and the skylark population dataset. My findings show that increasing landscape heterogeneity has a negative impact on the population of the Eurasian skylark at the regional (CLC) scale. The permanent crops category has a negative correlation with the skylark abundance, and it ranks second in the model, implying that it has a significant impact on skylark abundance. The height and coverage of vineyards and fruit plantations, which are not suitable habitats for this bird species, are most likely responsible for the negative correlation. I have also discovered a negative correlation between winter rape and silage maize and the Eurasian skylark population density. According to my multimodel estimate, winter rape has the most negative impact. This bird species is also negatively affected by the high heterogeneity of agricultural land, i.e., crop types. These findings suggest that crop type matters more than crop heterogeneity value for the skylark population. Based on the predicted marginal effects method, I was able to identify crop types that had a positive (potato and sugar beet) or negative (silage maize, permanent crops, and rape) impact on the abundance of this bird species. In addition, I ranked the variables according to their importance in GLM models. I conclude that the introduction of energy crops (silage maize) and the homogenization process of the energy landscape have a negative impact on the Eurasian skylark population throughout Schleswig-Holstein Federal State.

## T5 *The landscape structure (shape and size related metrics, proportion of land cover categories) influence the population of Eurasian skylark in Hungary*

I used a more detailed, high resolution LULC dataset, the Hungarian ecosystem basemap, to get a more precise result about the habitat change of the Eurasian skylark. I have also identified the skylark preferred and non-preferred LULC categories based on this dataset. Nonpreferred types had negative significant relations with skylark abundance. These were built-up and green urban areas with a high proportion of artificial surfaces that had a negative impact on the population due to a lack of openness The skylark data has a negative significant relationship with the complex cultivation pattern land cover type. Skylarks do not prefer heterogeneous agricultural lands because this rural landscape contains a variety of LULC patches. None of the forest area types are considered habitats for this species.

Grassland and pasture areas are well known habitat types of skylarks. The novelty of my results is that the LULC categories of salt steppes and meadows, as well as closed grasslands, had a significant positive relationship with skylark abundance and other grassland types have no connection with skylark population. Because of the medium vegetation height and optimal proportion, these three LULC category is suitable for skylarks.

According to my findings, landscape metrics of preferred LULC classes show a positive significant relationship with skylark abundance, implying that if arable-land and grassland proportion and shape complexity were higher, the skylark population would be higher as well. The skylark population density was found to have a negative significant relationship with the landscape metrics of the non-preferred LULC classes, indicating that skylark population density would be higher in landscapes with small size and compact shape of non-preferred LULC categories.

According to my findings, the EU agri-environmental policy should pay more attention to the management of salt steppes and meadows, as well as closed grasslands, for the prevention of farmland bird habitats. To increase skylark population density, the average LULC patch size and proportion of these land cover types in the landscape (compared to all) should both increase. For the protection of skylark habitat, it should be reducing the size and shape of the bush and forest LULC patches inside these grasslands dominated areas. As a result, the local farmers must use proper grazing or haymaking techniques to eradicate the naturally spreading bush vegetation (which is often full of invasive species).

## T6 *Validation of the estimated Eurasian skylark population*

According to my results, the application of landscape metrics into the model increased the precision of the skylark population data estimation, mean percentage error value decreased from 46.56% to 37.77%. The estimated population density values (0-6.13 individuals/$km^2$) fit to the results of international publications (1.72-7.45 individuals/$km^2$).

## T7 *European land cover changes in the last three decades affected the Eurasian skylark population and habitat*

I investigated the significance of general open-habitat changes in Europe and the ongoing land cover and habitat changes may have a significant impact on the species' distribution across most of its European range.

Hungarian study areas revealed significant statistical connections in the case of eight LULC types. In Schleswig-Holstein, skylark population data shows a significant relationship with six LULC categories. According to my findings there was no significant relation between skylark abundance and the pastures LULC category, because intensive grassland management in Hungary can be directly damaging to breeding skylarks. Based on my results in the Schleswig-Holstein study area, one of the most typical habitats of skylark is pasture, because these areas are exposed to grazing. In the two

European study areas I chose, I got different results. The differences are due to the study areas' different locations and different level of agricultural land use intensification in Western and Central-Eastern Europe.

Based on the calculated changes in habitat and non-habitat LULC categories, I was able to compare the changes in skylark habitat and population at country level and to map the total summarised changes in skylark habitat in European scale. The habitat changes hotspots in Europe: United Kingdom, Ireland, Germany, Denmark, Hungary, Slovakia, and Spain are among the hotspots. The population of skylarks has shown significant statistical correlations with recent habitat changes. This result confirms my findings, but according to my results the addition of other parameters (landscape indices) to the input data could improve the model's accuracy in predicting recent skylark population changes.

## Conclusion

In my thesis, I have investigated the feasibility of estimating the number of skylark individuals at different scales of land cover maps. My results can be important for estimating the number and density of farmland bird species in areas where detailed bird monitoring survey data and information on crop structure are not available. The outcomes of the thesis can be also important from the point of view of landscape planning, as they can be used to design a new landscape structure (composition) in protected areas that are suitable and favourable habitats for farmland birds, especially skylarks.

## Összefoglaló

Dolgozatom eredményeit összegezve megállapíthatom, hogy az európai felszínborítás és tájszerkezet változásai erősen befolyásolják a mezőgazdasági tájak faunáját, különösen a madárvilágot. Európa szerte különböző mozgatórugói vannak a felszínborítás-változásnak, ahogy Nyugat– és Kelet-Közép-Európában is. A mezei pacsirta élőhelyváltozása több területen is jelentős mértékű volt Európában – a negatív irányú változások a dominánsak. Magyarországi eredményeim szerint az elmúlt két évtizedben a művelés alól kivont mezőgazdasági területek és az erdősítés volt a két fő mozgatórugója a felszínborítás változásának. A legelők és állandó növényi kultúrák aránya az összes tájablakon belül szignifikáns pozitív statisztikai összefüggést mutattak a mezei pacsirta egyedszámával regionális léptékű adatbázis felhasználásával (CLC adatbázis). Nyugat-Európában, például Schleswig-Holstein szövetségi államban az energiatájak által okozott felszínborítás változás a mezőgazdasági fauna populációjának csökkenését okozta. Ezen a mintaterületen a nagy, homogén energianövény-parcellák erősen csökkentették a táj és a mezőgazdasági területek heterogenitását. Kimutattam, hogy a felszínborítás és a termesztett növények heterogenitása negatív hatással van a mezei pacsirta populációjára, azonosítottam azokat a növénytípusokat, amelyek pozitív (burgonya és cukorrépa) vagy negatív (silókukorica, állandó kultúrák és repce) hatással voltak e madárfaj egyedszám változására. Eredményeim szerint a pacsirta egyedszáma és annak változása szoros összefüggésben van a tájszerkezettel. Kimutattam, hogy a szikes gyepek és rétek, valamint a zárt gyepek szolgálnak élőhelyül a mezei pacsirta számára. A gyepfoltok alaki összetettségét leíró fraktáldimenzió-index pozitív kapcsolatot mutatott a pacsirta egyedszámával, míg a nem élőhelytípusok alaki összetettsége ellentétes összefüggést mutat. Kapott eredmények alapján a mezei pacsirta egyedszám becslése alacsony hibahatárokkal számítható.

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