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Coincidence of High Nature Value farmlands with bird and butterfly diversity

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ABSTRACT

The amount of High Nature Value farmland (HNVf) is a commonly used environmental indicator for assessing the performance of the Common Agricultural Policy, to support sustainable agriculture and monitor changes in agricultural land use in Europe. HNVf comprises agricultural areas of semi-natural state, low-intensity farming and fine-scale landscape mosaics of different habitat types. For a successful implementation, the identification of HNVf should correctly reflect the variation in biodiversity values between different agricultural landscapes. We examined how well the Finnish HNVf indicator and the sub-indicators constituting it – recalculated for the purposes of this study for five study regions – reflect the variation in bird and butterfly species richness and diversity patterns at different spatial scales. We found that butterfly diversity index was positively associated with the HNVf indicator at the finest scale of 0.5 km × 0.5 km squares. Among the HNVf sub-indicators, extensive cultivation of grasslands was most strongly related to the farmland bird diversity and the density of edge to the butterfly diversity. Thus, the HNVf concept reflects well the distribution of butterflies in the Finnish agricultural landscapes but insufficiently the diversity patterns of farmland birds. Importantly, semi-natural vegetation and long-term pastures – the backbone of the concept – presently occur in small and highly fragmented patches in agricultural landscapes in Finland. The Pan-European concept of HNVf has restricted application to farmland birds of this boreal country and the national HNVf concept may need to be revised.

1. Introduction

There are contrasting challenges in using agricultural environments: the imperative for intensifying food production for the growing human population, on one hand, and the need for protecting biodiversity and ecosystem services within them, on the other hand (Foley et al., 2011). In the pressure of these conflicting interests, many farmland biotopes of importance for biodiversity, as well as their biota, have declined drastically during the last century because of the intensified production (Benton et al., 2003; Donald et al., 2001; Stoate et al., 2001). For example, there are well documented population declines throughout Europe in farmland birds (Butler et al., 2010; Gregory et al., 2005) and butterflies (van Swaay et al., 2010, 2015). Improving the state of biodiversity in present-day agricultural landscapes is therefore crucial for halting the loss of biodiversity (Butchart et al., 2010).

The concept of ‘High Nature Value farmlands’ was developed in recognition of the importance of certain characteristics of farmland for biodiversity in Europe (Andersen et al., 2003). Based on the High Nature Value farmland (hereafter HNVf) concept, a suite of farmland indicators was defined to assess the environmental performance of the Common Agricultural Policy (CAP) and the effectiveness of Pillar 2 Rural Development Programs (Lomba et al., 2014). Though the HNVf is a landscape-level concept, it also includes a criterion that focuses on species whose survival depends on HNV farmlands (Andersen et al., 2003). However, only little is known about how well the HNVf-based indicators fulfil an important criterion of biodiversity indicators: a plausible association with the key underlying biodiversity elements, such as occurrences of declined and rare species (Gregory et al., 2005).

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HNVf refers to areas where agriculture is often the predominant land-use type, and which are characterized by 'a high species and habitat diversity' or 'the presence of species of European conservation concern or both' (Andersen et al., 2003). HNVf needs to fulfil at least one of the following criteria: (i) contain a high proportion of semi-natural vegetation, (ii) comprise a mosaic of extensive and intensive agriculture and structural elements such as field margins and hedgerows, or (iii) host rare species, with bird species as a focal group (Paracchini et al., 2008). Within the CAP, HNVf features are supported only by the agri-environment-climate measure (AECM) under Pillar 2. However, the AECMs have shown mixed outcomes for farmland biodiversity and partial ineffectiveness (Batáry et al., 2015; Kleijn et al., 2011; Tscharntke et al., 2005).

The identification of HNVf at the European level is based on CORINE Land Cover types that are closely-related to the semi-natural agricultural elements, as well as on data on both farming systems and bird species distribution (Andersen et al., 2003; Paracchini et al., 2008). However, there is much geographic variation in the amount, presence and characteristics of HNVf across Europe (Lomba et al., 2014; Schulman et al., 2005). Given this, the EU Member States have been encouraged to develop their own national-level indicators to measure, monitor and report the proportion of HNVf (Benedetti, 2017). The development of such indicators has greatly varied among the EU member states and no common approach currently exists for European-wide assessment (Lomba et al., 2014). To determine the national-level HNVf indicators with maximal potentiality, it is imperative to examine how they correspond to associated farmland biodiversity (see Aue et al., 2014; Benedetti, 2017; Doxa et al., 2010; Janišová et al., 2014; Morelli et al., 2014).

In Finland, the HNVf indicator was developed in 2006 (Heliölä et al., 2009) for the mandatory assessment of the Rural Development Program. It followed the EU guidelines (EC, 2006), emphasizing the need for simple and cost-efficient annual calculation. At the heart of the HNVf indicator in Finland is habitat availability and structural complexity, similarly to elsewhere in the EU. Actual distribution and diversity of farmland species is not considered. The national Finnish HNVf indicator is calculated based on annual field-level information, collected as part of farm-level agricultural reporting. The indicator sums up scores from three so-called strong sub-indicators (areas of semi-natural grasslands, permanent pastures and those under relevant AECM contracts), and three weak sub-indicators (edge density, extensive cultivation and livestock farming). All the sub-indicators reflect the spatial variation in element important to biodiversity in Finland (Heliölä et al., 2009), but the three strong sub-indicators are presumed to be more critical to farmland biodiversity than the three weak ones, and thus they receive higher weights in the HNVf indicator. Originally, only farms that reach the score of 20 for the national indicator were classified as HNVf (Heliölä et al., 2009) and, according to the indicator, the HNVf has declined from 10.2 to 8.7% of agricultural area in 2006–2014 (Biodiversity.fi, 2015). The total indicator score has been confirmed to correlate with local habitat diversity (Heliölä and Herzon, 2012), but it remains unknown how the indicator corresponds to species richness and diversity.

The objective of this study was to use two well-known indicator taxa - farmland birds and diurnal butterflies - the diversity of which reflects biologically valuable agricultural habitats at different spatial scales (Gregory et al., 2005; van Swaay et al., 2015). We investigated whether the amount of HNVf, recalculated to match the resolution of biological data is positively related to the richness and diversity of species, and at which spatial scales strongest relationships emerge. We related the HNVf to two aspects of biodiversity: (i) all farmland species recorded in our study areas, and (ii) a subset group of declining species (butterflies) or red-listed species (birds) (Kuussaari et al., 2007; Mikkola-Roos et al., 2010). Since the Finnish HNVf indicator is based on separate sub-indicators that can relate in different ways to the diversity of birds and butterflies, we also examined whether these HNVf sub-indicators relate to species diversity measures.

2. Methods

2.1. Bird and butterfly diversity data

Species distribution data were collected during research periods 2 and 3 of MYTVAS monitoring program (2000–2006 and 2007–2013) that studied the impacts of agri-environmental payments on biodiversity in Finland (Aakkula and Leppänen, 2014; Kuussaari et al., 2008). A similar assessment was made in a single year of 2010 on the Åland islands (Sandholm et al., 2012; Tiainen et al., 2012).

In this study, Finland was divided into five geographical regions: Karelia, Ostrobothnia, southern Finland, southwestern Finland and the Åland Islands. Firstly, this division was because the Åland islands is an autonomous region of Finland which has an own agricultural policy, including the HNVf assessment and the agri-environmental program. Secondly, the study areas in mainland Finland were, for logistical and resource reasons, situated within 150-km distance from four base sites (cities of Helsinki, Joensuu, Turku and Vaasa), from where the MYTVAS program was managed. However, these four mainland areas differ for their biogeographic, climatic and agricultural features (Rikkinen, 1994). For example, the amount of agricultural area and the size of continuous farmland landscape decrease and the proportion of dairy farming and the fragmentation of farmland landscape increase when moving from southwestern Finland, to southern Finland, Ostrobothnia, and finally to Karelia. The Åland islands is a mixture of all these features because of its location in the Baltic Sea, on one main and several smaller islands.

In total, 68 1-km^2 squares were placed in farmland landscapes in these five regions (for the division of regions and the location of their squares see Fig. 1). On continental Finland, half of them were randomly selected, and each square had a randomly selected couple at a distance of 10–20 km. On the Åland islands all the squares were randomly selected except for that they were requested to be located more than 5 km from each other. Squares had to consist at least 20% of farmland. We used bird territory data gathered in 2005 from the squares situated on mainland Finland (52 squares) and in 2011 from 10 squares located on the Åland Islands. Bird territories were counted in all farmland of the 1-km^2 squares, excluding forest. We used a mapping method in which the squares are surveyed three times during May and the first half of June. The accumulating observations were transferred to species maps on which the territories were interpreted, in the case of abundant species very much based on records of simultaneous observations. Thereafter, a rough mid-point was estimated based on observations in territories interpreted and introduced in a georeferenced database. Only species defined as farmland birds, excluding forest species, were recorded (Tiainen and Pakkala, 2001).

For butterfly censuses, the 1-km^2 squares were divided into four equal squares of 500 m × 500 m (25 ha in size) and two of them were selected to represent the most heterogeneous and most homogeneous landscapes from each 1-km^2 square; the selection was made with the aid of topographic maps and aerial photos, based on the number and size of fields and the amount of verges between them or between them and forest or farmsteads (Ekroos et al., 2010; Kuussaari et al., 2004). A total of ten 50-m line transects were placed within both of these squares, so that transects consisted of one as homogeneous habitat type as possible. They had also to be more than 50 m apart from each other, and mostly they were on different verges (this was not always possible). These line transects were counted for butterflies in 2010 on mainland of Finland (58 squares) and in 2011 on the Åland Islands (10 squares). We summed up the butterflies counted in each 500-m × 500-m square to achieve a standard number of individuals per 1000 m of counted transect in each 1-km^2 square.

We estimated the diversity of birds and butterflies separately. The diversity measures used were species richness (S), and the Shannon-Wiener diversity index (H'), since these depict different aspects of species diversity, species richness weighting each species equally and H'

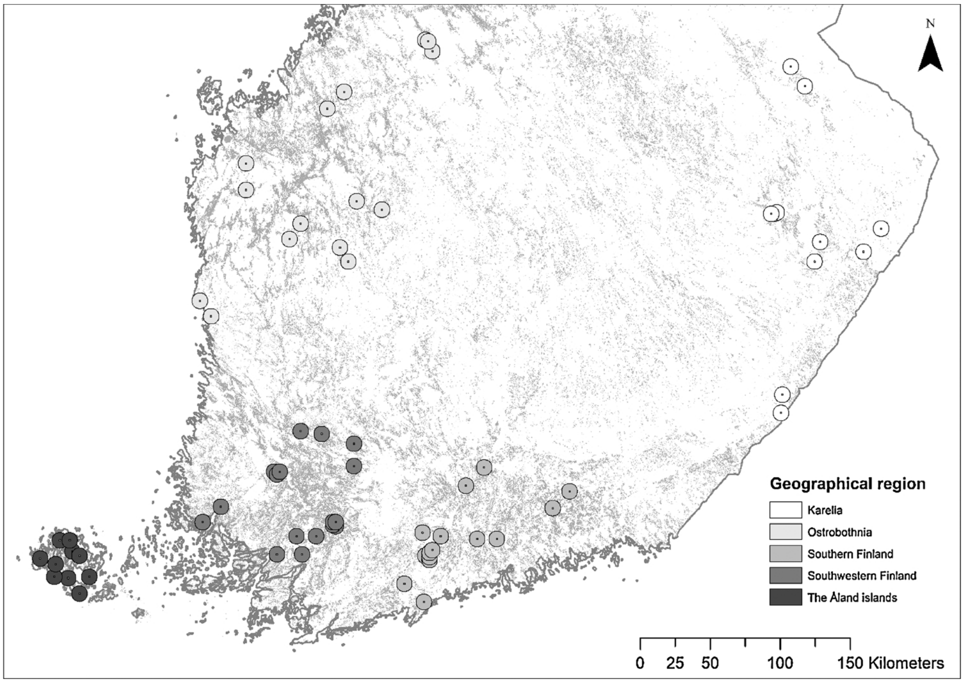

Fig. 1. Map of the location of squares (n = 68) to study the coincidence of High Nature Value farmland with species diversity in southern part of Finland. The 1-km^2 squares are denoted by small black squares and their surrounding landscape with a 5-km radius is denoted by circles. Colours of the circles indicate geographical regions whereas grey shaded areas represent farmland areas in Finland.

giving more weight to abundant species than to rare ones. The same measures were also counted for the subsets of species of conservation concern. These subsets included 10 nationally red-listed bird species that have been on decline nationally according to IUCN criteria (see Mikkola-Roos et al., 2010) and 11 butterfly species inhabiting boreal agricultural landscapes whose national populations have been declining in the recent decades and which thus are useful indicators of valuable farmland biotopes and biodiversity (see Kuussaari et al., 2007; for full lists of all recorded species see Appendix A). Following these species selection procedures, the subsets for birds and butterflies were of the same order of size and were well represented within our data.

2.2. High Nature Value farmland indicator

The Finnish HNVf indicator (HNVfi) was derived from the farm-level data in the registry maintained by the Information Centre of the Ministry of Agriculture and Forestry. The HNVfi is computed by summing the three strong sub-indicators (areas of semi-natural grasslands, permanent pastures and particular AECM contracts), and the three weak sub-indicators (edge density, extensive cultivation and livestock farming) (Heliölä et al., 2009, for the structure of Finnish HNVfi see Table 1). Accordingly, farms with the highest scores are characterized by major proportions of semi-natural grasslands, permanent pastures or areas with biodiversity-relevant AECM contracts or all of them. In addition, farms have fragmented field structure with small parcels, a low proportion of intensive crops such as cereals, and livestock. The regional distribution of these farm-level HNVfi scores is presented in Appendix B. Originally, farms with a threshold score of 20 are regarded as HNVf (see map in Appendix B).

However, the species data for this study have been collected for randomized squares that typically include parts of several individual farms. To circumvent the spatial mismatch in our analysis, we calculated the HNVfi values for each of the squares where species data were sampled following the exactly same procedure for the same data as used for the national HNVfi. We used data where each field parcel of a farm had an attribute of the crops and cultivation type and combined this information with a geospatial vector data of field parcels (Agency for Rural Affairs, 2007; Information Centre of the Ministry of Agriculture and Forestry, 2007). We created raster layers (cell size of 25 m × 25 m) that represented the HNVf sub-indicators (Heliölä et al., 2009) and covered the entire southern part of Finland.

The first three strong sub-indicators have been considered as the main criteria for HNVf and thus the construction of the total HNVfi score is essentially based on them; in the calculation of the HNVfi, this is enabled via the wider potential range of sub-indicator values compared to the values of three weak sub-indicators (Table 1). The strong sub-indicators were quantified as follows: 1) the proportion of semi-natural grasslands of utilized agricultural area (UAA) of the square (value range from 0 to 100), 2) the proportion of permanent pastures within UAA (range 0–100), and 3) the proportion of fields with particular agri-environmental contracts within UAA (range 0–100). Note that these categories may overlap, that is, a semi-natural grassland can be both a permanent pasture, and under the AECM. Thus, a semi-natural grassland that is both a permanent pasture and under AECM is considered three times as valuable as other semi-natural grasslands. In Finland, AECM-based contracts for Management of traditional rural biotopes, Promoting natural biodiversity and landscape development and management, whereas on the autonomous Åland Islands, contracts for Natural pastures and wooded meadows were included (Heliölä et al., 2009).

The sub-indicator 4 describes the fragmentation of fields. Here, all field edges were converted to lines, but no spatial duplicates per square were allowed. The edge density (m/ha) was then calculated by dividing the summed length of all field edges by the combined field area. The values were linearly re-scaled from 0 to 30. The sub-indicator 5 is based on the proportion of UUA under extensive cultivation (for list of farmland types considered as extensive cultivation see Appendix C) simplified to a scale of 0 to 10 points. For the sixth sub-indicator, either 0 or 5 points were appointed, reflecting the absence or presence of livestock farms within the square.

The summed value of the six individual sub-indicators constitutes the total score for HNVfi, with 345 as the maximal potential value. This total score was calculated for each 1-km^2 square and for its surrounding landscape at different spatial scales. The landscape context was accounted for by buffering squares with 0.5, 1, 2, and 5-km radii, creating buffers in relation to centroid of the square by the buffer polygons tool in ArcGIS. While calculating HNVfi values for these buffered areas, the area of the square within each buffer was always excluded (i.e. buffers were rounded square-shaped rings around a square). Landscape classification was conducted by ArcGIS 10.3.1 (Esri, 2015) and the

Table 1
Structure and rationale of the Finnish High Nature Value farmland (HNVf) indicator (after Heliölä et al., 2009).

Sub-indicator	Definition	Rationale	Source	Spatial scale	Unit	Partial score	Total score = HNVfi
Strong							
Semi-natural grasslands	Natural pastures and meadows	Central to HNVf concept	Information Centre of the Ministry of Agriculture and Forestry, 2007	Field parcel	% of UAA	0–100	
Permanent pastures	Field parcels used to cultivate hay and feed plants at least during five preceding years, kept open by grazing or mowing	Grazed and open grasslands are central to farmland biodiversity (Kivinen et al., 2006; Luoto et al., 2004)	Information Centre of the Ministry of Agriculture and Forestry, 2007	Field parcel	% of UAA	0–100	
Agricultural areas with agri-environmental contracts	Areas under AECM contracts: Management of traditional rural biotopes, Promoting natural biodiversity and landscape development and management (mainland Finland) or Natural pastures and wooded meadows (the Åland islands)	Traditional rural biotopes are a national concept for semi-natural grasslands under traditional management (Raatikainen et al., 2017); measure for "Promoting natural biodiversity and landscape development and management" targets landscape elements of relevance for biodiversity	Information Centre of the Ministry of Agriculture and Forestry, 2007	Field parcel	% of UAA	0–100	
Weak							max. 345
Extensive cultivation	Particular crop types that describe extensive (vs. intensive) cultivation (for full list see appendix C)	Extensive land use is central for HNVf concept; in Finland, increasing the proportion of different grasslands, including fallows, was shown to be key for biodiversity (Kuussaari et al., 2008; Toivonen et al., 2015)	Information Centre of the Ministry of Agriculture and Forestry, 2007	Field parcel	(% of UAA) /10	0–10	
Edge density of field parcels	Length of field parcel edges divided by the field area	Reflects the mosaic structure of the farmland (Type 2 HNV); in Finland, fragmentation of the field structure has positive biodiversity effects (Piha et al., 2007; Vepsäläinen, 2007).	Land parcel register; Agency of Rural Affairs, 2007	Field	m^3/ha	0–30	
Livestock farming	Main production sector of a farm is cattle farming, horse management, or sheep or goat farming	Indicates (potentially) pastures; in Finland, also cultivated grasslands increase bird diversity (Ekroos et al., 2018; Vepsäläinen et al., 2010).	Information Centre of the Ministry of Agriculture and Forestry, 2007	Farm level	presence/ absence	5/0	

computation of HNVfi values in R programming environment (R core team, 2016).

2.3. Statistical analyses

We used linear and generalized linear mixed models (LMMs and GLMMs, respectively) where the geographical region was added as a random effect of the intercept. To avoid convergence problems in mixed models, explanatory variables were standardized with a mean of 0 and a standard deviation of 0.5 (Grueber et al., 2011). Firstly, we analyzed which spatial scale of the HNVfi was most strongly related to the species richness by GLMMs with Poisson error structure, where the number of species was the response variable. The relationship of HNVfi at different spatial scales with the Shannon-Wiener diversity index was also analyzed using the same explanatory variables. Here, we employed LMMs and the calculated value of diversity index as the response variable. Secondly, we studied the importance of individual HNVf sub-indicators on the considered diversity measures using GLMMs with Poisson distribution in the models for the number of species and LMMs in the models for the Shannon-Wiener diversity index. In general, our models with Poisson errors were not overdispersed (residual deviance divided by the residual degrees of freedom < 1), except for models for red-listed bird and declining butterfly species richness, which showed slight underdispersion (0.7–0.8). Here, we tested for using negative binomial distribution assumption instead of Poisson error models, but a comparison with derived Akaike's Information Criterion (AIC) values indicated that this change did not improve model fits. Spatial autocorrelation in model residuals was assessed visually by spline correlograms with 95% bootstrap confidence intervals for GLMMs and by variograms for LMMs (Bjørnstad and Falck, 2001). Significant spatial autocorrelation was not observed or alternatively, adding spatial correlation structures did not improve the model fits.

We used multi-model inference and compared competing models within each diversity measure and each species data set based on their AIC values corrected for small sample sizes (AIC_c, Burnham and Anderson, 2002). We checked for the collinearity between explanatory variables in the models using variance inflation factors (VIFs). We aimed to use the same candidate models for each diversity measure and each species data set, and the null model was always included among candidate models. However, it was not possible to construct a global model including all possible variables due to high collinearity between HNVfi values at consecutive spatial scales. Thus, here the set of candidate models comprised of separate models constructed for each spatial scale, in addition to geographical location of the square and null model (for full list of candidate models see Appendix D). To investigate the relationship of the HNVf sub-indicators with diversity, we used aforementioned diversity measures as response variables and log-transformed sub-indicator values as explanatory variables. The first three sub-indicators (semi-natural grasslands, permanent pastures and areas with agri-environmental contracts) were summed up into one value representing a strong indicator of HNVf. The three other variables were field edge density, extensive cultivation and categorical variable for the presence of livestock farming. The derived VIFs were lower than 1.5 suggesting for a devoid of collinearity problems in the data.

In case where there was noticeable model uncertainty and more than one model received strong support, we conducted model-averaging over the best-approximated models within $\Delta AIC_c < 2$ by the full-averaging method (Symonds and Moussalli, 2011) and report the results of 95% confidence intervals with relative variable importances. Relative importance (Σwi) sums up the weights of all models where the variable is present and thus describes the probability that a variable is component of the best model (Symonds and Moussalli, 2011). Lists of best-approximated models are presented as supplementary tables, in appendices. All statistical analyses were run by R [version 3.3.1] with packages lme4 (Bates et al., 2015) for mixed models and MuMIn (Barton, 2014) for model averaging.

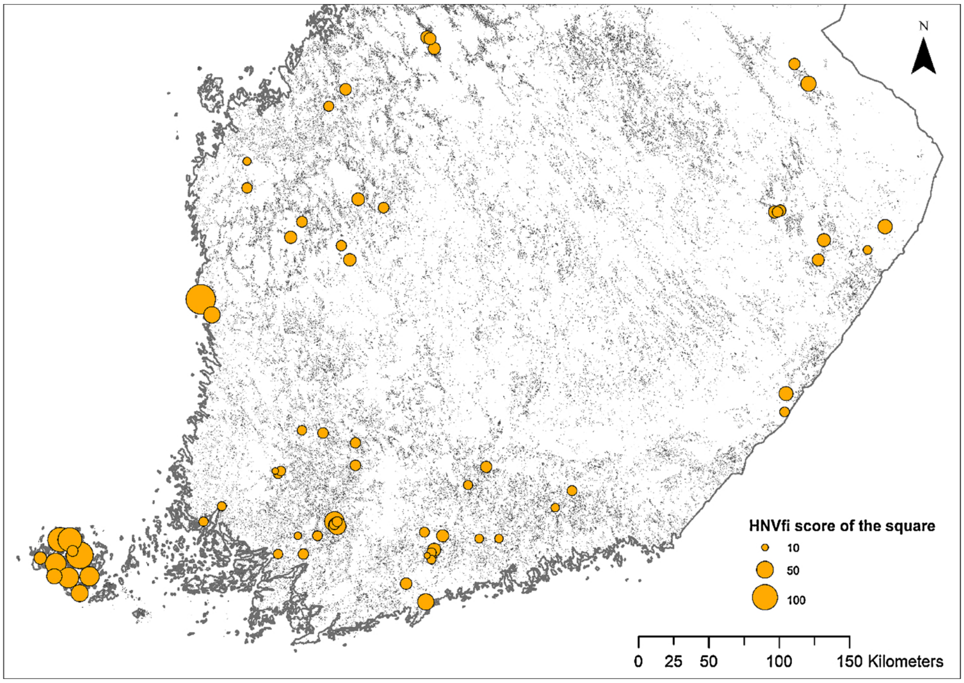

Fig. 2. Spatially-explicit presentation of the distribution and magnitude of the recalculated Finnish High Nature Value farmland indicator (HNVfi) of the 68 1-km^2 squares. Size of the symbol (orange circle) is proportional to total score of the HNVfi. Total score is a sum of the six High Nature Value farmland sub-indicators. For details of calculation see Methods. Grey shaded areas represent the sub-indicators, except the density of field edges.

3. Results

3.1. Variation in the High Nature Value farmland indicator

The total indicator values of HNVfi ranged from 8.8 to 130.6 among the 68 1-km^2 squares, with squares on the Åland Islands receiving the highest values (Fig. 2, Table 2). The HNVfi values at broader landscape scales around the 1-km^2 squares showed similar regional variation and there were only minor differences between the different scales (Table 2). Among the sub-indicators, the strongest regional variation was for the combined score of the three strong HNVf sub-indicators; semi-natural grasslands, permanent pastures and areas with AECM contracts (an average of 38.4 on the Åland Islands and an average of 4.3 on the mainland) (Table 2). For the 1-km landscape data used for bird diversity (surrounding the 62 surveyed 1-km^2 squares) both the combination of strong HNVf sub-indicators and weaker sub-indicators showed similar variation (Table 2).

3.2. High Nature Value farmland indicator and bird diversity

Species richness of all farmland birds varied between 11 and 31 (mean 19 ± SD 4.5) and that of red-listed birds between 0 and 5 (mean 2.3 ± SD 1.3), and the diversity index for all birds between 1.7 and 3.1 (mean 2.5 ± SD 0.3) and that of red-listed birds between 0 and 1.5 (mean 0.6 ± SD 0.5), respectively. Models with landscape-scale HNVfi values (0.5–5 km) performed better than models with 1-km^2 square-scale indicator values in explaining the diversity of all birds (see Appendix F.1). HNVfi of 1-km^2 square was the only scale that received any variable importance with diversity of red-listed birds (Table 3). For the diversity of red-listed birds, models with longitudinal location of the square showed a better performance than those with HNVfi variables. Longitude showed a clear negative relationship with the species richness and diversity index of red-listed birds, denoting that communities of species of conservation concern are more diverse and their abundances more evenly distributed in local communities occurring in south-westernmost Finland. No clear relationship of any of the spatial

Table 2
Mean (± SD) for the total High Nature Value farmland indicator (HNVfi) scores at different scales (squares, 0.5, 1, 2 and 5 km) and for the separate sub-indicators of the squares and 1-km landscapes (n = 68) for each of the five geographic regions (number of squares per region is shown in parentheses). The combined value for the strong HNVfi values included sub-indicators of the semi-natural grasslands, permanent pastures and areas with AECM contracts (see Methods for details).

Scale of HNVfi	Geographic region Karelia (n = 11)	Ostrobothnia (n = 15)	Southern (n = 15)	Southwestern (n = 17)	Åland (n = 10)
Square	29.3 ± 8.5	33.1 ± 28.4	22.9 ± 14.1	21.4 ± 9.2	62.9 ± 28.7
0.5 km	29.9 ± 6.6	32.4 ± 23.3	28.3 ± 19.9	21.2 ± 8.5	73.4 ± 25.2
1 km	32.0 ± 6.3	31.9 ± 19.1	29.8 ± 18.8	23.9 ± 15.1	68.1 ± 19.2
2 km	32.9 ± 4.9	33.3 ± 13.2	31.2 ± 13.0	27.1 ± 14.0	68.3 ± 18.0
5 km	34.1 ± 4.0	32.5 ± 8.9	28.0 ± 4.8	25.8 ± 6.4	70.5 ± 18.1
Sub-indicators					
Strong HNVfi	1.5 ± 3.6	7.3 ± 22.8	4.2 ± 12.2	3.2 ± 7.7	36.2 ± 27.7
1 km	3.1 ± 3.9	0.9 ± 1.8	8.5 ± 19.1	4.2 ± 14.8	38.4 ± 19.3
Edge density	18.0 ± 5.3	16.5 ± 4.6	12.3 ± 3.0	12.2 ± 2.7	16.3 ± 4.8
1 km	18.6 ± 5.4	15.7 ± 3.1	13.6 ± 2.2	11.5 ± 1.2	19.6 ± 3.9
Extensive cultivation	5.3 ± 2.6	5.0 ± 2.8	2.9 ± 2.3	2.9 ± 2.2	5.9 ± 2.9
1 km	5.9 ± 1.5	5.2 ± 1.4	3.1 ± 1.0	3.6 ± 1.8	5.2 ± 1.6
Livestock farming	4.5 ± 1.5	4.3 ± 1.8	3.5 ± 2.3	3.0 ± 2.5	4.5 ± 1.6
1 km	5.0 ± 0	4.2 ± 1.9	4.7 ± 1.3	4.3 ± 1.8	5.0 ± 0

Table 3
The 95% confidence intervals for model-averaged parameter estimates and relative variable importance values (Σw_i) of High Nature Value farmland indicator (HNVfi) values at different scales (HNV500 for 0.5 km, HNV1 for 1 km, HNV2 for 2 km and HNV5 for 5 km) and geographical location explaining the species richness (S) and diversity (H') in farmland birds and butterflies. Confidence intervals that do not include zero are bolded. Model-averaging for each diversity measure was conducted on best-approximated model sets (see Tables 1 and 2 in Appendix F) by the full-averaging method (Symonds and Moussalli, 2011).

Group	Diversity	HNV	HNV500	HNV1	HNV2	HNV5	Longitude	Latitude
Birds								
All	S		−0.109, 0.182	−0.116, 0.233	−0.109, 0.180	−0.109, 0.182	−0.164, 0.086	
Σw_i			0.22	0.34	0.22	0.22	0.44	
Red-listed	S	−0.290, 0.196					**−0.840, −0.069**	
Σw_i		0.31					1.00	
All	H'		−0.076, 0.106	−0.093, 0.155	−0.064, 0.084	−0.125, 0.273	−0.132, 0.093	−0.066, 0.099
Σw_i			0.11	0.25	0.08	0.38	0.17	0.18
Red-listed	H'	−0.173, 0.127					**−0.650, −0.176**	
Σw_i		0.28					1.00	
Butterflies								
All	S	−0.059, 0.084					−0.145, 0.099	−0.247, 0.113
Σw_i		0.24					0.26	0.50
Declining	S				−0.220, 0.172	−0.210, 0.166	−0.233, 0.296	**−2.215, −0.854**
Σw_i					0.18	0.18	0.18	1.00
All	H'[a]	**0.332, 1.058**					**0.121, 0.699**	**−0.640, −0.169**
Σw_i		1.00					1.00	1.00
Declining	H'	−0.071, 0.093	−0.080, 0.114					**−0.478, −0.172**
Σw_i		0.21	0.25					1.00

[a] Only one model was included within $\Delta AIC_c < 2$, thus no model-averaging was conducted for these variables.

scales of the HNVfi with the bird diversity measures was found (Table 3) and the explanatory power of variables was in general low (Fig. 3a, b).

3.3. High Nature Value farmland indicator, location and butterfly diversity

Numbers of all recorded butterfly species ranged from 11 to 33 (mean 22.7 ± SD 4.6) and the number of the declining butterflies from 0 to 5 (mean 1.3 ± SD 1.1). The diversity index averaged at 2.1 (± SD 0.3) among all species and 0.3 (± SD 0.4) among the declining species. Models with geographical location only performed better than models with HNVfi values for all diversity measures, except for the diversity index of all butterflies (see Appendix F.2). The HNVfi of square and that of the 0.5-km scale were important to butterfly diversity measures, except for the species richness of declining butterflies where the HNVfi values for greater landscape scales (2 to 5 km) received variable importance (Fig. 3a, b). The butterfly diversity index showed a positive relationship with the HNVfi at 1-km^2 square scale (Fig. 4a, Table 3) and with longitude but a negative with latitude. Also, the species richness and community diversity of declining butterflies were higher in southern than in northern squares.

3.4. High Nature Value farmland sub-indicators and species diversity

We conducted the analysis at 1-km landscape scale for all birds, and at the scale of square for red-listed birds and all butterfly diversity measures since these scales showed most importance by the multi-model inference (Appendix F.3). Since greater landscape scales of HNVfi (0.5, 2 and 5 km) showed some importance to diversity measures (S and H' for declining butterflies and H' of birds), the associations with sub-indicators were explored separately (see supporting information, Appendices F.4–F.5).

There was considerable uncertainty within models for the bird diversity measures, since models with the lowest AIC_c showed relatively low probabilities of being best models (Akaike weight for the highest approximated models varied from 0.22 to 0.66, see Appendix F.3). However, all the sub-indicators were represented among models that showed most support. For the bird diversity index, extensive cultivation (sub-indicator 5) had high variable importance (Fig. 3d) and the confidence intervals of model-averaged estimate indicated a positive relationship with diversity index of all birds (Fig. 4b, Table 4). Livestock farming (sub-indicator 6) had a substantial variable importance (0.66) for the diversity index of all birds (Fig. 3d). The combined index of the three strong sub-indicators was also shown to have importance on bird species richness (Fig. 3c). Longitude was negatively related to red-listed bird richness and diversity index.

Overall, all sub-indicators except livestock farming related with the butterfly diversity (Fig. 3c, d, Table 4). Models with the location variables showed highest performance for all other butterfly diversity aspects except for the diversity index of all farmland species (Appendix F.3), for which the edge density of all field parcels (sub-indicator 4) with the latitude was the best-approximated model with the highest weight. The edge density had a high relative importance and a clear positive relationship with butterfly diversity index (Fig. 3d, 4c, Table 4).

4. Discussion

We found that derived values for the HNVfi in Finland varied clearly between the geographical areas, the Åland Islands receiving the highest scores. Moreover, there were notable differences in how strongly the bird and butterfly patterns were related to the HNVfi measured at the different spatial scales. Importantly, even though different spatial HNVfi scales had different importance on bird and butterfly diversity measures, only butterfly diversity index had a clear positive relationship with the total HNVfi at the smallest studied scale, which is closest to the farm scale where the index is currently being used. Among the HNVf sub-indicators, the field edge density appeared as the most

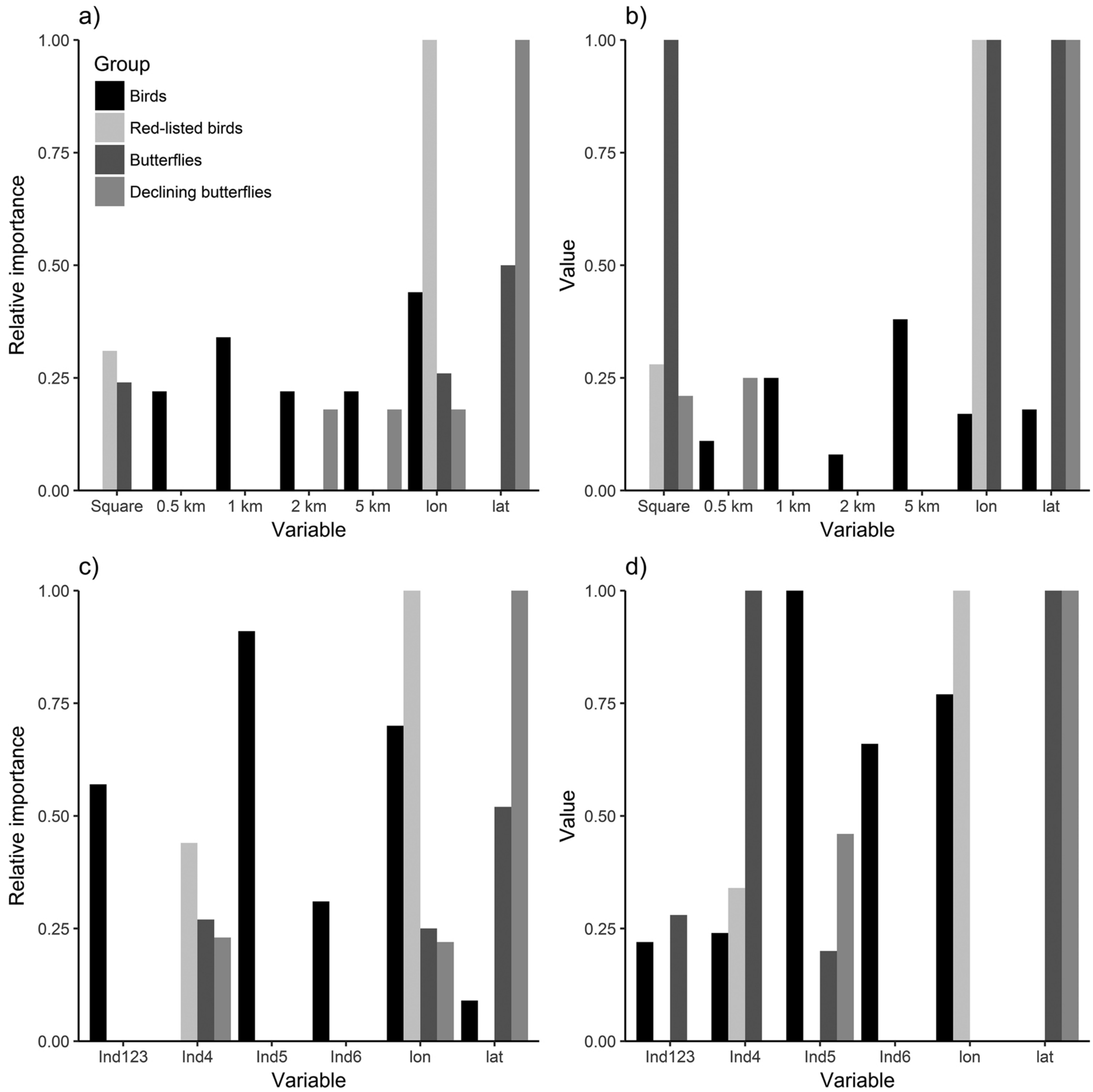

Fig. 3. Relative importance of variables explaining the relation between bird and butterfly species richness (**a**, **c**) and diversity index (**b**, **d**) with High Nature Value farmland (HNVf) indicator at different scales (upper panels), HNVf sub-indicators (lower panels) and location. Importance of different variables is shown separately for groups comprising of all birds and butterflies, and the sub-groups of red-listed birds and declining butterflies. Relative importance is calculated by summing the weights of models where a variable is present and thus describes the probability that a variable is included in the best-approximated models. If only one model is in the best-approximated set, variable importance is fixed to 1. Ind = code to the six sub-indicator groups.

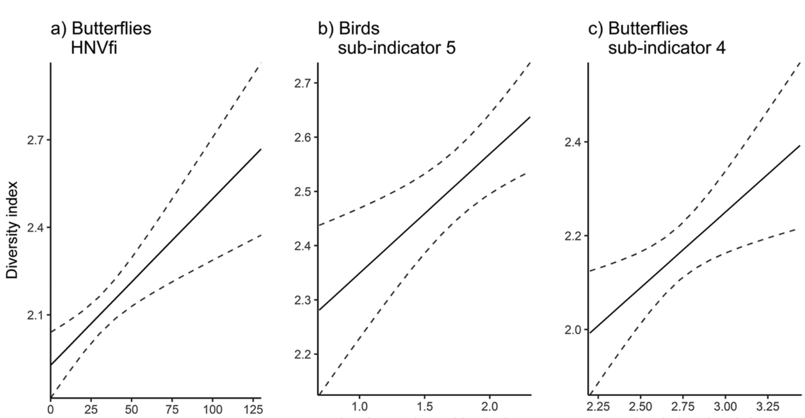

Fig. 4. Model predictions (black lines) and 95% confidence intervals (dashed dark grey lines) for butterfly diversity index with increasing High Nature Value farmland indicator (HNVfi) at square scale (**a**), bird diversity index with log-transformed extensive cultivation (**b**), and butterfly diversity index with log-transformed edge density (**c**). Predicted values were calculated either using the single best-approximated model (for a) or by model-averaged parameter estimates (for b and c). Variables not shown in predictions were set to their mean standardized values.

important explanatory variable for the diversity of butterflies and extensive cultivation to that of birds.

Our results confirmed that the Åland Islands stand apart from mainland Finland in the amount of HNVf as demonstrated by three main HNVf sub-indicators. This is in line with the observations that meadow-like habitats that have decreased strongly on mainland

Table 4
Relationships of the High Nature Value farmland (HNVf) sub-indicators with bird and butterfly diversity (S for species richness and H' for diversity index) in Finland as shown by the 95% confidence intervals of model-averaged parameter estimates and a relative variable importance (Σw_i). Confidence intervals not including zero are bolded. Used scales were the 1-km landscape scale for birds and the square scale for red-listed birds and for butterflies. Ind123 refers to the combined score of the strong HNVf sub-indicators, Ind4 is for edge density, Ind5 for extensive cultivation and Ind6 for the presence of livestock farming.

Group	Diversity	Ind123	Ind4	Ind5	Ind6	Longitude	Latitude
Birds							
All	S	−0.101, 0.269		−0.020, 0.312	−0.041, 0.026	−0.301, 0.076	−0.051, 0.043
Σw_i		0.57		0.91	0.31	0.70	0.09
Red-listed	S		−0.436, 0.225			**−0.798, −0.060**	
Σw_i			0.44			1.00	
All	H'	−0.084, 0.129	−0.064, 0.099	**0.074, 0.322**	−0.069, 0.023	−0.266, 0.055	
Σw_i		0.22	0.24	1.00	0.66	0.77	
Red-listed	H'		−0.217, 0.134			**−0.629, −0.166**	
Σw_i			0.34			1.00	
Butterflies							
All	S		−0.063, 0.095			−0.143, 0.098	−0.255, 0.113
Σw_i			0.27			0.25	0.52
Declining	S		−0.299, 0.221			−0.251, 0.327	**−2.188, −0.823**
Σw_i			0.23			0.22	1.00
All	H'	−0.073, 0.113	**0.048, 0.305**	−0.057, 0.074			**−0.401, −0.141**
Σw_i		0.28	1.00	0.20			1.00
Declining	H'			−0.099, 0.200			**−0.496, −0.186**
Σw_i				0.46			1.00

Finland still constitute a notable part of agricultural land use on the Åland Islands and have also habitat quality similar to that of traditional land use (Schulman et al., 2005). It is noteworthy that the agri-environmental program of the Åland Islands greatly differed from the Finnish system in 2000–2006, with a greater emphasis on nature values (Schulman et al., 2005), and this has potentially had effects on the landscape-level habitat diversity as well.

Bird communities show somewhat different, but still positive associations with HNVf in other European countries (Aue et al., 2014; Doxa et al., 2010; Morelli et al., 2014). Our results indicated that at least the overall number of species does not increase with rising amount in HNVf in Finland. However, while HNVfi did not show any clear association with bird diversity index after model-averaged parameters, in the single models especially at 1-km and 5-km landscape scales the HNVfi had a positive association. At these scales, thus, the bird diversity may benefit of landscape-level habitat heterogeneity (Benton et al., 2003), when semi-natural and other uncultivated patches are embedded into an agricultural landscape. In contrast, no relationship between the recalculated HNVfi and red-listed birds was found, most likely caused by the low representation of these species within our study squares and the low-representation of farmland species in the Finnish red list. But above all, our different result for birds originates due to, firstly, generally small sizes and amount of semi-natural areas and permanent pastures or both in Finland in comparison with countries of earlier studies (Aue et al., 2014; Doxa et al., 2010; Morelli et al., 2014). Secondly, the Finnish HNVf concept appears to take insufficiently into account some relevant agricultural elements for birds, for example, the realized grazing pressure or fertilization (Doxa et al., 2010; Tiainen and Seimola, 2014).

The positive relationship of butterfly diversity especially with the occurrence of grasslands (e.g. Dover et al., 2011) and its negative relationship with agricultural intensification have been confirmed earlier (Ekroos et al., 2010). Corresponding with those studies, our result suggests that HNVf is a good indicator for the spatial variation in grassland butterfly diversity. Furthermore, Pöyry et al. (2004) have shown that diversity and evenness of butterfly communities in southwest Finland is greater on semi-natural meadows under long-term continuous grazing than on unmanaged or restored meadows. Our results corroborate this since HNVf areas with the highest scores include management contracts for semi-natural meadows. However, the species richness and community diversity of declining butterfly species were more strongly related to latitude than to the distribution of valuable HNVf, which is consistent with endangered plants and butterflies being more abundant in southwestern Finland (Heliölä et al., 2009). However, it should be acknowledged that the spatial diversity patterns of different taxa do not necessarily correlate with each other (Jonason et al., 2017), and HNVfi may fail on some taxa for this reason.

Our results highlighted the importance of extensive cultivation, one of the HNVf sub-indicators, on the diversity index of all recorded farmland bird species. Individual HNVf elements had also positive relationship with specialist birds in Germany (Aue et al., 2014). These findings are supported by other Finnish studies where low-intensity agriculture had a positive relationship with bird diversity, species richness and abundance (Piha et al., 2007), non-cultivated areas in open farmland in southern Finland had higher bird densities than cultivated areas (Tiainen and Seimola, 2014) and set-aside fields doubled numbers of bird individuals and had 25 to 40% more species (Herzon et al., 2011). Extensive cultivation here is defined as all field types covered by grass, including intensively managed grasslands such as silage and rotational pastures (Heliölä et al., 2009, Appendix B). Such areas can have a positive effect on farmland biodiversity since they can provide profitable foraging and breeding grounds for birds (Vepsäläinen et al., 2010).

The density of field parcels' edges is a measure of landscape configuration, agricultural landscapes with high edge density values being fine-scale mosaics of habitat patches (Duelli, 1997; Hietala-Koivu et al., 2004). Our finding that field edge density is important to butterfly diversity index fully supports the idea that biodiversity can be promoted by leaving greater areas outside intensive cultivation (Batáry et al., 2015). Although field edges have different plant species composition than semi-natural grasslands (Toivonen et al., 2013), they provide important foraging habitat and dispersal corridors (Delattre et al., 2010; Marshall and Moonen, 2002), especially if situated in a landscape with high forest cover (Toivonen et al., 2017). In France, linear elements were observed to promote butterfly diversity more than grasslands (Ouin and Burel, 2002), and in Canada, butterfly species richness was higher in landscapes with smaller fields and patches than in landscapes with simpler configuration (Flick et al., 2012).

In our data, only the weak HNVf sub-indicators (such as extensive cultivation and edge density) considerably varied between geographical areas and squares. In contrast, the combined score for the three strong sub-indicators (semi-natural grasslands, permanent pastures and areas with AECM contracts) showed sporadically high values, but still for most of the areas the values were very small. This spatial imbalance between the strong sub-indicators and the weak sub-indicators is very likely reflected to the observed diversity patterns. On one hand, the amount of most valuable HNVf features is too small to contribute significantly to the diversity of all taxa studied here. On the other hand, the weak HNVf features are undervalued; attention to their preservation and development should be greater.

Unfortunately, there are no biodiversity data on the scale of the official Finnish HNVfi that is a farm's scale. Therefore, we had to recalculate the indicator for the landscape scale to match it with our biological data. However, since we used exactly the same data and procedure that is the basis for the HNVfi nationally, the indicative relationships between the indicator and the taxa established here is likely to be highly consistent. Moreover, in Finland, it would be beneficial to link the spatially more extensive and long-term datasets of farmland bird and butterfly monitoring to HNV farming to better identify indicator species for HNVf. We propose that also the facilitation of red-listed or specialist species by HNV farming should be examined closer with larger and more long-term data sets. Since the smallest spatial scales of HNVf did not show association with bird diversity, the connectivity of HNV farmlands in relation to species diversity should be followed. Furthermore, our results suggest that some features included into weak HNVf sub-indicators can promote biodiversity. Management and retention of such features is not as costly as managing areas corresponding to the strong HNVf indicators. This approach was reflected in the new political tool of Ecological Focus Areas in the current CAP (EU, 2013). Also, the inclusion of 'weak' sub-indicator types (including conventional production grasslands) into the Finnish HNVfi could be criticized due to its relatively minor relation to the traditional species-rich farmland. In the end, the concept of HNVf strives to grasp farmland of top importance for biodiversity in Europe, which is "characterized by long-established, low-intensity and often complex farming systems" (Keenleyside et al., 2014) that mostly ceased to exist in the modern landscape of Finland, except parts of the Åland Islands.

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Declarations of interest

None.

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Appendices A–F. Supplementary data

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References

Aakkula, J., Leppänen, J. (Eds.), 2014. Follow-up study on the impacts of agri-environment measures (MYTVAS 3). Final report.

Agengy for Rural Affairs Finland, 2007. Land parcel register. http://www.mavi.fi/en/about-the-agency/Pages/information-services.aspx (accessed 28 September 2018).

Andersen, E., Baldock, D., Bennett, H., Beaufoy, G., Bignal, E., Brouwer, F., Elbersen, B., Eiden, G., Godeschalk, F., Jones, G., McCracken, D., Nieuwenhuizen, W., van Eupen, M., Hennekens, S., Zervas, G., 2003. Developing a High Nature Value Farming Area Indicator. Internal Report for the European Environment Agency. IEEP.

Aue, B., Diekoetter, T., Gottschalk, T.K., Wolters, V., Hotes, S., 2014. How High Nature Value (HNV) farmland is related to bird diversity in agro-ecosystems – towards a versatile tool for biodiversity monitoring and conservation planning. Agric. Ecosyst. Environ. 194, 58–64.

Barton, K., 2014. MuMIn: Multi-Model Inference. R Package Version 1.10.5. http://CRAN.R-project.org/package=MuMIn.

Batáry, P., Dicks, L.V., Kleijn, D., Sutherland, W.J., 2015. The role of agri-environment schemes in conservation and environmental management. Conserv. Biol. 29, 1006–1016.

Bates, D., Maechler, M., Bolker, B., Walker, S., 2015. Fitting linear mixed-effects models using lme4. J. Stat. Softw. 67, 1–48.

Benedetti, J., 2017. Trends in High Nature Value farmland studies: a systematic review. Eur. J. Ecol. 3, 19–32. https://doi.org/10.1515/eje-2017-0012.

Benton, T., Vickery, J., Wilson, J., 2003. Farmland biodiversity: is habitat heterogeneity the key? Trends Ecol. Evol. 18, 182–188.

Biodiversity.fi, 2015, FA8 High Nature Value farmland. https://www.biodiversity.fi/en/habitats/farmlands/fa8-high-nature-value-hnv-farmland (accessed 1 December 2016).

Bjørnstad, O., Falck, W., 2001. Nonparametric spatial covariance functions: estimation and testing. Environ. Ecol. Stat. 8, 53–70.

Burnham, K.P., Anderson, D.R., 2002. Model Selection and Multimodel Inference. A Practical Information–Theoretic Approach, second ed. Springer, New York.

Butchart, S.H., Walpole, M., Collen, B., van Strien, A., Scharlemann, J.P., Almond, R.E., Baillie, J.E., Bomhard, B., Brown, C., Bruno, J., Carpenter, K.E., Carr, G.M., Chanson, J., Chenery, A.M., Csirke, J., Davidson, N.C., Dentener, F., Foster, M., Galli, A., Galloway, J.N., Genovesi, P., Gregory, R.D., Hockings, M., Kapos, V., Lamarque, J.F., Leverington, F., Loh, J., McGeoch, M.A., McRae, L., Minasyan, A., Hernández Morcillo, M., Oldfield, T.E., Pauly, D., Quader, S., Revenga, C., Sauer, J.R., Skolnik, B., Spear, D., Stanwell-Smith, D., Stuart, S.N., Symes, A., Tierney, M., Tyrrell, T.D., Vié, J.C., Watson, R., 2010. Global biodiversity: indicators of recent declines. Science 328, 1164–1168.

Butler, S.J., Boccaccio, L., Gregory, R.D., Voříšek, P., Norris, K., 2010. Quantifying the impact of land-use change to European farmland bird populations. Agric. Ecosyst. Environ. 137, 348–357.

Delattre, T., Pichancourt, J., Burel, F., Kindlmann, P., 2010. Grassy field margins as potential corridors for butterflies in agricultural landscapes: a simulation study. Ecol. Model. 221, 370–377.

Donald, P.F., Green, R.E., Heath, M.F., 2001. Agricultural intensification and the collapse of Europe's farmland bird populations. Proc. R. Soc. Lond. B 268, 25–29. https://doi.org/10.1098/rspb.2000.1325.

Dover, J.W., Spencer, S., Collins, S., Hadjigeorgiou, I., Rescia, A., 2011. Grassland butterflies and low intensity farming in Europe. J. Insect Conserv. 15, 129–137.

Doxa, A., Bas, Y., Paracchini, M.L., Pointereau, P., Terres, J., Jiguet, F., 2010. Low-intensity agriculture increases farmland bird abundances in France. J. Appl. Ecol. 47, 1348–1356.

Duelli, P., 1997. Biodiversity evaluation in agricultural landscapes, an approach at two different scales. Agric. Ecosyst. Environ. 62, 81–91.

EC, 2006. Council decision of 20 February 2006 on Community Strategic Guidelines for Rural Development (programming Period 2007 to 2013) (2006/144/ EC).

Ekroos, J., Heliölä, J., Kuussaari, M., 2010. Homogenization of lepidopteran communities in intensively cultivated agricultural landscapes. J. Appl. Ecol. 47, 459–467.

Ekroos, J., Tiainen, J., Seimola, T., Herzon, I., 2018. Weak effects of farming practices corresponding to CAP greening measures on farmland bird diversity in boreal agricultural landscapes. Submitted. Unpublished results. .

Esri, 2015. ArcGIS 10.3.1. for Desktop. Environmental Systems Research Institute, Redlands, California, USA.

EU, 2013. Regulation (EU) No 1307/2013 of the European Parliament and of the Council of 17 December 2013 establishing rules for direct payments to farmers under support schemes within the framework of the common agricultural policy and repealing Council Regulation (EC) No 637/2008 and Council Regulation (EC) No 73/2009.

Flick, T., Feagan, S., Fahrig, L., 2012. Effects of landscape structure on butterfly species richness and abundance in agricultural landscapes in eastern Ontario, Canada. Agric. Ecosyst. Environ. 156, 123–133.

Foley, J.A., Ramankutty, N., Brauman, K.A., Cassidy, E.S., Gerber, J.S., Johnston, M., Mueller, N.D., O'Connell, C., Ray, D.K., West, P.C., Balzer, C., Bennett, E.M., Carpenter, S.R., Hill, J., Monfreda, C., Polasky, S., Rockström, J., Sheehan, J., Siebert, S., Tilman, D., Zaks, D.P.M., 2011. Solutions for a cultivated planet. Nature 478, 337–342.
Gregory, R., van Strien, A., Voříšek, P., Meyling, A.W.G., Noble, D.G., Foppen, R.P.B., Gibbons, D.W., 2005. Developing indicators for European birds. Philos. Trans. Biol. Sci. 360, 269–288.
Grueber, C.E., Nakagawa, S., Laws, R.J., Jamieson, I.G., 2011. Multimodel inference in ecology and evolution: challenges and solutions. J. Evol. Biol. 24, 699–711.
Heliölä, J., Herzon, I., (Eds.), 2012. Measuring biodiversity in agricultural areas – environmental fallows, traditional biotopes and farm-level estimates, The Finnish Environment 26/2012, Finnish Environment Institute (SYKE), Helsinki.
Heliölä, J., Lehtomäki, J., Kuussaari, M., Tiainen, J., Piha, M., Schulman, A., Lehtonen, H., Miettinen, A., Koikkalainen, K., 2009. High Nature Value farmland in Finland – identification, monitoring and economic conditions for maintenance. Publications of the Ministry of Agriculture and Forestry 1/2009. Vammalan Kirjapaino Oy, Sastamala (in Finnish with English summary).
Herzon, I., Ekroos, J., Rintala, J., Tiainen, T., Seimola, T., Vepsäläinen, V., 2011. Importance of set-aside for breeding birds of open farmland in Finland. Agric. Ecosyst. Environ. 143, 3–7.
Hietala-Koivu, R., Järvenpää, T., Helenius, J., 2004. Value of semi-natural areas as biodiversity indicators in agricultural landscapes. Agric. Ecosyst. Environ. 101, 9–19.
Information Centre of the Ministry of Agriculture and Forestry, 2007. Statistics on the number of livestock, use of crops and utilized agricultural area. Current producer http://stat.luke.fi/en/maatalous (accessed in 28 September 2018).
Janišová, M., Michalcová, D., Bacaro, G., Ghisla, A., 2014. Landscape effects on diversity of semi-natural grasslands. Agric. Ecosyst. Environ. 182, 47–58.
Jonason, D., Ekroos, J., Öckinger, E., Helenius, J., Kuussaari, M., Tiainen, J., Smith, H.G., Lindborg, R., 2017. Weak functional response to agricultural landscape homogenization among plants, butterflies and birds. Ecography 40, 1221–1230.
Keenleyside, C., Beaufoy, G., Tucker, G., Jones, G., 2014. High Nature Value farming throughout EU-27 and its financial support under the CAP. Report Prepared for DG Environment, Contract No ENV B.1/ETU/2012/0035. IEEP, London.
Kivinen, S., Luoto, M., Kuussaari, M., Helenius, J., 2006. Multispecies richness of boreal agricultural landscapes: effects of climate, biotope, soil and geographical location. J. Biogeogr. 33, 862–875.
Kleijn, D., Rundlöf, M., Scheper, J., Smith, H.G., Tscharntke, T., 2011. Does conservation on farmland contribute to halting the biodiversity decline? Trends Ecol. Evol. 26, 474–481.
Kuussaari, M., Tiainen, J., Helenius, J., Hietala-Koivu, R., Heliölä, J., (Eds.), 2004. Significance of Finnish agri-environmental scheme for biodiversity and landscape: results of the MYTVAS project 2000–2003. The Finnish Environment 709/2004, Finnish Environment Institute (SYKE), Helsinki (in Finnish).
Kuussaari, M., Heliölä, J., Pöyry, J., Saarinen, K., 2007. Contrasting trends of butterfly species preferring semi-natural grasslands, field margins and forest edges in northern Europe. J. Insect Conserv. 11, 351–366.
Kuussaari, M., Heliölä, J., Tiainen, J., Helenius, J., (Eds.), 2008. Significance of Finnish agri-environmental support scheme for biodiversity and landscape: final report 2000–2006, The Finnish Environment 4/2008, Finnish Environment Institute (SYKE), Helsinki (in Finnish).
Lomba, A., Guerra, C., Alonso, J., Honrado, J.P., Jongman, R., McCracken, D., 2014. Mapping and monitoring High Nature Value farmlands: Challenges in European landscapes. J. Environ. Manag. 143, 140–150.
Luoto, M., Virkkala, R., Heikkinen, R.K., Rainio, K., 2004. Predicting bird species richness using remote sensing in boreal agriculture-forest mosaic. Ecol. Appl. 14, 1946–1962.
Marshall, E.J.P., Moonen, A.C., 2002. Field margins in northern Europe: their functions and interactions with agriculture. Agric. Ecosyst. Environ. 89, 5–21.
Mikkola-Roos, M., Tiainen, J., Below, A., Hario, M., Lehikoinen, A., Lehikoinen, E., Lehtiniemi, T., Rajasärkkä, A., Valkama, J., Väisänen, R.A., 2010. Birds aves. In: Rassi, P., Hyvärinen, E., Juslén, A., Mannerkoski, I. (Eds.), The 2010 Red List of Finnish Species. Ministry of Environment & Finnish Environment Institute, Helsinki, pp. 123–134.
Morelli, F., Jerzak, L., Tryjanowski, P., 2014. Birds as useful indicators of high nature value (HNV) farmland in Central Italy. Ecol. Indic. 38, 236–242.
Ouin, A., Burel, F., 2002. Influence of herbaceous elements on butterfly diversity in hedgerow agricultural landscapes. Agric. Ecosyst. Environ. 93, 45–53.
Paracchini, M.L., Petersen, J., Hoogeveen, Y., Bamps, C., Burfield, I., van Swaay, C., 2008. High Nature Value Farmland in Europe. An estimate of the distribution patterns on the basis of land cover and biodiversity data. European Commission, Joint Research Centre, Institute for Environment and Sustainability.
Piha, M., Tiainen, J., Seimola, T., Vepsäläinen, V., 2007. Modelling diversity and abundance of Finnish farmland birds – landscape characteristics define diversity and conservation hotspots. In: Piha, M., Spatial and temporal determinants of Finnish farmland bird populations. Doctoral dissertation. University of Helsinki.
Pöyry, J., Lindgren, S., Salminen, J., Kuussaari, M., 2004. Restoration of butterfly and moth communities in semi-natural grasslands by cattle grazing. Ecol. Appl. 14, 1656–1670.
R Core Team, 2016. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. URL https://www.R-project.org/.
Raatikainen, K., Mussaari, M., Raatikainen, K.M., Halme, P., 2017. Systematic targeting of management actions as a tool to enhance conservation of traditional rural biotopes. Biol. Conserv. 207, 90–99.
Rikkinen, K., 1994. Suomen aluemaantiede. Lahden tutkimus- ja koulutuskeskus. Oppimateriaaleja 29. University of Helsinki (in Finnish).
Sandholm, L., Heliölä, J., Tiainen, J., Seimola, T., Rintala, J., Holmström, H., 2012. Utvecklingen av naturens mångfald i jordbruksmiljön på Åland 2002–2011, Åländsk Utredningsserie 1/2012 (in Swedish). .
Schulman, A., Heliölä, J., Kuussaari, M., 2005. Farmland biodiversity on the Åland islands and assessment of the effects of the agri-environmental support scheme. The Finnish Environment 734, 1–210.
Stoate, C., Boatman, N.D., Borralho, R.J., Carvalho, C.R., de Snoo, G.R., Eden, P., 2001. Ecological impacts of arable intensification in Europe. J. Environ. Manag. 63, 337–365.
Symonds, M.R.E., Moussalli, A., 2011. A brief guide to model selection, multimodel inference and model averaging in behavioural ecology using Akaike's information criterion. Behav. Ecol. Sociobiol. 65, 13–21.
Tiainen, J., Pakkala, T., 2001. Birds. In: In: Pitkänen, M., Tiainen, J. (Eds.), Biodiversity inAgricultural Landscapes in Finland. BirdLife Finland Conservation Series 3. Helsinki University Press, Helsinki, pp. 33–50.
Tiainen, J., Seimola, T., 2014. Density variation among habitats of south Finnish farmland. Linnut-vuosikirja 2013, 72–79 (in Finnish with English summary).
Tiainen, J., Seimola, T., Holmström, H., Rintala, J., 2012. Farmland bird populations in Åland in 2011 with a comparison to 2001 and continental Finland. Linnut-vuosikirja 2011, 48–57 (in Finnish with English summary).
Toivonen, M., Herzon, I., Helenius, J., 2013. Environmental fallows as a new policy tool to safeguard farmland biodiversity in Finland. Biol. Conserv. 159, 355–366.
Toivonen, M., Herzon, I., Kuussaari, M., 2015. Differing effects of fallow type and landscape structure on the occurrence of plants, pollinators and birds on environmental fallows in Finland. Biol. Conserv. 181, 36–43.
Toivonen, M., Peltonen, A., Herzon, I., Heliölä, J., Leikola, N., Kuussaari, M., 2017. High cover of forest increases the abundance of most grassland butterflies in boreal farmland. Insect Conserv. Divers. 10, 321–330.
Tscharntke, T., Klein, A., Kruess, A., Steffan-Dewenter, I., Thies, C., 2005. Landscape perspectives on agricultural intensification and biodiversity – ecosystem service management. Ecol. Lett. 8, 857–874.
Van Swaay, C., Cuttelod, A., Collins, S., Maes, D., López Munguira, M., Šašić, M., Settele, J., Verovnik, R., Verstrael, T., Warren, M., Wiemers, M., Wynhof, I., 2010. European Red List of Butterfies. Publications Office of the European Union, Luxembourg.
Van Swaay, C., van Strien, A., Aghababyan, K., Åström, S., Botham, M., Brereton, T., Chambers, P., Collins, S., Domènech Ferrés, M., Escobés, R., Feldmann, R., Fernández-García, J.M., Fontaine, B., Goloshchapova, S., Gracianteparaluceta, A., Harpke, A., Heliölä, J., Khanamirian, G., Julliard, R., Kühn, E., Lang, A., Leopold, P., Loos, J., Maes, D., Mestdagh, X., Monasterio, Y., Munguira, M.L., Murray, T., Musche, M., Õunap, E., Pettersson, L.B., Popoff, S., Prokofev, I., Roth, T., Roy, D., Settele, J., Stefanescu, C., Švitra, G., Teixeira, S.M., Tiitsaar, A., Verovnik, R., Warren, M.S., 2015. The European Butterfly Indicator for Grassland Species 1990–2013. Report VS2015.009. De Vlinderstichting, Wageningen.
Vepsäläinen, V., 2007. Farmland Birds and Habitat Heterogeneity in Intensively Cultivated Boreal Agricultural Landscapes. Doctoral Dissertation. University of Helsinki.
Vepsäläinen, V., Tiainen, J., Holopainen, J., Piha, M., Seimola, T., 2010. Improvements in the Finnish agri-environment scheme are needed in order to support rich farmland avifauna. Ann. Zool. Fenn. 47, 287–305.