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Habitat assessment of woodlark territories, valuation of farmers attitude towards woodlarks and land use change impact in Mühlviertel

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Abstract

Farmland birds are declining all over Europe, mostly due to agricultural intensification. One of this farmland birds is the woodlark *Lullula arborea* a species of conservation concern and protected by the European bird directive. Woodlarks are nest breeders, are found in whole Europe and select vineyards, heathlands, forest clear cuts, newly reforested areas or Christmas-tree plantations for breeding. Although landscape heterogeneity has been recognized as a key component for habitat selection, little is known about its influence on the few populations occurring in Austria. The first aim of this study was to investigate the most important landscape characteristics for woodlarks to establish a territory in Mühlviertel, Austria. For this, territories of 18 singing males and 16 non-occupied territories were mapped and the landscape composition around the centre (7 ha) was analysed. Although woodlarks prefer, according to other studies, tall and dense vegetation to place their nest, this study found that the landscape heterogeneity and the distance to dirt roads have a significant effect on woodlark territories on the landscape scale. The probability of woodlark territories increased with landscape heterogeneity above 50 % and were at least 40 meters away from dirt roads. The second aim of this study was to identify farmers' attitude towards woodlarks in the Mühlviertel, because farmers are dealing in their daily work with farmland where woodlarks live and farmers are important players when it comes to protection. For this, 19 farmers, which own land of occupied woodlark territories or previous occupied territories, were interviewed. I found that the overall attitude of farmers towards woodlarks is good, because everyone thinks protection of woodlarks is important. The third aim of this study was to check if the land use change, which is happening all over Europe, is also happening in the area of Mühlviertel. There was no evidence of land use change found over the time of the years 2007 until 2016. Conservation measures in the study areas should preserve landscape heterogeneity and dirt roads to provide suitable woodlark habitats and the already existing awareness of farmers towards woodlarks can support this. Even though no land use change was found, it should be further monitored to preserve the important habitat characteristics of woodlark territories.

Zusammenfassung

Die Anzahl an Kulturlandschaftsvögel ist im letzten Jahrzehnt in ganz Europa gesunken, hauptsächlich aufgrund der Intensivierung der Landwirtschaft. Einer dieser Kulturlandschaftsvögel ist die Heidelerche *Lullula arborea*. Die Heidelerche ist ein gefährdeter Kulturlandschaftsvögel, der im Anhang I der Vogelschutzrichtlinie gelistet ist und aufgrund dessen unter Schutz steht. Heidelerchen sind in ganz Europa verbreitet und besiedeln Weingärten, Heidelandschaften, Forstkahlschläge, Aufforstungsflächen und Christbaumkulturen. Obwohl die Heterogenität der Landschaft bereits als wesentliches Element für die Wahl des Habitats erkannt wurde, ist über dessen Einfluss auf die österreichischen Populationen wenig bekannt. Das erste Ziel dieser Arbeit war, die wichtigsten Eigenschaften eines Heidelerchen Habitats im Studiengebiet Mühlviertel zu identifizieren. Dafür wurden 18 Habitate eines singenden Männchens und 16 unbesetzte Habitate kartiert und die Zusammensetzung der Landschaft um das Habitatzentrum (7 ha) wurde analysiert. Obwohl in früheren Studien festgestellt wurde, dass Heidelerchen für den Neststandort hohe und dichte Vegetation bevorzugen, wurde in dieser Arbeit festgestellt, dass die Landschaftsheterogenität und die Entfernung zu Feldwegen einen signifikanten Einfluss haben. Die Wahrscheinlichkeit, eines Heidelerchenhabitat steigt bei einer Landschaftsheterogenität über 50 %. Des Weiteren waren die Heidelerchenhabitate mindestens 40 Meter von Feldwegen entfernt. Das zweite Ziel dieser Arbeit war, die Einstellung der Landwirte zu Heidelerchen zu identifizieren, da die Landwirte täglich mit den landwirtschaftlichen Flächen arbeiten, die Heidelerchenhabitate beherbergen. Deshalb sind sie wichtige Akteure für Schutzmaßnahen. Um dies herauszufinden wurden 19 Landwirte, die Flächen besitzen auf denen sich besetzte und frühere Habitate befinden, befragt. Die allgemeine Einstellung der Landwirte zu Heidelerchen ist positiv, da alle der Befragten den Schutz der Heidelerche als wichtig empfinden. Das dritte Ziel dieser Arbeit war zu evaluieren ob die Änderung der Landnutzung, die überall in Europa stattfindet, auch im Mühlviertel existiert. Es wurde kein Nachweis für eine signifikante Änderung der Landnutzung im Zeitraum 2007 bis 2016 festgestellt. Schutzmaßnahmen im Mühlviertel sollen die Landschaftsheterogenität und die Feldwege bewahren um geeignete Heidelerchenhabitate bereitzustellen. Dies kann durch die bereits existierende positive Einstellung der Landwirte unterstützt werden. Obwohl kein Hinweis auf eine Landnutzungsänderung gefunden wurde, sollte dies weiterhin im Auge behalten werden.

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1. Introduction

Farmland birds are declining all over Europe. One reason for this decline is the intensification and change of agricultural management (Chamberlain et al. 2000, Jerrentrup et al. 2017). Major causes for the agricultural intensification are changes in management, for example the change in use of grassland from hay to silage, the change in time for certain agricultural management activities and the increased use of artificial produced fertilizers and herbicides (Chamberlain et al. 2000). Besides that, important elements for diversity of landscape, like hedgerows and ponds have decreased in the last decades (Chamberlain et al. 2000). If preferred farmland bird habitats are modified by intense farming, they do not offer the species specific required habitat conditions, e.g. for reproduction (Gil-Tena et al. 2015) or food resources for survival. Therefore, two things are of great importance for protecting farmland birds. First, to assess the important habitat characteristics of farmland bird species and second to understand how land use change impacts their habitats, for guiding the development of conservation measures (Jerrentrup et al. 2017) and protecting important habitat characteristics.

One of the farmland birds threatened by habitat modification caused by agricultural intensification is the woodlark (*Lullula arborea)*. Woodlarks are ground breeding birds, which can be found in different kinds of habitats all over Europe, like Christmas-tree plantations (Fartmann et al. 2018), vineyards (Bosco 2014, Buehler et al. 2017), heathlands (Mallord et al. 2007), forest clear cuts and reforestation (Wright et al. 2007). In Austria, rare and few populations occur in the region of Mühlviertel (Upper Austria) (Uhl et al. 2008, Uhl 2009, 2012, Uhl and Wichmann 2013), Lower Austria (Berg et al. 1992, Ragger 2000, Straka 2008) and Lake Neusiedl (Burgenland) (Dvorak et al. 2009). In the region Mühlviertel, where this study took place, the woodlark population decreased from 38-42 breeding territories in 2007 to 16-18 breeding territories in 2017 (Uhl and Wichmann 2018). Besides this decrease also the fact that the woodlark is listed on the Annex I of the European wild bird directive (79/409/EEC of 2 April 1979), highlights the demand for protection.

When it comes to conservation activities on behalf of farmland birds, farmers are important players. They are dealing with farmland in their daily work. A positive attitude and awareness towards farmland birds are very important for the successful breeding and survival of farmland birds. The knowledge of farmers about woodlarks can be implemented in the daily work on the field, for example farmers are aware of the possible disturbance of farm work activities (Swagemakers et al. 2009). Conservation activities can also benefit from the awareness of farmers towards woodlarks. If farmers identify protection of birds with themselves, they are more likely to implement protection activities (Van Dijk et al. 2015). Besides that, from the perspective of policymakers, it is important to understand farmers´ motivation for implementing conservation activities, because it can help encouraging more voluntary conservation activities (Mills et al. 2018).

The way farmers manage the land is shaping landscapes (Jerrentrup et al. 2017). Changes in policy or changes in farmers´ personal perspectives, also cause a change in land use (Van Vliet et al. 2015, Kristensen 2016). Land use change is happening all over Europe, but not everywhere in the same extent. It can also appear as a very punctual phenomena (Van der Sluis et al. 2016). Land use change refers to changes in size of agricultural land, in the intensity of land management, in landscape elements, in agricultural activity and changes of the focus of produced goods of a farm (Van Vliet et al. 2015). All this can have an impact on the landscape and the diversity (Kristensen 2016) and thus also can affect farmland birds (Chamberlain et al. 2000, Jerrentrup et al. 2017). Therefore, woodlarks could be influenced by land use change as well.

Most research about woodlarks paid attention on the very close surrounding of the center of the territory or the nest. For establishing a nest woodlarks prefer places with tall and dense vegetation to hide from predators (Harrison and Forster 1959, Mallord et al. 2007, Bosco 2014, Buehler et al. 2017), for orientation of nests woodlarks prefer to adjust the direction of nests to north and northeast (Mallord et al. 2007) and for foraging woodlarks prefer areas with short and sparse vegetation (Harrison and Forster 1959, Bosco 2014). By contrast, this study is assessing most important habitat characteristics on the landscape scale as few studies about woodlarks have been taking into account broad spatial scales. Studies focusing on broad scales were dealing with the habitat type (forest clear cuts, set aside fields) (Wright et al. 2007) or the size of a woodlark territory (Harrison and Forster 1959).

The first objective of this study was to determine the main characteristics of woodlarks´ habitat at the landscape scale. I expected that the height of cropland and grassland vegetation would be of great importance. Taller vegetation is preferred to place the nests (Harrison and Forster 1959, Mallord et al. 2007, Bosco 2014, Buehler et al. 2017), whereas foraging woodlarks prefer sites with short or sparse vegetation (Harrison and Forster 1959, Bosco 2014).

The second objective of this study was to assess the farmers´ attitude towards woodlarks and to voluntary conservation measures. I expect that farmers´ knowledge and awareness about woodlarks would be associated with positive attitudes towards woodlarks and willingness towards conservation measures. Swagemakers et. al. (2009) describe the importance of awareness as “eye for birds”. Farmers with an “eye for birds” are aware of possible disturbances caused by farm work, are able to see birds (e.g. from the tractor) when doing farm work and search for nests on fields together with bird experts before carrying out farm work to leave these spots out (Swagemakers et al. 2009).

The third objective of this study was to determine if land use types changed in the last decade in the study area, due to agricultural intensification. Van der Sluis et al. (2016) describe an ongoing intensification in Reichraming, Austria in the last decade. Therefore, I expected a change in the composition of land use types grassland, cropland, woody vegetation and protected areas.

Because farmers are one of the drivers for land use change, which also influence the habitat characteristics, and are also important players when it comes to farmland bird conservation, I attempt to better understand the most important woodlark habitat characteristics, the farmers’ attitude towards woodlarks and the land use change in the study area in the last decade. Altogether, this knowledge can be used to provide adequate support for this threatened species.

2. Materials and methods

2.1 Study area

This study took place in the region Mühlviertel, which is located in the northern part of Upper Austria, Austria (Figure 1). It covers an area of 3.090 km² and 270.000 people are living in this region (Furtschegger and Schermer 2015). The landscape of Mühlviertel is dominated by hills, the soil is affected by granite and it has a rough climate. The area is divided into grassland, cropland and forest, although grassland covers half of the region. Around a quarter of the agricultural area is cultivated organically (Furtschegger and Schermer 2015). The average farm size in this region is 30 hectares (Austrian Federal Ministry of Agriculture 2017).

The study area covered two parts. One part is partly located in a Nature Park (Rechberg 48°19′ N, 14°42′ E), which is in the eastern part of the region Mühlviertel and is shared by three communes (Rechberg, Windhaag bei Perg and St. Thomas am Blasenstein). The second part is located in the centre of the region Mühlviertel (Neumarkt im Mühlkreis 48°25′ N, 14°29′ E). This area is in the west of the first one and it is shared by four communes (Neumarkt im Mühlkreis, Alberndorf in der Riedmark, Ottenschlag im Mühlkreis and Lasberg). The Euclidean distance between those two study areas is approximately 20 kilometres. The study area was chosen because of the local existing population of woodlarks.

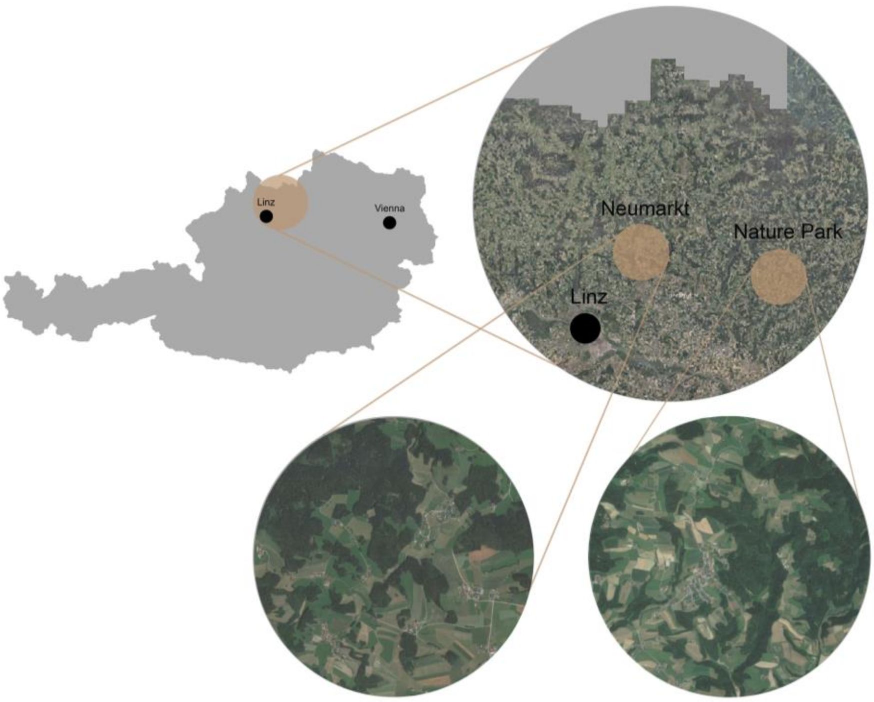


Figure 1: Location of the study areas (Source of aerial photos: www.geoland.at)

2.2 Sampling plots

Two kinds of sampling plots were established to assess the habitat characteristics of woodlark territories, namely presence and absence plots (Figure 2). With the help of two local ornithologists several places where woodlarks appeared in the past were visited to check if those spots are occupied by woodlarks again. When the habitat was occupied, territory mapping was done according to the guidelines of Südbeck et al. (2005) with the help of the two ornithologists. In the morning hours the perceptible behaviour (e.g. singing male, pairs) of the woodlarks in each plot was recorded in maps (Südbeck et al. 2005). This occupied woodlark habitats represented the presence plots (n = 18). The centre of these plots corresponded either to the woodlark territory centre (paper territories) or the nest. Because finding woodlark nests is time-intensive and difficult, most of the centres of the presence sampling plots were located in the woodlark territory centres. The second type of plots represent absence plots (n = 16), where no woodlarks appeared in the study period. These absence plots were randomly chosen or were previous woodlark habitats no longer occupied.

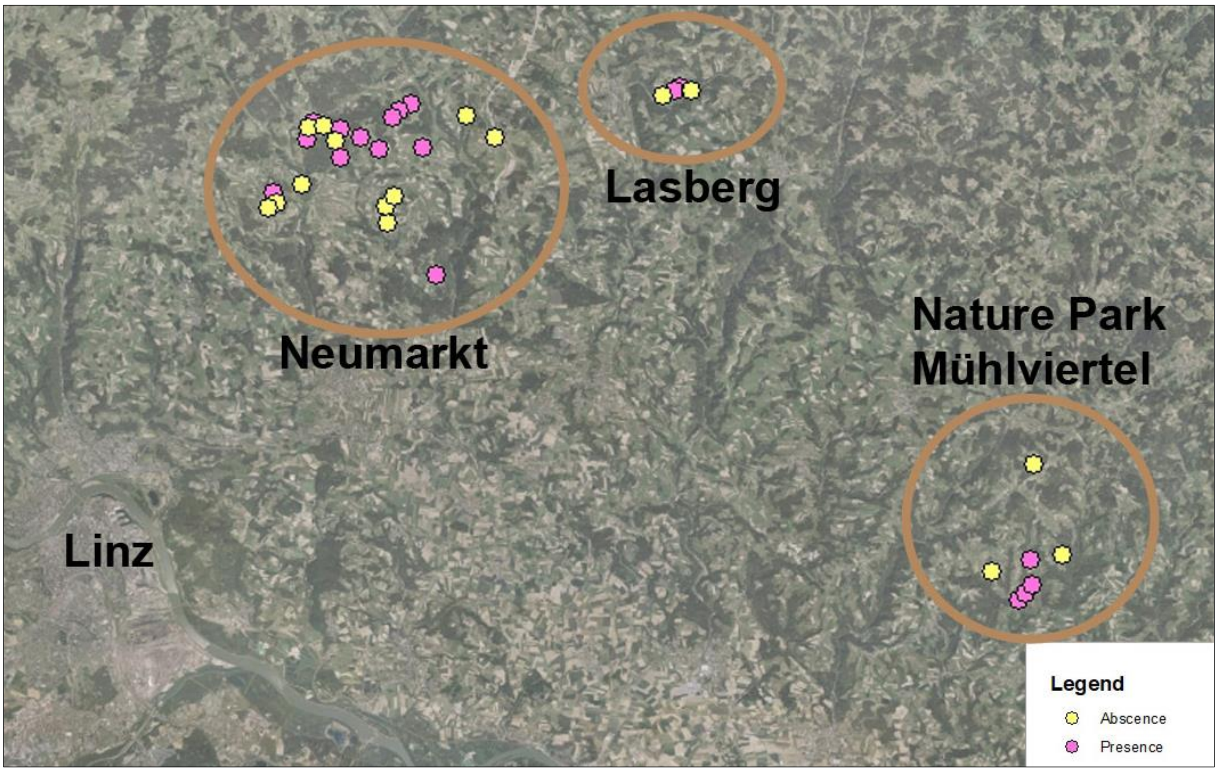


Figure 2: Occupied woodlark territories (presence) plots in pink and non-territories (absence) plots in yellow (Source of aerial photo: www.geoland.at)

Once the centre of the territories was identified, the size of each sampling plot was defined. For this, the study of Harrison & Forster (1959) was considered. In this study the minimum and maximum territory size in different life phases of woodlarks are described. From these findings, the mean size of a woodlark territory was calculated and translated into the size and radius of study plots for this thesis. Both, presence and absence study plots had the same size of approximately seven hectares and thus a radius of 150 meters.

2.3 Habitat characteristics

Within the study plots of seven hectares, the habitat characteristics of woodlark territories were determined between April and May 2017. For this, a set of landscape and vegetation variables was quantified. This set included vegetation, linear landscape elements, punctual landscape elements and human elements. Vegetation referred to grassland, arable land, forest and trees of wood clumps. Linear landscape elements referred to dirt roads, asphaltic roads, rough pastures and electricity lines. Punctual elements referred to wood clumps. Human elements referred to residential areas. The selection of these variables were based on previous woodlark studies in this region and other countries (Mallord et al. 2007, Wright et al. 2007, Uhl et al. 2008, Uhl 2012).

Out in the field, the first step was to identify the measuring polygons. A measuring polygon was defined to be one connected type of vegetation (e.g. meadow), linear landscape element (e.g. dirt road) or punctual element (e.g. wood clump). Polygons smaller than 15 m^2 were not measured. Based on the size of a measuring polygon, the amount of measuring points was set (Table 1). These points were distributed randomly over the measuring unit according to a stratified random design. The minimum distance between those points was ten meters. On each measuring point the height of the vegetation and in case of forests and wood clumps also the DBH (= diameter at breast height) was measured. Number of points for measurements of height and DBH within the polygons was done as predefined (Table 1) for all polygons. The height of vegetation was measured for grassland, arable land, forest, dirt roads (when vegetation existed), wood clumps and rough pasture. The DBH was measured for trees in the forest and wood clumps.

Table 1: Number of sampling points based on polygon size

Percentage of area covered by the polygon (%)	Area (m^2)	Number of measuring points
0 - 10.9	0 - 7 000	2
11 - 20.9	7 000 - 14 000	4
21 - 30.9	15 000 - 22 000	6
31 - 40.9	22 000 - 29 000	8
41 - 50.9	29 000 - 36 000	10
51 - 60.9	36 000 - 43 000	12
61 - 70.9	43 000 - 50 000	14
71 - 80.9	50 000 - 57 000	16
81 - 90.9	57 000 - 64 000	18
91 - 100	64 000 - 71 000	20

The second step was to identify the type of vegetation. Within these groups the vegetation was identified as detailed as possible. The third step was to identify the linear and punctual landscape elements within the sampling plot and estimate the distances from the centre of the territory to those elements. The distances to dirt roads, rough pastures, wood clumps, electricity lines and also forests were estimated. Besides that, also the length of the linear landscape elements dirt road, rough pasture, electricity line and asphaltic street were estimated.

After field mapping, ArcGIS (v. 10.5.1) (ESRI 2017) was used to digitalize the collected data of the sampling plots. FRAGSTATS (v4.2.1) (McGarigal 2015) was used to calculate several landscape metrics and class metrics. The landscape metrics calculated in FRAGSTATS were number of patches (NP), patch density (PD), landscape shape index (LSI), proximity mean (PROX_MN), contagion index (CONTAG) and Simpson diversity index (SIDI). The class metrics calculated in FRAGSTATS were percentage of land (PLAND), number of patches (NP), patch density (PD) and landscape shape index (LSI). These class metrics were calculated for the polygons identified in the field mapping (grassland, arable land without vegetation, arable land with small vegetation, arable land with mid or high vegetation, forest, dirt road, asphaltic street, wood clump, rough pasture, residential area and other used area). Patches referred to polygons identified in the field mapping. All together 69 variables were measured in the field or calculated in FRAGSTATS or ArcGIS.

2.4 Interviews

To identify farmer´s attitude towards woodlarks, farmers which owned land of occupied woodlark territories in the study period (presence plots) or in previous years (absence plots), were interviewed. In total 19 farmers participated and two farmers refused to take part in the interviews. I conducted face to face interviews to ensure high participation of farmers to get as much data as possible. The interviews took place on the farms and took about 10 to 15 minutes. I used a list of predetermined questions (see Appendix). In total, 21 questions about the farm, knowledge about woodlarks, land use change, willingness to implement conservation measures and demographic questions were asked. The answers were mostly predefined. There were three types of predefined answers. First, there was a Likert scale with a ranking from one (not important / definitely not / no) to five (important / for sure / yes). Second, there were answer options in form of a “yes” or “no” answers. Third, there were selections of pre-formulated answer possibilities.

2.5 Land use change

I used data about agricultural land use in the area of Mühlviertel from the years 2007, 2012 and 2016 provided by the Federal Ministry of Agriculture, Forestry, Environment and Water Management. I compared the land use types of these years to identify changes in grassland, cropland, woody vegetation and protected areas. The focus of this analysis was on communes where woodlark appeared in the last decade. Fifteen communes were identified, where woodlarks were recorded from 2007 until 2016 (BirdLife Austria 2017). For these fifteen communes the four land use types were analysed. The four analysed land use types contain different subcategories. Grassland referred to wild flower strips, permanent pasture, one to three or more times cut meadows, litter meadow and seeded pastures. Cropland referred to different types of legumes, field forage, summer grain, winter grain, potato, corn and other field crops. Woody vegetation referred to Christmas trees, energy forests, tree nurseries, pasture land with trees (“Hutweide”), different types of fruit trees and hop. Protected areas referred to protected arable land (“Landschaftselement Acker”), protected grassland (“Landschaftselement Grünland”), natural monuments and areas with good agricultural and environmental conditions (GAECs). For the analysis the mean (in hectare) of the four land use type of the years 2007, 2012 and 2016 was used.

2.6 Statistical analysis

For analysing habitat characteristics random forest and logistic regression were used. Random forest was performed to narrow down the dataset with 69 variables and identify the most important variables. For this the R-package “randomForest” (Liaw and Wiener 2018) was used. The NA values (not applicable) were replaced with the function of rough imputation of missing values (“na.roughfix”). Then the random forest was performed with using 3500 trees. The type of random forest was classification and the random forest had eight variables at each split. Before performing the logistic regression, the variance inflation factor (VIF) of the top nine variables determined with random forest was calculated with the R-package “usdm” (Naimi 2017), to avoid multicollinearity of the explanatory variables. A threshold of th = 5 was used to detect highly correlated variables and those variables were excluded from the model. To determine which habitat characteristics were the most important ones in the woodlark habitats in Mühlviertel a logistic regression was performed with the response variable absence (0) and presence (1) of woodlarks in the study plots and the remaining seven explanatory variables. These variables were Simpson diversity index (SIDI), patch density (PD), landscape shape index of arable land without vegetation (LSI_no_veg_A), percentage of dirt roads (PLAND_earth.road), percentage of forest (PLAND_forest), distance to dirt roads (dis_earth.road) and length of electricity line (len_el.line). The analysis of deviance (X^2) was calculated to drop variables in order to identify the best-fitted model.

For analysing the data of the interviews with farmers, a contingency table and the Fisher exact test were executed to identify associations between the answers of the questions asked during the interviews. The answers to questions willingness to implement nature conservation measures, seeing the woodlark habitats in danger for the future and importance of protecting woodlarks were tested with answers to the other questions asked. For this, the answers of each question were defined as Likert scale with the R-package “likert” (Bryer and Speerschneider 2016). Then contingency tables of possible associating questions were generated. Because the frequencies in some cells of the contingency tables were below five, the Fisher exact test was used to test the association of questions. In total 27 possible associations of answers to interview questions were tested.

An analysis of variance (ANOVA) was used to test the change of land use types (i.e., grassland, cropland, woody vegetation and protected areas) in the fifteen communes where woodlarks occurred in the last decade. Prior to test the assumptions of the ANOVA normality of residuals and the homogeneity of variances were tested. To check the normality of residuals the Q-Q plot was plotted and the Shapiro-Wilk normality test was performed. To check the homogeneity the residuals vs fitted values were plotted and the Levene's test for homogeneity of variance with the R-package “car” (Fox and Weisberg 2011) was performed. The respond variable was the mean area (in hectares) of the land use types. The explanatory variables were the type of land use and the year (2007, 2012 and 2016). The Tukey test was used as post hoc test to detect group differences in case of significant explanatory variables.

All statistics were done with R-Commander (Version 2.3-0) (R Core Team 2016). A significance value of $\alpha = 0.05$ was set.

3. Results

3.1 Habitat characteristics

The top nine most important variables were Simpson diversity index (SIDI), length of dirt road (len_earth.road), patch density (PD), landscape shape index of arable land without vegetation (LSI_no_veg_A), percentage of dirt roads (PLAND_earth.road), percentage of forest (PLAND_forest), distance to dirt roads (dis_earth.road), length of electricity line (len_el.line) and contagion index (CONTAG) (Figure 3). The Out of Bag Error (OBB) of the random forest was 23.53%.

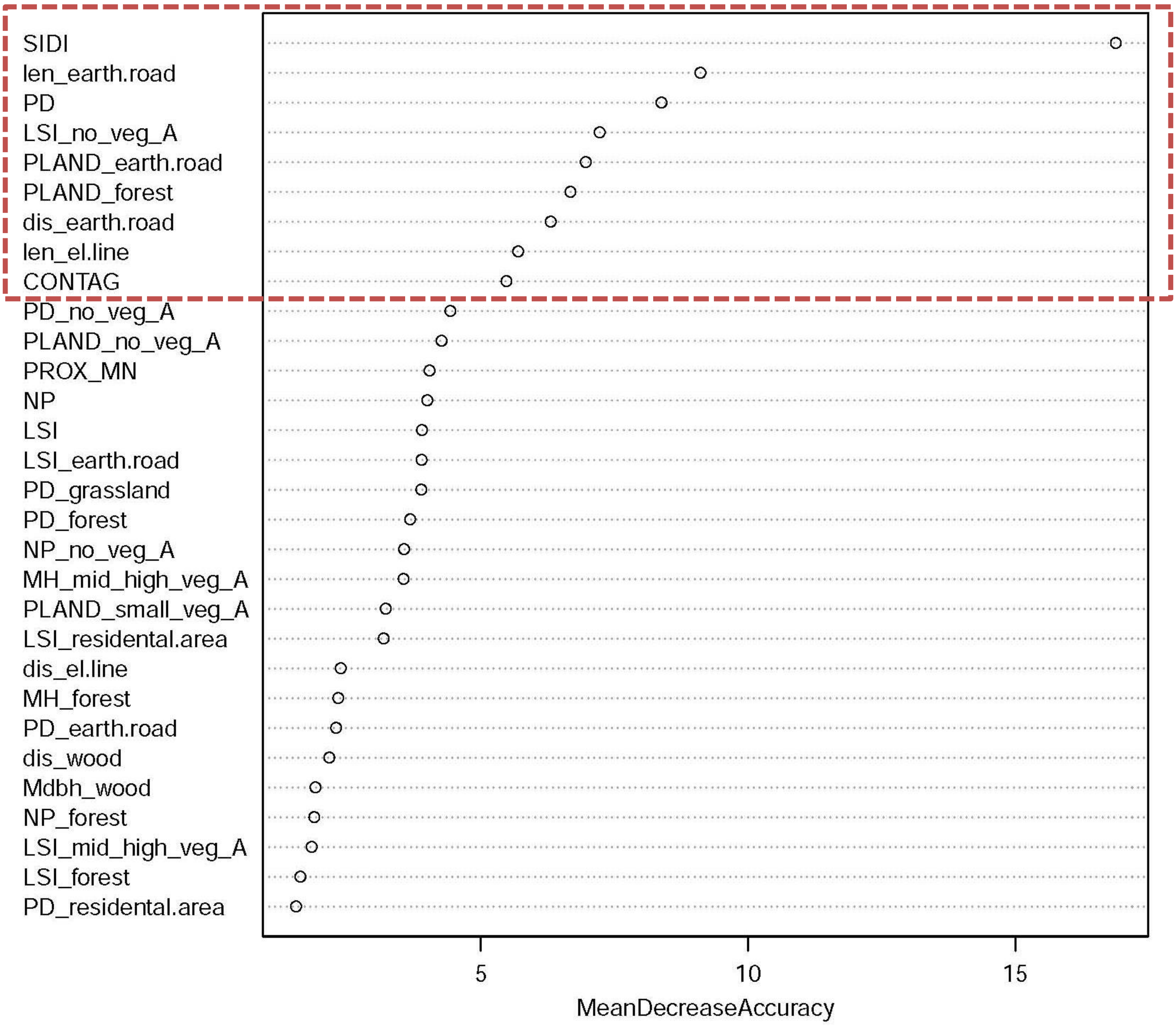


Figure 3: Results of the random forest approach. The red rectangle is highlighting the top nine variables

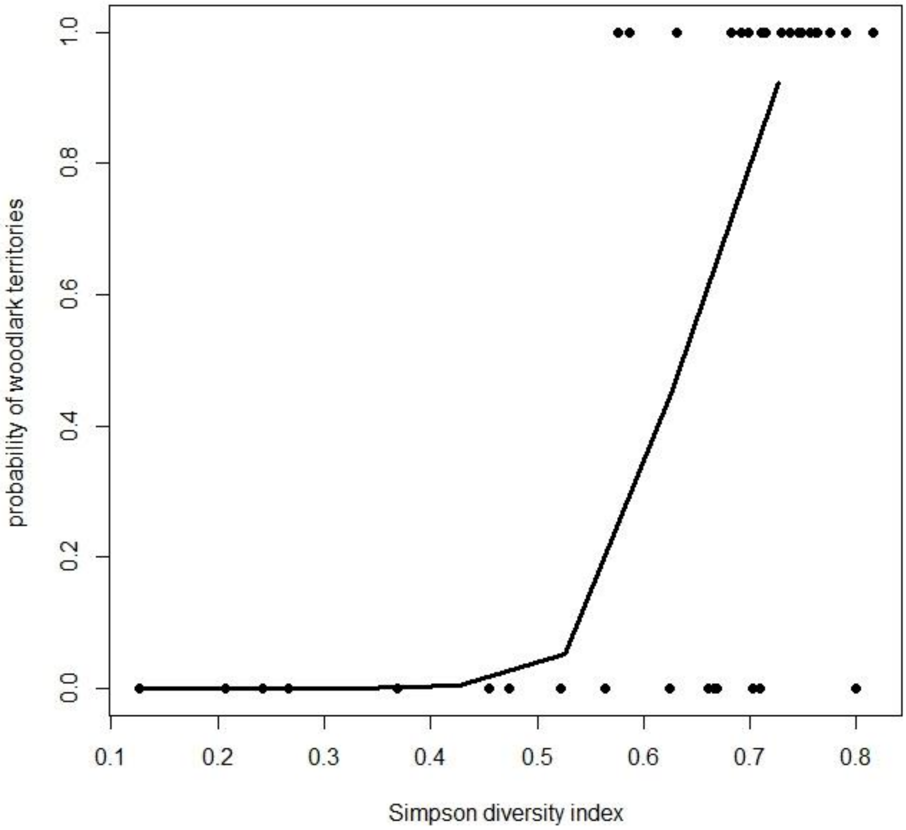
Analysing the variance inflation factor (VIF) of the top nine variables showed that length of dirt roads (len_earth.road) was highly correlated with percentage of dirt roads (PLAND_earth.road) and contagion index (CONTAG) was highly correlated with Simpson diversity index (SIDI). Thus, the variables length of dirt roads (len_earth.road) and contagion index (CONTAG) were excluded from further analysis. After calculating the analysis of deviance (X^2), variables were dropped and in the best-fitted model the variables Simpson diversity index (SIDI), patch density (PD), distance to dirt roads (dis_earth.road) and length of electricity lines (len_el.line) remained.

In the logistic regression two significant habitat characteristics were found. The Simpson diversity index (SIDI) and the distance to dirt roads (dis_earth.road) had a significant effect on woodlark territories (Table 2). From this model the Akaike information criterion (AIC = 30.45) was calculated. The probability that woodlarks establish a territory increases with a landscape heterogeneity above 50 %. With a distance to dirt roads of at least 40 meters, the probability of a woodlark territory increases as well (Figure 4).

Table 2: Result of logistic regression showing the estimate, standard error (Std. Error), z value and p-value (P), significant results are marked with stars (*)

	Estimate	Std. Error	z value	P
(Intercept)	-15.02	6.14	-2.45	0.014 *
SIDI	26.71	10.90	2.45	0.014 *
PD	-0.01	0.01	-1.44	0.151
dis_earth.road	0.06	0.03	2.22	0.027 *
len_el.line	-0.01	0.01	-1.63	0.101

(A)



(B)

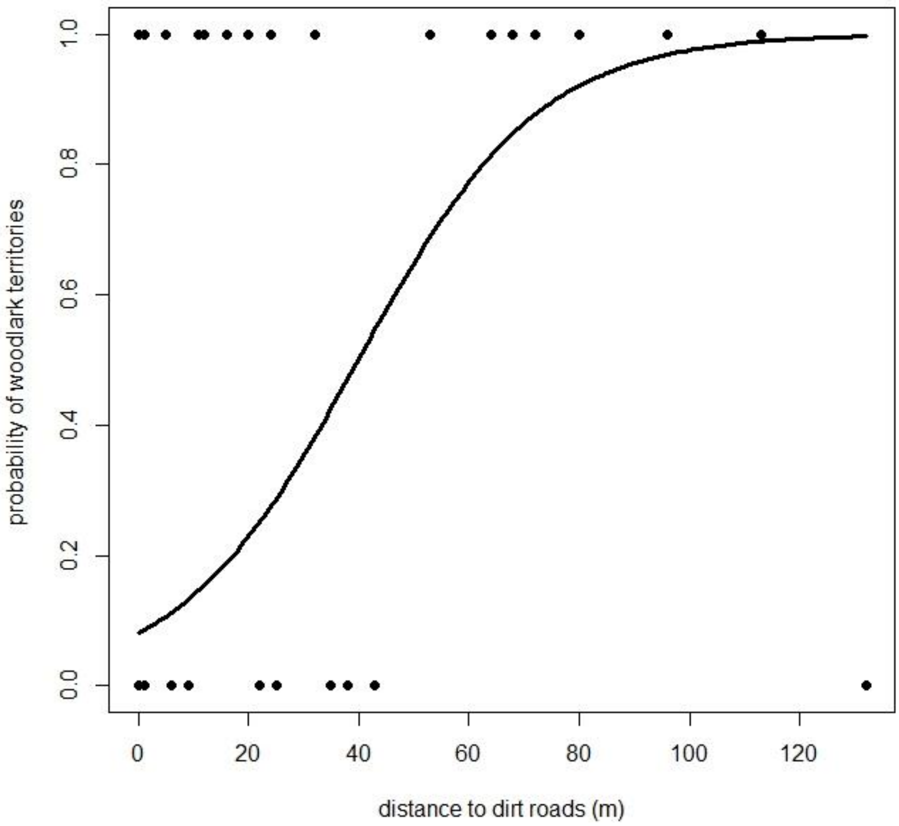


Figure 4: Fitted values (line) obtained by logistic regression (dots are observed values), (A) probability woodlarks establish territories with rising landscape heterogeneity represented in Simpson diversity index, (B) probability woodlarks establish territories with larger distance to dirt roads

3.2 Interviews

The first significant combination of answers was to the questions “how important is the protection of woodlarks to you” and “how much do you know about the woodlark” ($p = 0.010$). The more farmers knew about woodlarks, the more important was the protection of woodlarks to them. All of the interviewed farmers think the protection of woodlarks is important and no one of the interviewed farmers answered the protection of woodlarks is unimportant to them. The question “how important is the protection of woodlarks to you” was answered it is moderate important by 37% of the farmers, it is rather important by 21% of the farmers and it is important by 43% of the farmers. The answers to the question “how much do you know about the woodlark” were as following: 27% of the interviewed farmers did not know any fact about woodlarks, 16% of the farmers knew one fact and 10% of the farmers knew two facts. The remaining 48% of the farmers knew three or more facts about woodlarks, their life history and habitat.

The second significant combination was found between the answers to the questions “do you think woodlark habitats are in danger for the future” and “since how many generations does the family live on the farm” ($p = 0.013$). The shorter the farmers have lived on the farm, the less they think the woodlark habitats are in danger for the future. The main part of the interviewed farmer’s answered to the question “do you think woodlark habitats are in danger for the future” the habitats are not at all (27%) or rather not (37%) in danger for the future. Whereas, 16% of the farmers think the habitat could be in danger, 10% of the farmers think they are rather in danger and 10% of the farmers are sure, that the woodlark habitats are in danger for the future. The main parts of the interviewed farmers have lived five or less generations in the farm. More specifically, 32% of the farmers have lived three generations, 21% of the farmers have lived four generations and 16% of the farmers have lived five generations on the farm. Whereby 32% of the farmers have lived six generations or more on the farm.

3.3 Land use change

The area covered by cropland decreased from 630 ha (hectares) in 2007 to 600 ha in 2012 and further to 590 ha in 2016. The same happened for grassland covered area, which decreased from 960 ha in 2007 to 940 ha in 2012 and further to 930 ha in 2016. The area covered by woody vegetation decreased from 5 ha in 2007 to 3.5 ha in 2012 and finally to 3 ha in 2016. In contrast protected areas increased from 0.8 ha in 2007 and 2012 to 12 ha in 2016.

The tests of the assumptions of the ANOVA showed the data was normal distributed and had no significant differences in variances. The area covered differed significantly between land use types ($F = 4376.48$, $df = 3$, $p < 0.001$). There was no significant change of the mean area of the four land use types (i.e., grassland, cropland, woody vegetation and protected areas) between the years 2007, 2012 and 2016 ($F = 1.757$, $df = 2$, $p = 0.251$). The Tukey test (post-hoc test) showed that all but the areas covered by woody vegetation and protected areas were significantly different (grassland-cropland $p < 0.001$, protected-cropland $p = 0.000$, woody-cropland $p = 0.000$, protected-grassland $p = 0.000$, woody-grassland $p = 0.000$, except woody-protected $p = 0.999$). But this is not indicating a land use change.

Table 3: Result of ANOVA showing degrees of freedom (Df), sum of squares (Sum Sq), mean sum of square (Mean Sq), F value and p-value (P), significant results are marked with stars (*)

	Df	Sum Sq	Mean Sq	F value	P
type	3	1951297	650432	4376.48	<0.001*
year	2	522	261	1.76	0.251
residuals	6	892	149		

4. Discussion

The most important landscape characteristics of woodlark habitats in the region Mühlviertel were the distance to dirt roads and the landscape heterogeneity. In the study area dirt roads mostly consist of bare ground with a vegetated strip in the middle. Some were completely covered with short and sparse vegetation or they were without any vegetation. During the observation of woodlarks in the study period, woodlarks were seen dust bathing in the sand of dirt roads. This might be one reason for the significant positive effect of dirt roads in woodlark territories. Another possible reason why dirt roads were important for woodlarks could be that the birds might find insects as a food resource on the bare ground or in the short and sparse vegetation (Harrison and Forster 1959, Bosco 2014). Bosco (2014) found that woodlarks prefer for foraging sparse vegetation with a vegetation cover of 40-70%, because insects are more accessible there. Besides that, the surrounding vegetation is also crucial for the occurrence of insects (Bosco 2014). Here, the landscape heterogeneity could play an important role to provide a mixture of required resources. Pedersen and Krøgli (2017) found in their study that heterogeneity of land use has a significant positive impact on farmland birds and also on non-farmland birds. Landscape heterogeneity is related to high species richness of farmland birds but has a negative impact on abundance (Pedersen and Krøgli 2017).

In contrast to previous studies by Harrison and Forster 1959, Mallord et al. 2007, Buehler et al. 2017, in this study vegetation height was not identified as an important habitat characteristic for woodlark territories. A possible reason for this could be that this study is focusing at habitat characteristics of woodlark territories on the landscape scale, in contrast to previous studies, which focused on smaller scale. The broader scale was chosen because circumstances and impacts on the landscape scale can also have a possible impact on woodlarks and their territories.

Conservation measures for farmland birds, in particular woodlarks, should be customized to region specific features, to stop the decrease in farmland birds (Jerrentrup et al. 2017). For example, when planning conservation measures for woodlarks in the study area, the landscape heterogeneity and the dirt roads should be considered. Also the presence of possible or actual breeding territories should be included. Besides that, conservation activities should concentrate on maintaining or improving landscape diversity and dirt roads in the close surrounding (150 m) of woodlark territories. For implementing possible conservation measures in the study area, farmers are the most important players for this. Fortunately, farmers in the study area are well disposed to this as the results of the interviews show.

In this study two significant combinations of answers were found in the interviews with farmers. The first significant combination was between the answers to the questions “how important is the protection of woodlarks to you” and “how much do you know about the woodlark”. This implies that the sense about protection and knowledge are associated. It is very important for the successful breeding and survival of farmland birds, that famers are aware of the birds and their needs (Swagemakers et al. 2009). Farmers who think protection of woodlarks is important could be vigilant for the birds when working in the field. For example, farmers could identify together with regional experts the location of nests in their fields or meadows and avoid these areas when carrying out management operations. Besides avoiding the nest spots, it is also important to be able to see birds running in the fields when carrying out management activities to avoid killing the birds with machines. Besides knowledge also the personal attitude is important when it comes to protection of farmland birds. For implementing (unsubsided) conservation activities the personal motivation is very important (Van Dijk et al. 2016, Mills et al. 2018). If farmers identify protection of birds with themselves, they are more likely to implement protection activities (Van Dijk et al. 2015).

The second significant combination was “do you think woodlark habitats are in danger for the future” and “since how many generations does the family live on the farm”. A possible association of the answers to these questions could be that the change in landscape in the future, which could have negative impact on woodlarks as found in previous studies (Chamberlain et al. 2000, Jerrentrup et al. 2017), is not seen as problematic. This could be seen as unproblematic because changes in agricultural management are also personal decisions of farmers (Van Vliet et al. 2015, Kristensen 2016) and there are no bad intentions behind this. The shorter the farmers have lived on the farm, the less they think the woodlark habitats are in danger for the future. A possible explanation for this could be, that farmer families, who have lived since less generations on the farm have not experienced the habitats or farmland birds, who existed in former times. Another possible explanation could be that over 50% of the interviewed farmers think the woodlark habitats are not or rather not in danger for the future, because the interviewed farmers have not experienced a land use change in the last decade in Mühlviertel.

The typical case of intensification of farmland is for example the change from natural areas (e.g. permanent grassland) to annual crops or rotational grassland (Kristensen et al. 2016). The results of this study show there was no significant land use change of the land use types cropland, grassland, protected areas and woody vegetation over the last decade. Also the decrease in hectares of the land use types cropland, grassland and woody vegetation and the increase of protected areas cannot be seen as change in land use according to the typical case (see above) described by Kristensen et al. (2016). Even though there is no land use change over the last decade in the study area, it could be seen as stabilisation of intensification, as Van der Sluis et al. (2016) found in most regions in Europe for the period of 2001 to 2011. Whereby, in the same study for the case study of Reichraming, Austria intensification was found in the same period, which I also expected in this study. Another possible explanation for the not existing land use change could be, that land use change is a very region specific phenomena (Van der Sluis et al. 2016) and is not happening in the study area. It is also possible, that the impact factors for a land use change were missing. For example, changes in policy or changes in farmers´ personal perspectives (Van Vliet et al. 2015, Kristensen 2016), which impact land use change, were missing or not strong enough to cause a land use change. Another possible reason why no evidence for land use change was found could be that the small structured landscape of the study area was not vulnerable to land use change.

There was an overall decrease in hectares of the four land use types (i.e., grassland, cropland, woody vegetation and protected areas) investigated. A possible explanation could be that areas are used for other purposes, than these four land use types. It could be that these areas were used for settlement, roads or other construction works. Those land uses were not considered in this study. Besides a possible use of these areas for other land uses than investigated in this study, land use change can be a very personal decision of farmers. The influencing factors for farmers' decision about land use change can be personal interests of the farmer, the size or the type of the farm and external impacts (e.g. policy). The outcome of the decision process can be intensification or extensification (Kristensen et al. 2016). The economic situation might be also an important factor for farmers to intensify their farm, which leads to more yield, more farmland and a higher density of cattle on pastures. Also the geographical location, the size and the type of the farm should be taken into account for land use change (Van der Sluis et al. 2016). The focus on maximizing the economic output of the farm can lead to biodiversity loss among other things as well. The decision of scale on a farm can affect the services provided by agriculture, like the character of landscapes and the biodiversity on landscape scale. Therefore a balance in the economic and biodiversity services, can help to serve satisfactory solutions for the demands of all interests (Gutzler et al. 2015).

There are some limitations in the study design. The first one is the small sample size of the interviews. The limiting factor for the sample size is the fact, that the interviewed farmers are landowners of occupied woodlark territories in 2017 or landowners of previous occupied woodlark territories (2016 or earlier). It was decided to interview people with this specific background, because these interview partners have a possible connection with woodlarks. As a result of this circumstance for this study in total 19 farmers were interviewed. The second limitation for the interviews is that for the question about the willingness to implement nature conservation measures for woodlarks no specific examples of conservation measures were provided during the interview. By explaining or showing examples of possible conservation measures it would have been easier for the surveyed farmers to imagine how woodlarks could be protected. A limiting factor in analysing the land use change could be the time span of the last decade. According to Van der Sluis et al. (2016) a stabilisation of change in land use intensity has been observed in the last decade. If drastic changes in agriculture happened before, they did not affect the results described in this study.

Further research about woodlarks in the study area should be conducted. For those studies the landscape scale should be incorporated as well to collect more findings on this scale. Although, in this study no land use change of the last decade was found, it should be of interest of further studies to have an eye on the ongoing development of land use change. This might threaten the habitats of the small woodlark population living in Mühlviertel.

5. Conclusion

Supporting the landscape heterogeneity and the occurrence of dirt roads in the study area helps to provide suitable woodlark habitats. Conservation measures should focus on maintaining the landscape heterogeneity and dirt roads in the surrounding of woodlark habitats. Even though there was no evident change in land use types in the last decade, it should be further monitored to react when there is a land use change in the future to preserve the landscape heterogeneity. Farmers in the study area are already aware of the importance of protection of woodlarks and their habitats. This awareness should be used to support woodlarks in the study area with possible conservation measures. Related to the opinion of Jerrentrup et al. (2017) very regional and farm tailor-made conservation measures developed by local experts (ornithologists) and farmers are suitable here. This might stop the decline of woodlark populations in the study area.

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7. Appendix

Befragung

Liebe Landwirte!

Im Zuge meiner Masterarbeit befasse ich mich mit der Heidelerche und ihrem Lebensraum. Dabei ist es mir auch wichtig, die Meinung der Landwirte zu kennen. Das Interview ist anonym und alle Informationen werden vertraulich behandelt. Das Interview dauert ca. **10 Minuten**.

Vielen Dank, dass Sie sich für die Befragung Zeit nehmen!

Fragen zum landwirtschaftlichen Betrieb:

Ist Ihr landwirtschaftlicher Betrieb…

☐ Haupterwerbsbetrieb ☐ Nebenerwerbsbetrieb

☐ konventionell ☐ biologisch

☐ Teil eines Naturschutzprogrammes ☐ nicht Teil eines Naturschutzprogrammes

Wenn ja, welches:____

Wie viele Menschen sind in der Landwirtschaft beschäftigt?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 oder mehr

☐ Familienmitglieder ☐ Angestellte ☐ Familienmitglieder & Angestellte

Wie viele Generationen ist die Landwirtschaft in Familienbesitz?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 oder mehr

Allgemeine Fragen zur Heidelerche:

Kennen Sie die Heidelerche?

☐ Ja ☐ Nein

Haben Sie die Heidelerche schon einmal auf Ihren Feldern und Wiesen gesehen oder gehört?

☐ Ja ☐ Nein

Wie viel wissen Sie über die Heidelerche? (Aufzählung)

* ________________________________ * ________________________________
* ________________________________ * ________________________________
* ________________________________ * ________________________________
* ________________________________ * ________________________________

Wie wichtig schätzen Sie den Schutz der Heidelerche ein?

unwichtig	eher unwichtig	mittelmäßig	ziemlich wichtig	wichtig
☐	☐	☐	☐	☐

<u>Fragen zum Lebensraum der Heidelerche</u>:

Laut früheren Studien ist der Lebensraum der Heidelerche in dieser Region unter anderem mit folgenden Elementen ausgestattet: **mageren Flächen** (Rainen, Magerwiesen), schütteren **Getreidefeldern, Einzelbäumen, Baumgruppen, offenen Feldwegen**, **Baumreihen**, Elektroleitungen und einem **Waldrand** in der Nähe (Frühauf 2008, Uhl et al. 2008).

Sehen Sie für die Zukunft, diesen Lebensraum in Gefahr (beispielsweise durch Änderungen der Bewirtschaftungsweise, Ausräumung und Homogenisierung der Landschaft)**?**

keinesfalls	wahrscheinlich nicht	vielleicht	sehr wahrscheinlich	ganz sicher
☐	☐	☐	☐	☐

Falls Sie diesen Lebensraum in Zukunft <u>in Gefahr</u> sehen, warum? (bei Antwort *vielleicht, sehr wahrscheinlich* und *ganz sicher*)

☐ zu viel Aufwand um diese Elemente zu erhalten
☐ der Wert wird nicht geschätzt
☐ kein Interesse der Nachkommen daran
☐ nicht wirtschaftlich
☐ keine passenden Maschinen
☐ Intensivierung lässt es nicht zu
☐ Sonstiges:____

Falls Sie den Lebensraum in Gefahr sehen, wie könnte dem entgegen gewirkt werden:

<u>Fragen zu möglichen Schutzmaßnahmen</u>:

Wären Sie bereit Naturschutzmaßnahmen umzusetzen um den Lebensraum der Heidelerche zu erhalten bzw. zu verbessern?

nein	eher nicht	vielleicht	eher schon	ja
☐	☐	☐	☐	☐

Wenn *eher schon* oder *ja*, warum? (mehrere Antworten möglich)

☐ mir ist die Heidelerche wichtig
☐ um die Biodiversität zu erhalten
☐ um zum Naturschutz beizutragen
☐ Sonstiges: ____________________________
☐ gute Erfahrungen mit Schutzmaßnahmen
☐ finanzieller Anreiz
☐ gutes Gefühl

Wenn *eher nicht* oder *nein*, warum? (mehrere Antworten möglich)

☐ mir ist die Heidelerche nicht wichtig
☐ keine Zeit
☐ zu viel Aufwand
☐ viele andere Auflagen
☐ schlechte Erfahrungen mit Schutzmaßnahmen
☐ andere erzählten mir von schlechten Erfahrungen mit Schutzmaßnahmen
☐ ich mache schon genug für den Naturschutz
☐ Sonstiges: ____________________________

Persönliche Angaben:

Alter:	Geschlecht:	Höchste abgeschlossene Ausbildung:
☐ 0 -20	☐ weiblich	☐ kein Schulabschluss
☐ 21 - 30	☐ männlich	☐ Pflichtschule
☐ 31 - 40		☐ Lehre / berufsbildende Fachschule
☐ 41 - 50		☐ Matura
☐ 51 - 60		☐ Meister
☐ 61 - 70		☐ Universität, FH
☐ 71 oder älter		☐ Andere:______________________

Table 4: List of all variables measured during field mapping or calculated in ArcGIS or FRAGSTATS. Acronym, name, definition, source of information (measured in the field, calculated in ArcGIS or FRAGSTATS), minimum, maximum, mean and standard deviation are given.

Acronym	Name	Definition	Calculated / Measured	Min	Max	Mean ± SD
NP	Number of patches	Number of patches (= polygons identified in the field mapping, e.g. forest, dirt road) in the (sampling) plot	FRAGSTATS	4.00	37.00	16.85 ± 8.19
PD	Patch density	Patch density in the plot	FRAGSTATS	56.68	524.44	238.85 ± 116.03
LSI	Landscape shape index	Gives information about the aggregation or disaggregation of patches in the plot	FRAGSTATS	1.54	5.63	3.64 ± 1.02
PROX_MN	Proximity mean	Measures the degree of patch isolation and the degree of fragmentation	FRAGSTATS	0.00	2148.36	194.72 ± 367.39
CONTAG	Contagion index	Measures the interspersion and dispersion of different patch types in the plot	FRAGSTATS	54.19	88.81	65.09 ± 8.38
SIDI	Simpson diversity index	Calculates the landscape diversity within the plot	FRAGSTATS	0.13	0.82	0.62 ± 0.18
PLAND_grassland	Percentage of grassland	Percentage of the total plot area covered by grassland	FRAGSTATS	0.00	68.87	22.32 ± 16.53
PLAND_no_veg_A	Percentage of arable land without vegetation	Percentage of the total plot area covered by arable land without vegetation	FRAGSTATS	0.00	45.58	7.40 ± 13.12
PLAND_small_veg_A	Percentage of arable land with small vegetation	Percentage of the total plot area covered by arable land with small vegetation (1-20 cm)	FRAGSTATS	0.00	49.36	9.85 ± 14.26

PLAND_mid_high_veg_A	Percentage of arable land with mid / high vegetation	Percentage of the total plot area covered by arable land with mid or high vegetation (21-150 cm)	FRAGSTATS	0.00	60.79	17.16 ± 17.38
PLAND_forest	Percentage of forest	Percentage of the total plot area covered by forest	FRAGSTATS	0.00	93.35	33.30 ± 26.71
PLAND_earth.road	Percentage of dirt roads	Percentage of the total plot area covered by dirt roads	FRAGSTATS	0.00	4.06	1.26 ± 0.94
PLAND_asphaltic.street	Percentage of asphaltic street	Percentage of the total plot area covered by asphaltic streets	FRAGSTATS	0.00	19.83	1.98 ± 3.52
PLAND_wood	Percentage of wood clumps	Percentage of the total plot area covered by wood clumps	FRAGSTATS	0.00	6.64	1.91 ± 1.69
PLAND_rough.pasture	Percentage of rough pasture	Percentage of the total plot area covered by rough pasture	FRAGSTATS	0.00	3.69	0.60 ± 0.87
PLAND_residental.area	Percentage of residential area	Percentage of the total plot area covered by residential	FRAGSTATS	0.00	65.31	3.82 ± 11.23
PLAND_other.use	Percentage of other used area	Percentage of the total plot area covered by other used area	FRAGSTATS	0.00	4.68	0.40 ± 0.94
NP_grassland	Number of grassland patches	Number of grassland patches in the plot	FRAGSTATS	0.00	8.00	3.47 ± 2.19
NP_no_veg_A	Number of arable land without vegetation patches	Number of arable land without vegetation patches in the plot	FRAGSTATS	0.00	3.00	0.65 ± 0.92
NP_small_veg_A	Number of arable land with small vegetation patches	Number of arable land with small vegetation (1-20 cm) patches in the plot	FRAGSTATS	0.00	2.00	0.62 ± 0.78

NP_mid_high_veg_A	Number of arable land with mid / high vegetation patches	Number of arable land with mid or high vegetation (21-150 cm) patches in the plot	FRAGSTATS	0.00	4.00	1.59 ± 1.21
NP_forest	Number of forest patches	Number of forest patches in the plot	FRAGSTATS	0.00	4.00	2.06 ± 1.13
NP_earth.road	Number of dirt road patches	Number of dirt road patches in the plot	FRAGSTATS	0.00	4.00	1.36 ± 1.01
NP_asphaltic.street	Number of asphaltic street patches	Number of asphaltic street patches in the plot	FRAGSTATS	0.00	3.00	0.74 ± 0.71
NP_wood	Number of wood clump patches	Number of wood clump patches in the plot	FRAGSTATS	0.00	15.00	3.94 ± 3.84
NP_rough.pasture	Number of rough pasture patches	Number of rough pasture patches in the plot	FRAGSTATS	0.00	5.00	1.09 ± 1.16
NP_residental.area	Number of residential area patches	Number of residential area patches in the plot	FRAGSTATS	0.00	10.00	1.03 ± 1.87
NP_other.use	Number of other used patches	Number of other used area patches in the plot	FRAGSTATS	0.00	2.00	0.32 ± 0.53
PD_grassland	Patch density of grassland patches	Density of grassland patches in the plot	FRAGSTATS	0.00	113.39	49.19 ± 31.06
PD_no_veg_A	Patch density of arable land without vegetation patches	Density of arable land without vegetation patches in the plot	FRAGSTATS	0.00	42.51	9.17 ± 13.00
PD_small_veg_A	Patch density of arable land with small vegetation patches	Density of arable land with small vegetation (1-20 cm) patches in the plot	FRAGSTATS	0.00	28.37	9.02 ± 11.10

PD_mid_high_veg_A	Patch density of arable land with mid / high vegetation patches	Density of arable land with mid or high vegetation (21-150 cm) patches in the plot	FRAGSTATS	0.00	56.70	22.51 ± 17.13
PD_forest	Patch density of forest patches	Density of forest patches in the plot	FRAGSTATS	0.00	56.70	29.18 ± 15.97
PD_earth.road	Patch density of dirt road patches	Density of dirt road patches in the plot	FRAGSTATS	0.00	56.68	19.17 ± 14.33
PD_asphaltic.street	Patch density of asphaltic street patches	Density of asphaltic street patches in the plot	FRAGSTATS	0.00	45.52	10.42 ± 10.06
PD_wood	Patch density of wood clump patches	Density of wood clump patches in the plot	FRAGSTATS	0.00	212.60	55.85 ± 54.38
PD_rough.pasture	Patch density of rough pasture patches	density of rough pasture patches in the plot	FRAGSTATS	0.00	70.87	15.42 ± 16.50
PD_residental.area	Patch density of residential area patches	Density of residential area patches in the plot	FRAGSTATS	0.00	141.74	14.59 ± 26.45
PD_other.use	Patch density of other used patches	Density of other used area patches in the plot	FRAGSTATS	0.00	28.34	4.59 ± 7.58
LSI_grassland	Landscape shape index of grassland	Measures the disaggregation or aggregation of grassland patches in the plot	FRAGSTATS	0.00	5.63	3.11 ± 1.44
LSI_no_veg_A	Landscape shape index of arable land without vegetation	Measures the disaggregation or aggregation of arable land without vegetation patches in the plot	FRAGSTATS	0.00	2.98	0.77 ± 0.99

LSI_small_veg_A	Landscape shape index of arable land with small vegetation	Measures the disaggregation or aggregation of arable land with small vegetation (1-20 cm) patches in the plot	FRAGSTATS	0.00	2.74	0.83 ± 0.98
LSI_mid_high_veg_A	Landscape shape index of arable land with mid / high vegetation	Measures the disaggregation or aggregation of arable land with mid or high vegetation (21-150 cm) patches in the plot	FRAGSTATS	0.00	3.70	1.61 ± 1.02
LSI_forest	Landscape shape index of forest	Measures the disaggregation or aggregation of forest patches in the plot	FRAGSTATS	0.00	3.23	2.09 ± 0.65
LSI_earth.road	Landscape shape index of dirt road	Measures the disaggregation or aggregation of dirt road patches in the plot	FRAGSTATS	0.00	8.11	4.28 ± 2.46
LSI_asphaltic.street	Landscape shape index of asphaltic street	Measures the disaggregation or aggregation of asphaltic street patches in the plot	FRAGSTATS	0.00	7.19	2.89 ± 2.52
LSI_wood	Landscape shape index of wood clump	Measures the disaggregation or aggregation of wood clump patches in the plot	FRAGSTATS	0.00	7.74	2.72 ± 1.76
LSI_rough.pasture	Landscape shape index of rough pasture	Measures the disaggregation or aggregation of rough pasture patches in the plot	FRAGSTATS	0.00	7.03	2.53 ± 2.24
LSI_residental.area	Landscape shape index of residential area	Measures the disaggregation or aggregation of residential area patches in the plot	FRAGSTATS	0.00	5.55	0.96 ± 1.25
LSI_other.use	Landscape shape index of other used patches	Measures the disaggregation or aggregation of other used patches in the plot	FRAGSTATS	0.00	5.88	0.74 ± 1.50

MH_grassland	Mean height of grassland vegetation (cm)	Mean height of grassland vegetation, measured at several points according to the size of the polygon	field mapping	0.00	47.50	19.91 ± 9.97
MH_no_veg_A	Mean height of arable land with no vegetation (cm)	Mean height of arable land without vegetation, measured at several points according to the size of the polygon	field mapping	0.00	0.01	0.00 ± 0.00
MH_small_veg_A	Mean height of arable land with small vegetation (cm)	Mean height of arable land with small vegetation (1-20 cm), measured at several points according to the size of the polygon	field mapping	0.00	20.75	5.20 ± 6.57
MH_mid_high_veg_A	Mean height of arable land with mid / high vegetation (cm)	Mean height of arable land with mid or high vegetation (21-150 cm), measured at several points according to the size of the polygon	field mapping	0.00	153.17	27.15 ± 29.55
MH_forest	Mean height of forest vegetation (cm)	Mean height of forest vegetation, measured at several points according to the size of the polygon	field mapping	0.00	2518.33	1852.90 ± 509.75
MH_earth.road	Mean height of dirt road vegetation (cm)	Mean height of dirt road vegetation, measured at several points according to the size of the polygon	field mapping	0.00	21.00	6.83 ± 5.94
MH_wood	Mean height of wood clump vegetation (cm)	Mean height of wood clump vegetation, measured at several points according to the size of the polygon	field mapping	0.00	2500.00	681.87 ± 540.36

MH_rough pasture	Mean height of rough pasture vegetation (cm)	Mean height of rough pasture vegetation, measured at several points according to the size of the polygon	field mapping	0.00	37.50	9.96 ± 10.48
Mdbh_forest	Mean diameter at breast height of forest vegetation (cm)	Mean diameter at breast height of forest vegetation, measured at several points according to the size of the polygon	field mapping	0.00	42.65	31.55 ± 8.26
Mdbh_wood	Mean diameter at breast height of wood clump vegetation (cm)	Mean diameter at breast height of wood clump vegetation, measured at several points according to the size of the polygon	field mapping	0.00	55.70	26.43 ± 17.66
dis_forest	Distance to a forest (m)	Distance from the centre of the plot to the closest forest within the plot	ArcGIS / field mapping	0.00	211.00	58.24 ± 41.87
dis_earth.road	Distance to an earth road (m)	Distance from the centre of the plot to the closest dirt road within the plot	ArcGIS / field mapping	0.00	132.00	32.56 ± 36.93
dis_rough.pasture	Distance to a rough pasture (m)	Distance from the centre of the plot to the closest rough pasture within the plot	ArcGIS / field mapping	0.00	133.00	34.71 ± 41.15
dis_wood	Distance to a wood clump (m)	Distance from the centre of the plot to the closest wood clump within the plot	ArcGIS / field mapping	0.00	135.00	48.32 ± 44.20
dis_el.line	Distance to an electricity line (m)	Distance from the centre of the plot to the closest electricity line within the plot	ArcGIS / field mapping	0.00	115.00	16.50 ± 30.21

len_earth.road	Length of dirt road (m)	Length of dirt roads within the plot	ArcGIS	0.00	649.00	225.91 ± 169.12
len_asphaltic.street	Length of asphaltic street (m)	Length of asphaltic streets within the plot	ArcGIS	0.00	1048.00	193.59 ± 216.61
len_rough.pasture	Length of rough pasture (m)	Length of rough pastures within the plot	ArcGIS	0.00	411.00	97.88 ± 110.63
len_el.line	Length of electricity line (m)	Length of electricity lines within the plot	ArcGIS	0.00	462.00	121.24 ± 156.64