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New high nature value map of Estonian agricultural land: Application of an expert system to integrate biodiversity, landscape and land use management indicators

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ABSTRACT

This paper describes the national databases and methods that have been used to construct a new expert system-based tool to map High Nature Value (HNV) agricultural land in Estonia. Twenty appropriate indicators from four thematic groups, i.e., land use management, nature conservation, landscape diversity and inherent natural quality, were selected on the basis of use in the literature, the requirement of consistent national datasets and statistical analysis. Each variable was divided into four appropriate classes to produce indicator values according to expert judgement. These classes were added together for each 1 km square to provide a single score to develop an expert system to define HNV. A statistical analysis showed there are few moderate correlations between the individual indicators, suggesting that their selection was sound. The HNV scores for all 1 km squares with agricultural land in Estonia exhibit a normal distribution. The top and bottom 10% of the 1 km squares (3707 and 3501 squares, respectively) were identified in order to investigate the structure of the data further. The former is termed Exceptionally High HNV (EHNV) and the latter Relatively Low HNV (RLNV), while the intermediate class is termed Median HNV (MHNV). The distribution of these groups in Estonia shows readily identifiable patterns linked to known biodiversity "hot spots". A cluster analysis within the EHNV squares produced three classes whose distribution and composition are described to demonstrate the detailed character of Estonian agricultural land with high biodiversity. The methodology is adaptable to other countries that have extensive relevant data bases. The map will be valuable for agricultural policy makers to identify zones with high biodiversity where agri-environment schemes can be targeted. Other stakeholders could also direct development away from EHNV 1 km squares.

1. Introduction

The concept of High Nature Value (HNV) is the identification of areas of agricultural land that contain high biodiversity in order to provide a basis for policy development. In this paper, the term agricultural land is used rather than agricultural landscape because the latter can contain forests and wetlands, which in Estonia at present are not used by farmers nor used to calculate farm subsidies, unless there are less than 50 trees per hectare (e.g., wooded meadows).

Over the last several decades, the concept of High Nature Farmland (HNV) has been developed progressively, following the original descriptions by Baldock et al. (1993) and Beaufoy et al. (1994). The cornerstones of HNV, as described in Oppermann et al. (2012), are seminatural pastures, meadows and orchards, including peripheral features on farmland, such as hedges and small patches of trees, but excluding forests used for wood production. Farms with a low intensity of management are often associated with high biodiversity (Bignal, 1996; Bignal and McCracken, 2000; Egan and Mortensen, 2012) and are widely in decline throughout Europe (Ąndersen, 2003; Baldock et al., 1993; Beaufoy, 2008; Hoogeveen et al., 2004; Oppermann et al., 2012; Ribeiro et al., 2014).

EU common methodological guidelines broadly rely on land cover, farming systems and species data to identify the extent, condition, and dynamics of HNV farmlands (Ąndersen, 2003; Lomba et al., 2015; Paracchini et al., 2008). At the same time, the diversity of rural landscapes across the EU, the lack of suitable datasets on essential indicators, and especially the absence of a common methodology for mapping currently constrain the oper-

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ationalization of the HNV concept as a policy instrument across Europe (Lomba et al., 2015; Oppermann et al., 2012; Pedroli et al., 2007). Several authors have emphasized that in order to maintain low-intensity farming systems, the identification, classification and mapping of HNV farmland becomes an overriding concern (Lazzerini et al., 2015; Lomba et al., 2014; Wascher et al., 2010).

Whilst only guidelines have been suggested to identify and monitor HNV farmland areas, EU member states are addressing the development of national HNV farmland indicators in different ways (Lomba et al., 2014, 2015; van Doorn and Elbersen, 2012). Recently, therefore, several countries have developed sets of indicators for HNV farmland (Brunbjerg et al., 2016; Klimek et al., 2014; Lazzerini et al., 2015; Lomba et al., 2015).

The first map of HNV farmland for Estonia was developed in 2004–2008 by Paracchini et al. (2008) in cooperation with the Estonian Environment Information Centre. The map was based on a combination of selected CLC classes and some information on biodiversity, but Kikas et al. (2015) showed that it had serious limitations in Estonia because the databases used were not sufficiently detailed. The two major problems identified were the labelling of raised bogs as being in agricultural use and in the inadequate detail of the Corine Land Cover map (Bossard et al., 2000). It was therefore concluded that more detailed Estonian national databases should be identified and then used to produce a more accurate map of HNV for the country.

The present paper describes the composition of the indicators and the reasons for adding an additional five parameters to those identified by the expert group. The explanation for the adoption of an expert system approach is also described, as well as how it was used to convert the indicator parameters into values to act as indicators of HNV. The main part of the paper then describes the analysis of these data in order to explain their roles in the definition of HNV and how they were then used to finalize the groups for mapping. Thus, the final stage is the presentation of the new HNV map of Estonia and the interpretation of the distribution patterns.

2. Material and methods

2.1. Developing an expert system for designating the HNV farming area

The expert system for designating HNV farming land has been developed in order to help the Ministry of Rural Affairs identify important areas of biodiversity for conservation measures. To start refining the distribution of HNV farmland in Estonia, the Agricultural Research Centre (ARC) created an HNV working group in 2009, which reviewed the study by the Joint Research Centre (JRC) of the European Commission on HNV farmland in Europe. A working group of 20 experts was formed, and for specific topics, additional researchers were invited. Researchers, especially those who have experience in environmental monitoring and management, in the fields of agricultural management, plant protection, nature conservation, biodiversity and landscapes and representatives from agricultural and environmental institutions (Ministry pf Environment, Ministry of Rural Affairs, Environmental Board, Environmental Agency, Estonian Agricultural Registers, Ornithological Society), were involved. The group identified 60 suitable indicator parameters that also had consistent national cover. This list was reduced to 15 following the rejection of some parameters because of duplication and others that were spatially or temporally not consistently recorded. Five of these measures concern low-intensity management, five parameters relate to nature conservation value and five reflect landscape diversity. A further group of five indicator parameters were added later to help add information on the inherent landscape structure. Lomba et al. (2014) lists the indicators that have been used previously and these have all been included, except those such as crop diversity, which are not relevant to the Baltic region because only short rotation crops are present and orchards are rare.

Evaluating the landscape diversity or calculating indices only for farmland areas is not technically feasible. The HNV working group therefore chose to introduce a nationwide grid approach, using a 1×1 km grid compatible with the standard grid of the European Environmental Agency, as the basis for calculating HNV indicators. The aim of the grid was to enable the working group to demarcate HNV agricultural land throughout Estonia and to determine its value in terms of the indicators. To achieve this aim, the data for each cell were given qualitative values (e.g., landscape diversity) and quantitative values (e.g., the number of animals in dairy herds). Division of the indicator parameters into even classes is not correct because, in some cases, high values may indicate low biodiversity, e.g., large numbers of livestock units per hectare of Utilizable Agricultural Land (UAA) in 1 km squares. In contrast, in the case of other parameters, the opposite applies, e.g., a high percentage of semi-natural habitats in 1 km squares indicate high biodiversity. Different ranges are therefore required for each variable to produce indicator values that can be combined into a single score to identify HNV land. The ranges for each parameter need to be determined by expert judgement to ensure that the divisions are reliable indicators of biodiversity and are given the following values – 0 for no value and 5 for the highest value within each parameter. These values are then added together to obtain a single value for each 1 km square. Since there are four indicator sets, each with five parameters, as shown in Table 1 below, then the total potential score is 4×5 x 5, i.e., 100 points. The method is therefore an expert system, using the technical definition of this term, because the individual indicator values are combined to obtain a single score to reflect the potential biodiversity. This procedure therefore avoids the criticism that values on different scales cannot be validly added together. The divisions are based on the judgement of the authors and an expert group to provide indicator values of the strength of the link of the individual parameters to biodiversity. The values of the cells can subsequently be used to assess the HNV of every field.

The list of the four groups of indicator parameters is given in Table 1, which also summarizes their derivation from different databases. Each group has five parameters divided according to expert judgement into indicator values, with the ranges used as shown in Table 1. Expert judgement in determining indicator values is based on statistical evidence with the objective of maintaining the mosaic features of agricultural land with regard to high biodiversity and landscape diversity. In the case of each indicator based on previous studies, literature reviews or EU policy documents, the optimal interval for maintaining high diversity was determined, and this interval was assigned the highest score. A value of 0 is assigned for missing values (e.g., no permanent grasslands existing in a particular 1 km square for indicator $G_1$1) or completely undesirable status (e.g., density of livestock units by species per hectare of utilizable agricultural area >1.5). Intermediate values (1 and 3) were assigned to intervals contributing below or above average to the desired diversity level. In the case of a lack statistical evidence or non-linear character of the relationship between the indicator and diversity, only a single intermittent value (1 or 3, e.g., indicators $G_1$1, $G_1$2, $G_1$3) was assigned. A value of 1 was assigned if the effect of the suboptimal interval was considered by expert group to be rather unfavourable (e.g., for $G_1$1 and $G_1$2, the share of permanent or short term grassland, respectively, is $>0 \leq 20\%$ or >40%) and a value of 3 was assigned when the suboptimal interval was considered to contribute towards higher diversity (e.g., $G_1$3, density of livestock units by species per hectare >0.8–1.5). However, in both cases, after obtaining addition statistical evidence, the intermedi-