Remote sensing imagery for mapping and monitoring High Nature Value Farmland area (HNVF)

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Abstract. The definition of High Nature Value Farmland Area (HNVF) was provided by Andersen in 2003: "HNVF comprises those areas in Europe where agriculture is the major (usually the dominant) land use and where that agriculture supports or is associated with either a high species and habitats diversity, or the presence of species of European conservation concern or both". The study area was located in the Basilicata region, in southern Italy. The map of HNVF area was elaborated at municipal level (spatial resolution) in 2012. The objective is to develop a GIS prototype service for the identification and characterization of HNVF adaptable to different scales (local, regional, national). The proposed methodology is based on the statistical and farm systems approach. The developed procedure uses MODIS satellite images to improve the number and the accuracy of the land cover classes of the Corine Land Cover map and to calculate indicators aimed at monitoring soil and vegetation properties. A good agreement was found between our HNVF map and the results of literature works, although the analysis approaches were different. The developed algorithm provides the possibility to vary the spatial resolution of the HNVF map from the national to farm level. The main advantage of the proposed methodology is that the inputs are free data, accessible from the public authority data-base.

Keywords: biodiversity conservation, natural value, MODIS, GIS, bioeconomic, Big-Data.

1 INTRODUCTION

In agriculture, generally, a higher level of biodiversity is found in those areas where agricultural production systems make use of fewer inputs of fertilizers, pesticides and machinery, or in semi-natural areas with extensive agriculture or, again, in agricultural areas which have preserved particular structural elements such as hedges, grassy strips, rows of trees, patches of spontaneous vegetation (Morelli et al., 2014, De Lucia S., 2013). Crop diversity alone, if not associated with low input intensity management, is not an indication of agricultural areas with high naturalistic value (European Evaluation Network for Rural Development, 2008). The term "High Nature Value Farming" (HNVF) was first introduced in the early 1990s by Baldock et al., (1993), Beaufoy et al., (1994), Bignal and McCracken (1996). The issue of HNVF was addressed by the European Commission with the agro-environmental indicators (COM (2000) 20) and, even more, becoming one of the main themes of the Pan-European Ministerial Conference 'Environment for Europe' of Kiev in 2003 (UN / ECE, 2003) and of the European Conference on Biodiversity in 2004. The definition of High Nature Value Farmland Area (HNVF) was provided by Andersen in 2003: “HNVF comprises those areas in Europe where agriculture is the major (usually the dominant) land use and where that agriculture supports or is associated with either a high species and habitats diversity, or the presence of species of European conservation concern or both” (ISPRA 2010 p. 12). Since the first studies, starting with Andersen (2003), three types of HNVF area have been defined:

- Type 1: Agricultural land with high coverage of semi-natural vegetation;
- Type 2: Agricultural lands dominated by low-intensity agriculture or by a mosaic of semi-natural and cultivated territories;
- Type 3: Agricultural land with rare species or a high proportion of animal and/or plant species of conservation interest at European or world level.

As described in Beaufoy and Cooper (2008), HNVs are agricultural areas characterized by low intensity soil management, low animal density and the presence of semi-natural vegetation. Martino (2018) pointed out that low-intensity agricultural systems often have labor-intensive production cycles, low chemical inputs and are in general ecologically sustainable. Particular habitats, such as semi-natural grasslands, steppes and small mosaic areas with numerous landscape elements constitute these areas; HVNFs are also abundantly present in mountain areas. In Italy, these agricultural systems can be mainly associated with semi-natural pastures, permanent meadows, traditional orchards and arable crops (Trisorio *et al.*, 2012; Bozzo et al., 2019). The last ISPRA report (May 2021) on biodiversity in Italy shows the updated conservation status of animal and plant species and habitats (protected at EU level) present in our country in both the marine and terrestrial areas. The situation that emerges is critical for the species and habitats that populate our country: although protected for decades, 54% of the flora and 53% of the terrestrial fauna, 22% of the marine and marine species are in an unfavorable state of conservation. 89% of terrestrial habitats, while marine habitats show favorable status in 63% of cases and unknown in the remaining 37%. The results highlight the urgent need for greater commitment to the conservation and management of species and habitats in Italy, also with reference to the objectives of the new European Biodiversity Strategy for 2030. Further improvements of a more local nature can be adopted, for instance, Tarjuelo et al. (2021) found that an increase of measures aimed at improving food availability (e.g., reduced pesticide applications) enhanced diversity of farmland birds at field scales, whereas balanced food and shelter measures (e.g. delaying harvest) enhanced bird abundance. HNVF support biodiversity conservation, but they are also increasingly recognized for delivering valuable ecosystem services to wider society, contributing to both sustainability and resilience in the Europe (Plieninger et al. 2019). HNVF will have a key role in future CAP. However, the level of definition of HNVF, in scientific terms, as well as in relation to their spatial distribution is still rather limited, on both a European scale and, even more, a national and regional scale (Madureira et al., 2013; Campedelli et al. 2018). The objectives of the present work are:

1. define the indicators to elaborate the HNVF map by using the Big Data available (free of charge) in the valuable repository of information of the public authority database;
2. to asses a GIS prototype (QGIS software) service for the identification and characterization of HNVF area adaptable to different scales (local, regional, national).

The proposed methodology has the advantage of using free input data, accessible from the local, national and international public data-base (e.g., the regional orthophotos, the national and regional statistical information, the maps of Corine Land Cover (CLC), Remote sensing images, etc.).

2. MATERIAL AND METHODS

2.1 Study site

The study area was the entire Basilicata region at municipal level spatial resolution. The developed algorithm provides the possibility, having adequate data available, to vary the spatial resolution of the HNVF map from the national to the corporate level. The year of study is 2012. In order to produce a map of the HNVF area, the following data were used to compute the HNVF indicators. The training data consists of three categories of data, that were uploaded in a GIS project (QGIS):

1. Landscape conformation and structure: DEM/DTM computed from remote sensing SAR images (http://rsdi.regione.basilicata.it/); Topographic maps (http://rsdi.regione.basilicata.it/); Map of coastal areas and dunes covered by vegetation.
2. Land Use: Corine Land Cover map (CLC); Modis Satellite Images; Orthophoto 2012(http://rsdi.regione.basilicata.it/); Map of protected area: National and Regional Parks, SPAs, SIC and Habitat map; Map of DOP, IGP and organic crops; Vulnerability maps (http://rsdi.regione.basilicata.it/); Zoning map (2007-2013 RDPs) divides the Basilicata territory into 3 homogeneous zone. This layer provides information on the degree of agricultural specialization and indirectly on the intensity of external inputs.
3. Statistical data: Data from the 6th agricultural census (ISTAT, http://www.istat.it/it/censimentoagricoltura/); FDAN Farm accountancy data network; RICA Structural data and economic indicators network (Italian CREA).

The test data were the HNVF maps found in the literature (reported in the previous paragraph) on the study area and processed in the same period to which our study refers.

2.2 Experimental design

The methodology proposed in this paper is based on the statistical and farm systems approach. The developed procedure uses MODIS satellite images to improve the number and the accuracy of the land cover classes of the Corine Land Cover map and to calculate indicators aimed at monitoring soil and vegetation properties. The methodology for identifying HNVF is based on the integration of three components that are summarized in a single index that characterizes the areas of interest:

1. Crop Diversity (CD Index);
2. Extensive practices (EP Index);
3. Presence of natural elements (Index Ne).

The criterion for defining the belonging of a municipality to the HNVF area is as follows:

$$\text{Index HNVF} = (CD + EP + Ne) > \text{Threshold};$$

The threshold value, according to the literature (Pointereau et al., 2007 and 2010, Lazzerini 2015, Paracchini 2006 and 2008), should oscillate between the 15th and 30th percentile. The detailed calculation of the indicators is shown in table 1 in Appendix A, the indicators refer to the Utilized Agricultural Area (UAA). The UAA was calculated by excluding from the total municipal area the woods, the man-made areas, the stretches of water (including rivers and canals) and the coastal areas of dunes covered by vegetation. The formulas of the indicators in table 1 were applied to each of the 131 municipality of the Basilicata region.

3 RESULT AND DISCUSSION

The HNVF area was identified according to the criterion: HNVF Index > Threshold. In the specific case of Basilicata, the range of variability of the threshold goes from the minimum value corresponding to the 30th percentile of the value of the HNVF Index equal to 18.34 to the maximum value corresponding to the 15th percentile equal to 19.27. Using the maps of protected areas as training data, the threshold at the 30th percentile seemed the most appropriate to adopt. 39 municipalities were found to respond to the characteristics of agricultural areas with a high naturalistic value, showed in green in figure 1. These areas have greater crop diversity and a greater presence of natural elements that favor biodiversity. As far as extensive practices are concerned, in these areas there is a lower coverage of extensive crops, but this is linked to the greater crop diversity. The average value relating to the presence of extensive meadows and pastures is much lower in the areas classified as non-HNVF. The soil moisture index is on average higher for HNVF area, while the nitrogen supplied to crops but not used is lower in these areas. A further subdivision of these two macro-areas into sub-areas, characterizing their properties in detail, would be interesting, especially for non-HNVF, in order to identify the critical factors on which to intervene. Figure 1 shows the map of HNVF municipalities, highlighting the municipalities that have a HNVF index value closest to that of the municipalities classified as HNVF (in green). In particular, the municipalities that fall between the 30th and 40th percentile, equal to 13 municipalities, were examined. The closest to the HNVF area by value of the total index (differs from the minimum HNVF value of 0.001) is the municipality of Salandra, this is characterized by a lower CD index value than to the average value of the HNVF class, a value of the EP index comparable to the average value of the HNVF class and a value of the Ne index slightly lower than the average value of the HNVF class.

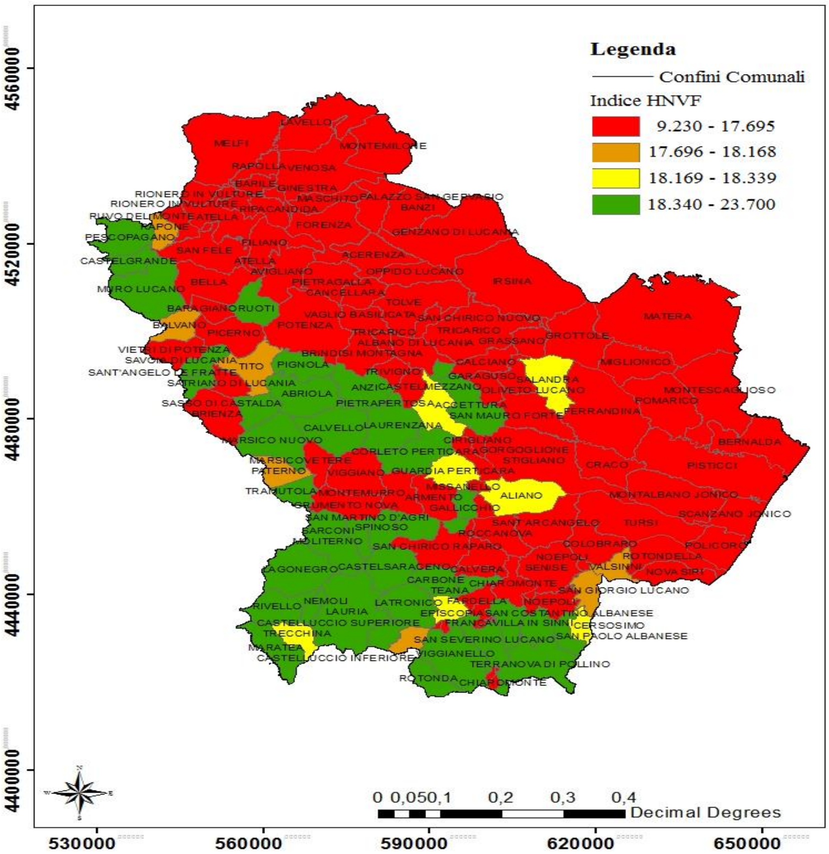

Figure 1. Map of the HNVF Index. The municipalities classified HNVF (at the 30th percentile) are displayed in green. The municipalities that fall between the 65th and 70th percentile are shown in yellow, while those that fall between the 60th and 65th percentile are displayed in orange.

Analyzing the sub-indices that make up the EP index, it can be seen that the municipality of Salandra has a greater coverage dedicated to extensive crops than the average of the HNVF class, as well as a better value than the index relating to extensive farms, but the presence of natural meadows is practically comparable with the average index value of the non-HNVF class. Therefore, the municipality of Salandra should increase crop diversity and/or increase the area of extensive meadows and pastures in order to re-enter the HNVF area, but only 4% of the UAA is intended for non-extensive meadows and pastures. Another aspect not to be overlooked is that uncultivated crops also contribute to the EMC index associated with the presence of extensive crops, which in 2010 for the municipality of Salandra represented 35% of the total UAA, compared to 35% of the UAA intended for agricultural crops, of which extensive crops accounted for 15%. In conclusion, the municipality of Salandra should maintain and increase the agricultural area dedicated to extensive crops in order to be able to return to the HNVF area. Many factors contribute to maintaining biodiversity and improving soil conservation. For example, the regulations on organic farming set limits on the application of synthetic chemicals but do not guarantee high levels of biodiversity and ecosystem services. The benefits of the absence of chemicals can be offset by the negative effects of increased mechanical processing or irrigation to increase production (Clark, 2020; Schmitz et al., 2021). The organically grown area cannot be considered dedicated to biodiversity conservation unless direct evidence of net positive effects is provided (Schneider et al., 2014). Monitoring, evaluating multiple aspects by calculating multiple indicators, would help assess the impacts of these practices on biodiversity and soil. In this way it would be possible to identify and intervene in a targeted manner to introduce, if possible, virtuous practices.

4 CONCLUSIONS

HNVF index, elaborated with the statistical approach, was integrated by the processing of medium resolution satellite images. The GIS allows to visualize the individual sub-indices selecting some of them in order to focus on specific problems. The proposed approach is very versatile both because it allows to manage multiple geo-referenced information layers and because it is applicable to different spatial scales (local, regional, national). The HNVF map was validated and it was found a good agreement with the results of literature works, although the analysis approaches were different. Our future research will be oriented towards the study of a wide range of social, economic, biodiversity and ecosystem services indicators, because to advance HNV farmland management change needs to be seen as an opportunity rather than as a constraint.

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Appendix A

Table 1. Indicators for the calculation of HNVF with the statistical approach.

Index	Sub-Index	Calculation Procedure
Cultural Diversity (CD)	-	*CD= 10+(1-(C1/UAA*10))+(1-(C2/UAA*10))* *C1 is the crop area > 10% of the UAA In addition to temporary and permanent forage areas.* 1≤CD≤10
Extensive practices (EP)	2.1. **Extensive Managed Crops (EMC) (Weight = 2)** 2.2. **Soil Moisture Index (SMI) (Weight = 2)** 2.3. **Extensive Breeding (EB) (Weight = 2)** 2.4. **Extensive Managed Pastures (EMP) (Weight = 2)** 2.5. **Nitrogen Surplus (Ns) (Weight = 2)**	*EMC= (Extensive crops+Fallow)(ha) /UAA(ha)* *SMI derived from Surface Temperature and NDVI (MODIS images)* *EB=1-∑(Number of livestock units*LSU Grazing) /UAA(ha)* *EMP=Permanent Grassland(ha)/UAA(ha)* $Ns=\sum_{c=crop}(Nf_c - Nr_c * R_c) * A_c(i)$ *Nf=Suggested fertilization* *Nr=nutrient content per unit of biomass of the crop c* *R=Yield of the crop c* *Ac(ha)=area occupied by crop c in cluster i* *(The value of each indicator is between 0 and 1)*
Presence of natural elements (Ne)	3.1 **Hedges and stone wall Length (LSM) (Weight = 2)** 3.2 **Canals and Streams Length (LC) (Weight = 2)** 3.3 **Lagoons, wetlands, and ponds (SPLS) (Weight = 2)** 3.4 **Numbers of Lakes (N) (Weight = 2)** 3.5 **Number of isolated Trees (Nt) (Weight = 2)**	*LSM=Hedges and dry-stone wall Length(mt) /UAA(ha)* *(if 0<LSM<50 mt/ha) LSM=LSM/50* *(if LSM>50 Mt/ha) LSM=1)* *LC=Canals and Streams Length (mt)/UAA(ha)* *(if 0<LC<0.1 mt/ha) LC=LC/0.1* *(if LC>0.1 mt/ha) LC=1* *SPLS=Lagoons, wetland and ponds surface(ha) /UAA(ha)* *(if 0<SPLS<0.001 mt/ha) SPLS=SPLS/0.001* *(if SPLS>0.001 mt/ha) SPLS=1* *L= Number of lakes/UAA(ha)* *(if 0<L<0.003 mt/ha) L=L/0.003* *(if SPLS>0.003 mt/ha) L=1* *Nt=Number of isolated trees/UAA(ha)* *(if Nt>1) Nt=1* *(The value of each indicator is between 0 and 1)*