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# Identification of high nature value grassland with remote sensing and minimal field data

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ABSTRACT

In the last 50 years intensification of agricultural land use systems drastically reduced extensively used grassland areas. These areas are of high ecological value due to high species richness and occurring rare species. Therefore, recent European Union (EU) laws stipulate the conservation and monitoring of this farmland, also called "high nature value" (HNV) farmland. As a consequence of these new laws, a so called HNV indicator system was implemented that requires all EU member states to establish a nationwide monitoring system for HNV areas. These monitoring systems are challenged among other by the difficult differentiation between grassland types which today at fine scale is only possible with time and cost intensive field work. Due to this high work-load and financial limitations, nationwide field campaigns have to be sample-based and hence will not deliver a spatially consistent result.

In this study, we examine whether low and high nature value grasslands can be differentiated with remotely-sensed reflectance data, which could support existing field survey-based monitoring approaches. We used multi-seasonal, multispectral remote sensing data (RapidEye) in combination with sparse field data (collected in southern Germany) and three one-class classifiers to classify A) HNV grassland against other areas and to differentiate between B) three quality classes of HNV grassland according to the current German HNV monitoring approach.

The results for A) indicated high performances of the tested approaches to identify HNV grassland areas. Biased support vector machine delivered best overall results (high detection rate and low false positive rates). However, the results also showed a consistent underestimation of HNV grasslands. Results for B) showed that a separation into several HNV quality classes is not possible with any of the tested approaches.

We conclude that with the presented approach HNV grasslands can be identified from the landscape matrix based on its spectral signal. Combining the presented approach with an object oriented classifier or with land registry data could further improve the results.



## 1. Introduction

Due to their high species richness and as habitats of numerous endangered species, non-intensively used grassland regions are primary targets of nature conservation in Europe (Dierschke and Peppler-Lisbach, 2009; Rennwald, 2000). In the European Common Agricultural Policy (CAP) (Council regulation (EC) 1974/2006) these kinds of grasslands are considered as an important part of high nature value (HNV) farmland. The concept of HNV farming was developed in the 1990s from a growing understanding that the conservation of biodiversity in Europe is linked to the persistence of low-intensity farming systems (Baldock et al., 1993). The HNV farmland definition differentiates three HNV types: i) farmland with a high proportion of semi natural features, ii) dominated by low intensity farming or a mosaic of semi-natural and cultivated land and large-scale features, and iii) as farmland supporting rare species or a high proportion of European or world populations of species (Andersen et al., 2003).

HNV grasslands are often leftovers from traditional land use and are hence found at low nutrient sites featuring habitats for specialist species (plants and animals) with narrow niches (Henle et al., 2008; Sukopp et al., 2006). HNV grasslands have therefore been assigned with a high conservation value (Critchley et al., 2003; Sullivan et al., 2010). Since the 1970s, due to the intensification of agricultural land use systems, the area of grasslands in general and of species rich HNV grasslands in particular is decreasing dra-

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matically (Haber, 2014; Korneck, et al., 1998; Meisel, 1983; Veen et al., 2009). Currently, permanent grassland covers 15% of the European Union (EU) and 34% of the European agricultural area (European Union, 2010; Eurostat, 2015). According to the European environmental agency (EEA, 2010), today only one quarter of these grasslands can still be considered as non-intensive, meaning that most areas are already depleted of species. Since grasslands contribute an essential part of species richness (Veen et al., 2009) such a decrease is a major threat to the conservation of biodiversity (Stoate et al., 2009).

To limit further losses of semi-natural or extensive grasslands, several conservation programs were established. The aim of these programs is to ensure that high species richness will coexist alongside productive agricultural areas (Armsworth et al., 2012; Scherr and McNeely, 2008). For an evaluation of the applied measures, some indicators have been proposed and put forward (CEC, 2001) by the EU Rural Development policy framework (Benzler, 2009, 2012). This also includes the HNV farmland indicator which aims on quantifying the proportion of ecological valuable farmland in Europe.

Since every EU state independently decides about the way to derive the HNV farmland indicator, a variety of differing approaches exists (Oppermann et al., 2012). In many cases available land use-, land cover-, remote sensing- or species-data have been used, while in some other cases specific field surveys have been conducted (Evaluation Expert Network, 2009). However, no European wide standardized framework exists and some of the conducted approaches have either been highly work-intensive of were lacking accuracy. For example, the German Federal Agency for Nature Conservation found CORINE data as well as evaluations on farm-level too coarse for monitoring HNV farmland areas, since they often appear as small patches in a matrix of intensively managed areas (Begemann et al., 2007). Integration of the HNV farmland monitoring into other national programs was not achievable because of misfits in spatial resolution, temporal resolution or thematic content.

The current monitoring method in Germany for identifying HNV grassland areas uses a list of HNV character species for the identification of HNV grasslands (Benzler et al., 2015) (in this study, the focus lays on grassland areas, hence we refrain from presenting the additionally existing approaches to identify HNV crop fields or HNV agricultural landscape elements). Every four years, a number of fixed 1 $km^2$ sample areas are checked for the appearance of HNV character species to evaluate a trend in changes of grassland. In a hierarchic approach, every seemingly species-rich and homogeneous area is examined for character species by using transects. According to the number of character species the plot is assigned to one of three HNV quality classes (not to be confused with the three HNV types of Andersen et al. (2003) described above). The results of this sample based approach are then extrapolated at the national scale. Although this approach is already highly optimized in terms of workload, the regular monitoring is labour-intensive due to the relatively large amount of monitoring sites, which have to adequately represent approximately 5 million hectare of grasslands in Germany.

In this context, the application of (high temporal and spatial) resolution remote sensing data have been discussed in the scientific literature as an efficient supplement to field-based monitoring systems that are used to identify and monitor natural vegetation areas (e.g. Feilhauer et al., 2014; Förster et al., 2008; Rocchini et al., 2012; Schmidtlein and Sassin, 2004; Schuster et al., 2015; Stenzel et al., 2014 and many more). Several more studies had a specific focus on HNV areas but mainly used comparably coarse remote sensing and other spatial data to identify areas of HNV farmland on broad scales (e.g., Weissteiner et al., 2011; Belenyesi et al., 2008; Pointereau et al., 2007; Samoy et al., 2007; Parr et al., 2006; Jackson et al., 2009; Lang and Langank, 2005). On the other hand, the number of studies on finer scales is very sparse. One exception is the study of Hazeu et al. (2014) who used fraction of vegetation cover and land cover/use data products derived from multi-seasonal SPOT4/5 and Rapid Eye data to map HNV farmland types. Additionally, multi-seasonal remote sensing data was used in a step-wise classification approach based on object-based image analyses to highlight changes in the HNV farmland landscape. Another relevant study stems from Sullivan et al. (2011) who studied the possibilities of using fine-scale spatial data to map semi-natural habitat cover on farms for the identification of HNV farmland in Ireland. Although not directly pointing on remote sensing data, the authors clearly state that the more commonly used broad scale mapping methods for HNV farmland have a high risk of overseeing farmland biodiversity on the individual farm level.

In our study, we addressed this knowledge gap by attempting to match the current German practice for surveying HNV areas in the field with remote sensing data. The current HNV grassland mapping procedure in Germany consists of (1) an identification of the HNV grasslands themselves and (2) a differentiation between three HNV quality classes. A differentiation of other (intensively used) agricultural areas is not relevant. With typical supervised classification methods in remote sensing, all classes need to be covered by the training data to ensure classification success. However, collecting sufficient and accurate training data (especially in non-relevant patches) is connected to financial challenges. This raises the question, whether alternative methods exist to differentiate HNV grassland from other grassland with remote sensing data. Potential approaches include the integration of a mask that can be used to exclude all areas which do not belong to the classes of interest, but this requires a priori information or a pre-classification of the area which again requires reliable reference information. Suitable methodological alternatives to conventional multi-class supervised classifiers include classification with reject option (Dubuisson and Masson, 1993), partially supervised classification (Mantero et al., 2005) or one-class classifiers (Mack, 2015; Minter, 1975; Phillips et al., 2004). These methods have in common that they focus on few or only one target class and thereby minimize the required reference information.

Here, we combine a small sample of ground reference data from relevant grassland classes with multi-seasonal, multispectral RapidEye data and recent one-class classifiers (OCC) from the field of machine learning. The big advantage of using an OCC is that it can deal with presence only data, so no sampling in non-relevant areas is needed. This can increase the efficiency of large scale mapping and monitoring as needed for HNV farmland monitoring. The proposed approach can only work (1) if the HNV grassland areas are spectrally separable from all intensively used grasslands (including various intensity levels and species compositions) and (2) if the three defined HNV quality classes differ in their spectral properties.

Based on earlier research, we hypothesize that a spectral separation of intensively and non-intensively used grassland might be possible due to differing functional traits of the two grassland types affecting the spectral properties of the plants. While in highly intensive grassland areas, plants are typically not facing shortage of environmental factors such as nutrient or water supply, non-intensively used grasslands can often be found to be short on at least one of these factors. In non-limited environments, competitive species featuring for example tall-growing, productive grasses, or herbs with large leaves both with high chlorophyll content typically prevail, while in limited environments, other species featuring properties adapted to survive under non-optimal conditions (e.g., smaller or shorter leaves, thicker wax layers, etc.) occur (Cingolani et al., 2005; Pierce et al., 2013). In addition the effect of intensive or extensive mowing or grazing has a huge impact on occurring plant functional traits. Such differences in traits were found to influence the spectral properties of plants and hence support their differ-