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Coincidence of High Nature Value farmlands with bird and butterfly diversity

Sanna Mäkeläinen\textsuperscript{a,*}, Annika Harlio\textsuperscript{b}, Risto K Heikkinen\textsuperscript{b}, Irina Herzon\textsuperscript{c,f}, Mikko Kuussaari\textsuperscript{b}, Katri Lepikkö\textsuperscript{a}, Andrea Maiera\textsuperscript{a}, Tuomas Seimolad\textsuperscript{d}, Juha Tiainen\textsuperscript{d}, Anni Arponen\textsuperscript{e,f}

\textsuperscript{a} Faculty of Biological and Environmental Sciences, P. O. Box 65, FI-00014, University of Helsinki, Finland
\textsuperscript{b} Finnish Environment Institute (SYKE), P. O. Box 140, FI-00251, Helsinki, Finland
\textsuperscript{c} Department of Agricultural Sciences, P. O. Box 27, FI-00014, University of Helsinki, Finland
\textsuperscript{d} Natural Resources Institute Finland (Luke), P. O. Box 2, FI-00791, Helsinki, Finland
\textsuperscript{e} Ecosystems and Environment Research Programme, Faculty of Biological and Environmental Sciences, P. O. Box 65, FI-00014, University of Helsinki, Finland
\textsuperscript{f} Helsinki Institute of Sustainability Science, HELSUS, P. O. Box 65, FI-00014, University of Helsinki, Finland

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\textbf{ABSTRACT}

The amount of High Nature Value farmland (HNVI) 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. HNVI 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 HNVI should correctly reflect the variation in biodiversity values between different agricultural landscapes. We examined how well the Finnish HNVI 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 HNVI indicator at the finest scale of 0.5 km × 0.5 km squares. Among the HNVI 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 HNVI 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 HNVI has restricted application to farmland birds of this boreal country and the national HNVI 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 HNVI) 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 HNVI is a landscape-level concept, it also includes a criterion that focuses on species whose survival depends on HNVI farmlands (Andersen et al., 2003). However, only little is known about how well the HNVI-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).
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). HN VF needs to fulfill 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 hedges, or (iii) host rare species, with bird species as a focal group (Paracchini et al., 2008). Within the CAP, HN VF 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; Tscharkne et al., 2005).

The identification of HN VF 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 HN VF 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 HN VF (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 HN VF 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 HN VF 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 HN VF 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 HN VF 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 HN VF indicator. Originally, only farms that reach the score of 20 for the national indicator were classified as HN VF (Heliölä et al., 2009) and, according to the indicator, the HN VF 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 HN VF, 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 HN VF 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 HN VF 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 HN VF 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 MYSVAS 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 HN VF 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, Joesuu, Turku and Vaasa), from where the MYSVAS program was managed. However, three 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-km² 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-km² 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-km² 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-km² 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-km² 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' weighting equally the abundance of each species.
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 HNV (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 HNVfi 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-km² 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).

<table>
<thead>
<tr>
<th>Sub-indicator</th>
<th>Definition</th>
<th>Rationale</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-natural grasslands</td>
<td>Natural pastures and meadows</td>
<td>Central to HNVf concept</td>
<td>Information Centre of the Ministry of Agriculture and Forestry, 2007</td>
</tr>
<tr>
<td>Permanent pastures</td>
<td>Used to cultivate hay and feed plants at least during five preceding years, kept open by grazing or mowing</td>
<td>Extensive 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., 2014); promotes natural biodiversity effects (Piha et al., 2007; Vepsäläinen et al., 2010).</td>
<td>Information Centre of the Ministry of Agriculture and Forestry, 2007</td>
</tr>
<tr>
<td>Traditional rural biotopes</td>
<td>A national concept for semi-natural grasslands under traditional management during five preceding years</td>
<td>Extensive land use is central for HNVf concept; in Finland, the proportion of different grasslands, including fallows, was shown to be key for biodiversity (Kuussaari et al., 2014); promotes natural biodiversity effects (Piha et al., 2007; Vepsäläinen et al., 2010).</td>
<td>Information Centre of the Ministry of Agriculture and Forestry, 2007</td>
</tr>
<tr>
<td>Natural pastures and wooded meadows (the Åland islands)</td>
<td></td>
<td></td>
<td>Information Centre of the Ministry of Agriculture and Forestry, 2007</td>
</tr>
<tr>
<td>Exposed field parcels</td>
<td>Field parcels used to cultivate hay and feed plants at least during five preceding years, kept open by grazing or mowing</td>
<td>Extensive 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., 2014); promotes natural biodiversity effects (Piha et al., 2007; Vepsäläinen et al., 2010).</td>
<td>Information Centre of the Ministry of Agriculture and Forestry, 2007</td>
</tr>
<tr>
<td>Edge density of field parcels</td>
<td>Length of field parcel edges divided by the field area</td>
<td>Extensive land use is central for HNVf concept; in Finland, the proportion of different grasslands, including fallows, was shown to be key for biodiversity (Kuussaari et al., 2014); promotes natural biodiversity effects (Piha et al., 2007; Vepsäläinen et al., 2010).</td>
<td>Information Centre of the Ministry of Agriculture and Forestry, 2007</td>
</tr>
<tr>
<td>Extensive cultivation</td>
<td>Particular crop types that describe extensive (vs. intensive) cultivation</td>
<td>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., 2014); promotes natural biodiversity effects (Piha et al., 2007; Vepsäläinen et al., 2010).</td>
<td>Information Centre of the Ministry of Agriculture and Forestry, 2007</td>
</tr>
<tr>
<td>Main productive sector of farm in earth farming, hectar management, agri-environmental contracts</td>
<td></td>
<td></td>
<td>Information Centre of the Ministry of Agriculture and Forestry, 2007</td>
</tr>
</tbody>
</table>

**Partial scale**

- **Spatial scale**: Field parcel
- **Unit**: % of UAA
- **Scale**: 0–100
- **Total score**: HNVf

**Rationale**

- Central to HNVf concept
- Extensive 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., 2014); promotes natural biodiversity effects (Piha et al., 2007; Vepsäläinen et al., 2010).
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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 HNVf 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 HNVf 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 (AICc, 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 HNVf 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 ΔAICc < 2 by the full-averaging method (Symonds and Moussalli, 2011) and report the results of 95% confidence intervals with relative variable importances. Relative importance (Swi) 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.
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-km² 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-km² 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-km² squares) both the combination of strong HNVfi 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-km² square-scale indicator values in explaining the diversity of all birds (see Appendix F.1). HNVfi of 1-km² 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).

<table>
<thead>
<tr>
<th>Scale of HNVfi</th>
<th>Geographic region</th>
<th>Karelia (n = 11)</th>
<th>Ostrobothnia (n = 15)</th>
<th>Southern (n = 15)</th>
<th>Southwestern (n = 17)</th>
<th>Åland (n = 10)</th>
</tr>
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<tbody>
<tr>
<td>Square</td>
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<td>0.5 km</td>
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<td>1 km</td>
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<td>2 km</td>
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<td>5 km</td>
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<tr>
<td>Sub-indicators</td>
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<td>Strong HNVfi</td>
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<td>1 km</td>
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<td>Edge density</td>
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<td>1 km</td>
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<td>Extensive cultivation</td>
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<td>1 km</td>
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<tr>
<td>Livestock farming</td>
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</table>

Fig. 2. Spatially-explicit presentation of the distribution and magnitude of the recalculated Finnish High Nature Value farmland indicator (HNVfi) of the 68 1-km² 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.
3.3. 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 HNVf values for all diversity measures, except for the diversity index of all butterflies (see Appendix F.2). The HNVf of square and that of the 0.5-km scale were important to butterfly diversity measures, since models with the lowest AIC showed highest performance for all other butterfly diversity as-

All S −0.059, 0.084
H' 0.24

Declining S −0.220, 0.172
H' 0.11

All H' 0.332, 1.058

Declining H' −0.071, 0.093
H' 0.25

All S −0.109, 0.182
H' 0.22

Red-listed S −0.290, 0.196
H' 0.31

All H' −0.076, 0.106

Declining H' −0.173, 0.127

The 95% confidence intervals for model-averaged parameter estimates and relative variable importance values (Σwi) of High Nature Value farmland indicator (HNVf) 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).

We found that derived values for the HNVf 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 HNVf measured at the different spatial scales. Importantly, even though different spatial HNVf scales had different importance on bird and butterfly diversity measures, only butterfly diversity index had a clear positive relationship with the total HNVf 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 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).
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...
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 HNVf 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 HNVf 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 re-calculated HNVf 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 these species within 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).

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 (Σwi). 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.

<table>
<thead>
<tr>
<th>Group</th>
<th>Diversity</th>
<th>Ind123</th>
<th>Ind4</th>
<th>Ind5</th>
<th>Ind6</th>
<th>Longitude</th>
<th>Latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birds</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>All S</td>
<td>−0.101, 0.269</td>
<td>0.57</td>
<td>−0.020, 0.312</td>
<td>0.91</td>
<td>−0.041, 0.026</td>
<td>0.31</td>
<td>−0.301, 0.076</td>
</tr>
<tr>
<td>Red-listed</td>
<td>S</td>
<td>−0.436, 0.225</td>
<td>0.44</td>
<td></td>
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</tr>
<tr>
<td>All H'</td>
<td>−0.084, 0.129</td>
<td>0.22</td>
<td>−0.064, 0.099</td>
<td>0.44</td>
<td>0.074, 0.322</td>
<td>1.00</td>
<td>−0.069, 0.023</td>
</tr>
<tr>
<td>Red-listed</td>
<td>H'</td>
<td>−0.217, 0.134</td>
<td>0.34</td>
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<tr>
<td>Butterflies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All S</td>
<td>−0.063, 0.095</td>
<td>0.27</td>
<td>−0.143, 0.098</td>
<td>0.27</td>
<td>−0.255, 0.113</td>
<td>0.25</td>
<td>−0.215, 0.327</td>
</tr>
<tr>
<td>Declining S</td>
<td>−0.299, 0.221</td>
<td>0.23</td>
<td>−0.251, 0.327</td>
<td>0.23</td>
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<td></td>
</tr>
<tr>
<td>All H'</td>
<td>−0.073, 0.113</td>
<td>0.28</td>
<td>−0.057, 0.074</td>
<td>0.28</td>
<td>0.048, 0.305</td>
<td>1.00</td>
<td>−0.020, 0.020</td>
</tr>
<tr>
<td>Declining H'</td>
<td>−0.099, 0.200</td>
<td>0.46</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

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 HNVf 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 (Pihl 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., 2007). 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
Declarations of interest

None.

Acknowledgements

We want to thank all people who took part in field work in counting butterflies and farmland birds. Information Centre of the Ministry of Agriculture and Forestry is acknowledged for giving the field parcel and cultivation data.

Appendices A-F. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.agee.2018.09.030.

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