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Pollinator-promoting wildflower fields attract farmland birds and rodents, depending on spatial configuration and landscape context

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Abstract. To mitigate the decline of pollinators in farmlands, a widely used approach is to establish wildflower fields. Their effects beyond pollinators, however, require further investigation in Central-Eastern Europe, even regarding popular taxa such as birds, and potential pest species such as rodents. We established wildflower plantings in two spatial configurations (one field or three strips with the same area per plot) in both homogeneous and heterogeneous agricultural landscapes in Central Hungary. We found that fields increase bird species number, individual number and Shannon-diversity in homogeneous agricultural landscapes, but not in heterogeneous landscapes, which in general are more diverse regardless of wildflower plantings. Also, wildflower fields promote rodents compared to arable fields. Thus, wildflower fields may have a wide range of biodiversity benefits beyond pollinators depending on field area and landscape context. These results provide evidence from Central-Eastern Europe to support the implementation of the European Union's Nature Restoration Regulation.

1 Introduction

Biodiversity is declining rapidly, largely driven by intensive agricultural land-use and habitat loss (Díaz et al., 2019). In Europe roughly half of the land is devoted to agriculture (EEA, 2025), with diminishing biodiversity (Emmerson et al., 2016). In response, the European Union's Biodiversity Strategy and Nature Restoration Regulation (NRR) was developed to restore semi-natural habitats within agricultural landscapes, to help restore biodiversity and ecosystem functions, especially pollination (Hermoso et al., 2022). NRR has several measures to reverse the decline of pollinator groups. Such restoration interventions are more effective if they benefit further groups beyond pollinators, like birds. These interventions may also benefit rodent pests, which are important parts of the food web in agricultural systems. Establishment of wildflower plantings is a widely used intervention to counteract pollinator decline in agricultural landscapes, as it provides more flower resources for pollinating insects (e.g. Bihaly et al., 2024; Williams et al., 2015). A growing body of evidence has accumulated on the effects of wildflower plantings on non-target, but key farmland groups for example birds, as wildflower plantings provide nesting and foraging sites for birds. These studies found that the presence of wildflower plantings is consistently linked to higher breeding bird abundance and species number compared to intensively managed arable fields (Redhead et al., 2018; Rieger et al., 2022; Schmidt et al., 2022). Landscape heterogeneity in agricultural areas increases bird abundance and diversity (Bosco et al., 2024; Rösch et al., 2023). It was also found that larger wildflower plantings promote birds and pollinators more effectively (Bihaly et al., 2024; Meichtry-Stier et al., 2018). Both pollinators and birds contribute to agricultural yield via pollination and pest control services, as insectivorous birds may contribute to pest control (Garcia et al., 2020), and raptors may regulate rodent pest populations (Labuschagne et al., 2016; Paz et al., 2013).

Although the evidence on the effect of both wildflower planting area, and landscape structure on birds is well established, significant knowledge gaps remain. First, the interaction of these factors is rarely assessed, especially in a rigorous experimental design. For example, landscape con-

text may interact with the effectiveness of local interventions (Batáry et al., 2011). Second, most evidence is from Western and Northern European biogeographic regions (e.g. Bosco et al., 2024; Redhead et al., 2018; Rösch et al., 2023; Staggenborg and Anthes, 2022), so it is geographically biased, with less knowledge from the Eastern parts of the EU with higher farmland biodiversity (Báldi and Batáry, 2011; Sutcliffe et al., 2015). Knowledge from less studied regions is essential to fully understand the relationships, and to reliably provide evidence for the NRR's national implementation plans. These have to be specific to local context, thus local information is badly needed. Third, most studies searched for biodiversity benefits of wildflower plantings, and associated increase in yield, but few addressed potential harms to yield in surrounding crops, like spillover of rodent pests (Briner et al., 2005). Wildflower plantings are non-tilled, therefore they provide undisturbed burrows and constant feed for rodent pests, like common voles (*Microtus arvalis*), which may seriously damage crops (Heroldová et al., 2018). Generally speaking, interventions on the one hand may significantly contribute to NRR targets, like increased ecosystem function, and pollinator and farmland bird populations, but on the other hand may reduce the net benefits of the intervention for farmers and thereby lower acceptance of restoration efforts.

We established a landscape-scale experiment to promote pollinators in 2020, by sowing wildflower plantings in the agricultural landscape of Central Hungary. Wildflowers were sown in two different configurations (larger, continuous field, or three smaller strips), but with the same cumulative area in both homogeneous ($> 90\,\%$ arable land) and heterogeneous (40 %–60 % semi-natural habitats) agricultural landscape plots (Báldi et al., 2022). We already showed that they promote insect pollinators (Bihaly et al., 2024), so in this paper, we aim to assess their effects on two different taxa that are important for farmland ecosystems, birds and rodents. Namely, our questions were: (1) How do different configurations of wildflower plantings in heterogeneous and homogeneous agricultural landscapes affect breeding bird species number, number of individuals and Shannon-diversity, and is there an interaction between landscape structure and spatial configuration of plantings? (2) Is the response of bird communities to treatment and landscape structure similar to patterns found in Western and Northern European biogeographic regions? (3) How do wildflower fields affect rodent populations in heterogeneous and homogeneous agricultural landscapes?

2 Materials and methods

2.1 Study area

We selected 8 triplets of landscape circles with 500 m radius, half of them were in homogeneous (1 %–10 % semi-natural habitats, 90 %–99 % arable fields within a 500 m radius) and half in heterogeneous (40 %–60 % semi-natural habitats, 40 %–60 % arable fields) agricultural landscapes in Central Hungary, resulting in 24 landscape plots altogether. In each landscape plot triplet, we established wildflower fields in two spatial configurations, and left one as control. We sowed either a single compact wildflower field (50 m × 100 m, 0.5 ha; hereinafter: field plots) or three smaller wildflower strips, ca. 100 m apart (each 24 m × 70 m strips, total area of 0.5 ha; hereinafter: strip plots) in the middle of the landscape circles. The most common semi-natural habitats were extensive grasslands, with some forest belts and wetlands. The most commonly cultivated crops were maize, sunflower and winter cereals. The wildflower plantings were established in January 2020 with a seed mixture consisting of 32 native, insect-pollinated flowering herb species. In the first two years, the wildflower plantings were mown once a year in autumn to remove litter. From the third year on, we switched to a rotational early summer mowing with half of each planting cut every year. More details about the study sites can be found in Báldi et al. (2022), and exact location of plots and wildflower plantings can be found here (https://www.google.com/maps/d/u/0/viewer?mid=130c6ZN_0SNC7WizrkGQemaTlcsxz7XnH&amp%3Bll=46.81638979653133%2C19.104997500000014&amp%3Bz=11&ll=46.81638979653133%2C19.104997500000014&z=11, last access: 2 November 2026).

2.2 Field methods

2.2.1 Bird census

We placed a single point count station in each landscape plot. The points were located in the middle of the field, in the middle of the strip closest to the access road, and in the middle of the control plot. We conducted a bird census in two rounds in the spring of 2024, 5 years after establishing the wildflower plantings, as breeding bird species number and densities peaked when the wildflower plantings were 5 years (Zollinger et al., 2013). We adapted the guidance from the Hungarian Monitoring of Common Birds program (Szép et al., 2022). The first round was on 18–19 April, the second on 13–14 May, in the peak breeding season of birds, to focus on local populations. One of two observers (SL or SG) navigated to each point count station with a handheld GPS receiver, and conducted a 10 min observation of birds. The surveys were done between sunrise and 10:00 LT, which coincides with the peak vocal activity of breeding birds. We recorded observed birds within a 100 m radius. We recorded the species, the behaviour of the species (landing, singing, hunting, walking, flying over etc.). We recorded in which habitat type the bird initially interacted with the plot (grain or tilled arable fields with small seedlings, road verge, grassland, forest strip, inland water, etc.) Surveys were not conducted in wind exceeding 16 km h^{-1} and during rainfall.

2.2.2 Rodent census

To estimate rodent abundance, we searched for active common vole (*Microtus arvalis*) and steppe mouse (*Mus spicilegus*) burrows in the wildflower fields between 4–18 April and 22–23 October 2024, to capture seasonal variance (Esther et al., 2014). Strips were not included into this study due to lack of resources. We used a different control from what we used for the birds to adapt the sampling to the restricted mobility of rodents.

We marked a 50 m × 100 m area 100–200 m from the edge of each wildflower field within the same arable field, next to the same access road (for more details, see Vajna et al., 2024). Two control plots were on alfalfa fields, which were not tilled, the rest of the control plots were tilled. To assess the build-up of rodents within the wildflower fields and on arable land, we slowly walked across the 0.5 ha of the wildflower field and its control pair, and recorded the coordinates of each burrow, marked them with flags, and filled the openings loosely with a thin layer of soil. 24 h later we searched for all the burrows, and recorded the number of reopened, active ones, which is the burrow index for half a hectare (Esther et al., 2014; Heroldová et al., 2025). We only found three inactive steppe mouse mounds in two plots during autumn, so we only analysed data of common voles.

2.3 Statistical analysis

2.3.1 Farmland birds

We used generalised linear mixed models (GLMM) to investigate the effects of wildflower plantings on the number of bird species, the number of individuals and Shannon-diversity. We excluded from analysis the birds that did not interact with the landscape plots, only flew over. For the number of species and the number of individual models, we used Poisson distribution and log-link function, and for diversity we used Gaussian distribution and identity function. In each model, sampling round (April, May), spatial configuration (field, strip, control), landscape context (heterogeneous vs homogeneous), and the interaction of spatial configuration and landscape context were included as fixed effects, and landscape plot triplet ID as a random factor. We performed post-hoc pairwise comparisons with Tukey's method for multiple testing. In case of a significant interaction, we compared differences between spatial configurations within landscape context, and landscape context within a given spatial configuration.

As the experimental sites were originally designed for pollinators, there were a few issues we had to address when investigating birds. We found that the species recorded in wildflower plantings next to forest strips (only found in homogeneous landscape plots, two field plots and two strip plots) are mostly woodland passerine species (e.g. chaffinch (*Fringilla coelebs*) and great spotted woodpecker (*Dendrocopos major*). None of the species were recorded in any other habitat, therefore we excluded these species from the analyses, as these are not affected by the wildflower plantings, which are the focus of this research. Furthermore, there were three landscape plots with an outlying number of birds. One field plot in a heterogeneous landscape on the edge of a strictly protected national park area that had an extreme value of species number, and two had open water surfaces on waterlogged cereal fields (a homogeneous strip and field plot). In the latter two, we found that the majority of the recorded individuals were on the edge of the water for drinking. As our goal is to assess the effects of wildflower plantings in agricultural landscapes, we excluded these three landscape plots from the analysis.

2.3.2 Rodents

We used GLMM with negative binomial distribution and log-link function to assess the effect of landscape context and wildflower fields on the number of active vole burrows. We included treatment, landscape context, sampling round as fixed effects and landscape plot as a random effect. Interaction effects were removed due to overparameterization.

We tested the significance of effects with Wald χ^2 statistics. We prepared all analyses and data visualisation in R 4.5.1 (R Core Team, 2025).

3 Results

We recorded 24 bird species and 183 individuals, with skylark (*Alauda arvensis*; $n = 29$) and stonechat (*Saxicola rubicola*; $n = 26$) as the most abundant species. For bird species number, individual number and diversity we found significant effects of spatial configuration (species number: $\chi^2 = 10.47$, $P = 0.005$; individual number: $\chi^2 = 15.66$, $P < 0.001$; diversity: $\chi^2 = 9.64$, $P = 0.008$), landscape context (species number: $\chi^2 = 18.34$, $P < 0.001$; individual number: $\chi^2 = 23.0$, $P < 0.001$; diversity: $\chi^2 = 18.42$, $P < 0.001$) and the interaction of spatial configuration and landscape context (species number: $\chi^2 = 8.80$, $P = 0.012$; individual number: $\chi^2 = 11.09$, $P < 0.001$; diversity: $\chi^2 = 9.64$, $P = 0.008$) (Fig. 1). The sampling round had no significant effect on species number ($\chi^2 = 2.59$, $P = 0.11$), marginal effect on individual number ($\chi^2 = 2.84$, $P = 0.092$) and significant effect on Shannon-diversity ($\chi^2 = 4.21$, $P = 0.040$), as diversity was higher in the second sampling round. Post-hoc analysis revealed that there were no significant differences between spatial configurations in heterogeneous landscape in birds species and individual number and diversity (species number: all $P > 0.44$; individual number: all $P > 0.58$; diversity: all $P > 0.11$), while in homogeneous landscapes field plots had significantly higher number of species, individuals and diversity than strip plots (species number: $z = 2.52$, $P = 0.031$; individual number: $z = 2.93$, $P = 0.0096$; diversity: $z = 2.88$, $P = 0.011$) or control plots (species number: $z = 2.65$, $P = 0.022$; indi-

vidual number: $z = 3.00$, $P = 0.0079$; diversity: $z = 3.76$, $P < 0.001$), and there was no difference between strip and control plots (species number: $z = -0.44$, $P = 0.90$; individual number: $z = -0.44$, $P = 0.90$; diversity $z = -0.85$, $P = 0.67$) (Fig. 1). Also, we found that in heterogeneous landscapes there were significantly higher number of species, individuals and diversity than in homogeneous landscape plots in both strips (species number: $z = 2.74$, $P = 0.006$; individual number: $z = 3.53$, $P < 0.001$; diversity: $z = 2.92$, $P = 0.0035$) and control areas (species number: $z = 3.33$, $P < 0.001$; individual number: $z = 3.72$, $P < 0.001$; diversity: $z = 5.03$, $P < 0.001$), however, this difference was only present on field plots in terms of individual number ($z = 2.01$, $P = 0.045$), not in species number ($z = 1.18$, $P = 0.24$) or diversity ($z = 1.60$, $P = 0.11$) (Fig. 1).

There were significantly more active vole burrows in wildflower fields than in control areas ($\chi^2 = 18.47$, $P < 0.001$; Fig. 2a). The number of active burrows was also higher in April than in October ($\chi^2 = 6.63$, $P = 0.010$; Fig. 2b), while landscape context had no effect ($\chi^2 = 0.002$, $P = 0.964$). Active burrows in control areas were recorded only in alfalfa (*Medicago sativa*) fields.

4 Discussion

In this study, we examined how an experimental setup of pollinator-promoting wildflower plantings in agricultural landscapes of Central-Eastern Europe affects key groups of ecosystem functioning beyond pollinators. We found that these plantings have positive effects on two key vertebrate groups, birds and rodents, depending on planting spatial configuration and landscape context. In homogeneous agricultural landscapes, wildflower fields enhanced bird species number, abundance, and diversity, whereas strips offered no significant improvement over crop fields. Wildflower fields also created undisturbed soil conditions within otherwise intensively tilled landscapes, allowing burrowing rodent pests to persist, as indicated by the presence of vole burrows almost exclusively within these fields. Note that our burrow surveys were restricted to the wildflower fields and the crop fields; other uncultivated habitats in the landscape, such as tree rows and semi-natural grasslands, undoubtedly support voles as well, but were not sampled.

In homogeneous agricultural landscapes, where arable land exceeds 90 % of the area, only plots containing wildflower fields supported bird species number and diversity comparable to those observed in heterogeneous landscapes. In homogeneous landscapes strip plots had similarly low bird species number, individual numbers and diversity as control plots, indicating that they are less effective in attracting farmland birds than larger wildflower fields of at least 0.5 ha, which we used in this study. Bird communities in heterogeneous landscapes were similar to or richer than those recorded in wildflower fields within homogeneous

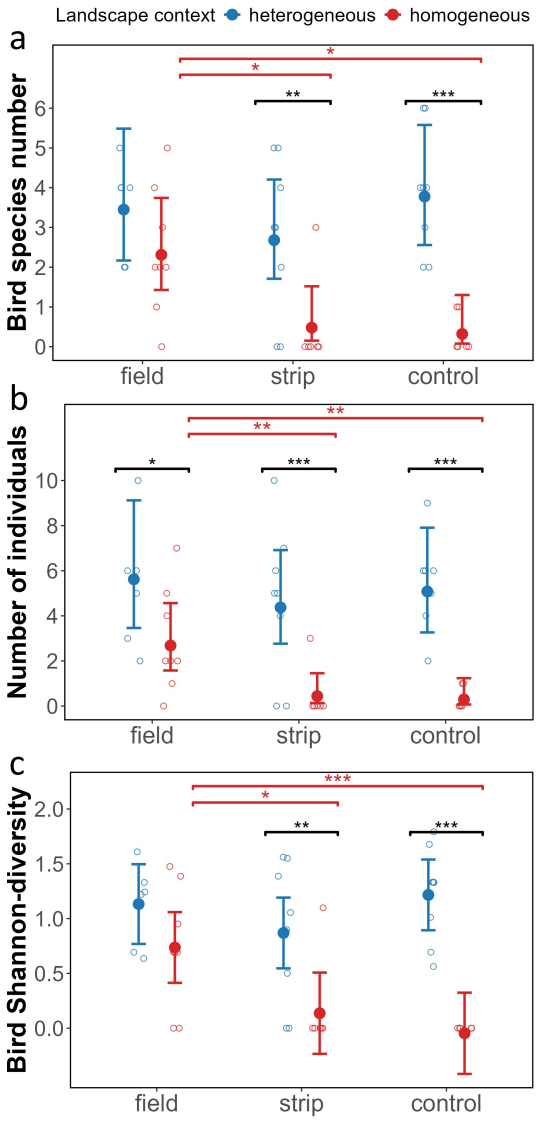


Figure 1. Bird **(a)** species number, **(b)** individual number and **(c)** Shannon-diversity across treatments in heterogeneous and homogeneous landscapes (model-estimated marginal means (averaged over sampling rounds) ±95 % CI), circles show observed values jittered to increase visibility. In the case of species number and abundance, Poisson GLMM with log link was back-transformed to the response scale. Red brackets denote significant pairwise differences between spatial configurations in homogeneous landscape plots, and black brackets show pairwise significant differences between heterogeneous and homogeneous landscape plots, with the same spatial configuration, based on Tukey-adjusted post-hoc comparisons.

landscapes, regardless of planting configuration. This is consistent with previous observations that habitat diversity and landscape heterogeneity increase bird numbers and diversity (Bosco et al., 2024; Rösch et al., 2023), but here we showed it using an experimental set-up. Our results suggest that the additional benefits of wildflower plantings may be lim-

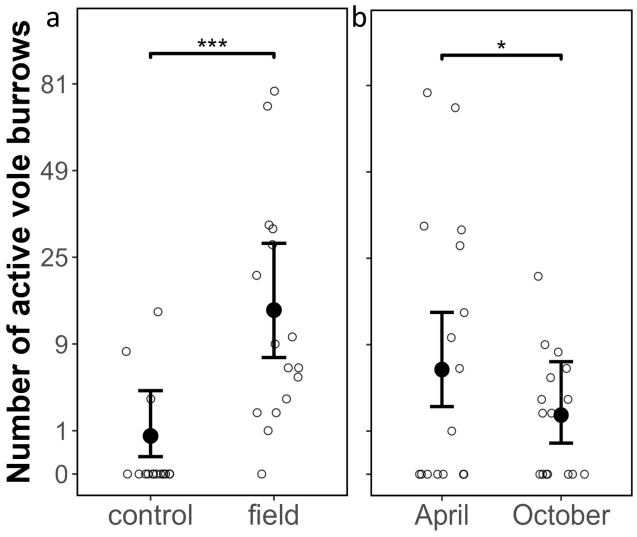


Figure 2. Number of active vole burrows across **(a)** treatments and **(b)** sampling rounds (model-estimated marginal means ±95 % CI); circles show observed values jittered to increase visibility. Estimates were back-transformed from the negative binomial GLMMs with log-link scale to the original response scale. Brackets indicate significant differences. The *y* axis is shown on a square-root scale for visualisation.

ited in structurally diverse landscapes, where baseline habitat heterogeneity is already high. According to our results, wildflower plantings larger than those typically implemented (< 0.5 ha area and at least 12–20 m width) are more effective at attracting birds, consistent with findings by Rieger et al. (2022) in Western Europe.

In the same study system, Bihaly et al. (2024) showed that both fields and strips increased pollinator species number and abundance in homogeneous landscapes, particularly in late summer. Thus, while pollinators benefit from both wildflower fields and strips, birds appear to respond primarily to fields. Based on this, we recommend promoting larger wildflower fields (like 50 m × 100 m, as in our study) in agri-environmental schemes. A drawback of wider, larger plantings is the loss of productive crop area, which may reduce farmer acceptance despite their ecological benefits, as they aim to maximize yield. Acceptance, however, can be improved by dedicated payments and outreach.

Wildflower fields support ecosystem services by providing habitat for pollinators that enhance crop pollination and for birds that contribute to pest control, but they may also promote ecosystem disservices by offering refuge to potential agricultural pests such as voles. Voles may have negative effects, as they consume entire plants, including seeds (Heroldová et al., 2021) and may reduce yield in neighbouring fields (Jacob and Tkadlec, 2010). In our study, common voles were present in all but one wildflower field, and absent in all but one control plot. This is consistent with their preference for undisturbed soil for burrowing (Heroldová et al., 2018), as the only control plots with active burrows were on alfalfa fields, which was only mown, not tilled. These observations suggest that, although wildflower fields can support vole populations, their impact on crops may be limited. Briner et al. (2005) showed that voles in wildflower fields rarely venture into neighbouring crop fields, thereby not causing crop damage.

Most studies find that vole density increases from spring to autumn, due to production of offspring (Aschwanden et al., 2007; Tkadlec et al., 2026). However, we found a decrease in active vole burrows from spring to autumn. We suspect that this may be the result of predation. Predation by raptors, like common kestrels (*Falco tinnunculus*) can decrease common vole population sizes in agricultural landscapes (for review, see Labuschagne et al., 2016). In our study area, raptors like common kestrels and marsh harriers (*Circus aeruginosus*) were recorded repeatedly during point counts flying over or outside of the 100 m radius and during other field surveys. Additionally, we put ca. 3 m tall posts on all corners of each field and strip plots when establishing the wildflower fields, to mark them for tractor drivers. These posts act as perches for birds, which can increase raptors' presence at the wildflower fields (Labuschagne et al., 2016; Paz et al., 2013). During the point counts, we recorded birds perching on posts on the majority of fields. Wildflower fields may provide food for raptors by attracting voles.

Our results should be interpreted with caution given the small scale of this pilot study. The design comprised only eight replicates (landscape triplets for birds and field–control pairs for voles), each surveyed in two rounds, and for birds three plots had to be excluded. Bird observations were limited (typically 3–5 individuals per visit), so some effects may reflect chance detection, while subtler ones – such as potential benefits of wildflower plantings in heterogeneous landscapes – may have remained undetected. Our landscape classification was also coarse: grasslands and wetlands were pooled as semi-natural habitat, although they may affect birds differently. Furthermore, we measured only alpha diversity, which does not capture changes in community composition, nor demographic parameters such as breeding success or foraging, on which wildflower fields may have effects beyond those detected here. Longer-term monitoring of these sites producing a larger dataset is needed to confirm these patterns and to assess finer-scale responses.

5 Conclusions

Pollinator promoting interventions can have positive effects on vertebrate groups, but these depend on both field size and landscape structure. Despite the limited sample size, our results provide evidence that farmland birds benefit from larger wildflower fields in homogeneous agricultural landscapes, in line with similar benefits for pollinators in the same system (Bihaly et al., 2024). In heterogeneous landscapes, where

bird communities were already richer, we could not detect an additional effect within the scope of this study. Wildflower fields also provide refuge for potential agricultural pests such as voles; however, these species may simultaneously play a beneficial role as a key food source for raptors. Overall, our results demonstrate that well-designed wildflower plantings can deliver multiple biodiversity and ecosystem service benefits supporting the effective implementation of the Nature Restoration Regulation in Eastern European agricultural landscapes.

Code and data availability. Code and data are available at https://doi.org/10.5281/zenodo.19691460 (Baldi et al., 2026).

Author contributions. BA and GS conceptualised the experiments and methodology. GS, LS and FK carried out the experiments and collected data. GS carried out data curation and formal analysis. GS prepared the manuscript with contributions from all co-authors.

Competing interests. The contact author has declared that none of the authors has any competing interests.

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