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DEVELOPMENT OF A NEW GIS-BASED METHOD TO DETECT HIGH NATURAL VALUE FARMLANDS: A CASE STUDY IN CENTRAL ITALY

Fanfarillo E.[*,1], Latini M.[1], Nicolella G.[1], Abbate G.[1]

[1] *Dipartimento di Biologia Ambientale, Università di Roma "La Sapienza", P.le Aldo Moro 5, 00185 Roma, Italy*
**Corresponding Author: Telephone: +393490069573; email: emanuele.fanfarillo@uniroma1.it*

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Abstract - An original method for the identification of High Natural Value farmlands is presented. Gathering information about land use (CORINE Land Cover), geomorphology (elevation and Terrain Ruggedness Index) and remote sensing data in a GIS environment we were able to develop a new detection process; its application to a wide sector of central Italy, in areas characterized by high biodiversity and relevant agronomic and cultural value, is presented. Thus, a new tool for diminishing sampling efforts and economic and time wastes in territorial studies is provided.

Keywords: HNVF, agroecosystems, Latium region, Abruzzo region, GIS, biodiversity, extensive agriculture, remote sensing

Introduction

With the beginning of agriculture, man-related activities were the main cause of modification for natural landscapes, since gaining new cultivated surfaces involves a removal of natural vegetation, with a consequent direct loss of biodiversity; across the centuries, farmers have developed a large set of agricultural practices which nowadays we refer to as extensive or organic (Etingoff, 2017). The interaction between men and nature resulted in the creation of agricultural landscapes which are highly valuable both in environmental and cultural terms; such landscapes are characterized by a highly complex mosaic of differently cultivated land, pastures and natural vegetation patches as woods and hedges, which guarantee not only a conservation of natural biodiversity, but even its increase (Loos et al., 2014; Baiamonte et al., 2015). After the so-called "Green Revolution" around the 1950's, agriculture underwent a strong process of intensification through the introduction of mechanic practises, chemical fertilizers and pesticides. These deep changes caused a radical transformation of many agroecosystems, with a double effect on traditional agricultural landscapes: on the one hand, they were drastically replaced by intensive monocultures practiced on a large scale, especially in large plains and valleys; on the other, the abandonment of rougher areas, not suitable for intensive agriculture, led to the triggering of extensive secondary succession processes. Both of these phenomena led to the disappearance of agricultural ecosystems hosting a large number of plant and animal species, even rare or endangered (Rich & Woodruff, 1996; Tscharntke et al., 2005; Pinke et al., 2009).

The importance of conserving biodiversity in agroecosystems comes especially from the high number of ecosystem services it is able to provide, such as soil conservation, detoxification of noxious chemicals and support of wild animals (Altieri, 1994); these mechanisms are essential to ensure a sustainable production, as they are able to reduce significantly the need for energy inputs from the outside (Altieri, 1999).

In the last decades, the scientific community has showed an increasing interest towards these issues; the European Community itself has recognized extensive agriculture to be essential for biodiversity conservation aims and described the landscape contexts which extensive practices are able to produce, as High Natural Value farmlands (HNVF) (http://www.high-nature-value-farming.eu/what-is-hnv).

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Nowadays, in industrialized countries extensive agriculture is known to be strongly related to hilly and mountainous areas, where the mechanization of agricultural practices is hindered by features of the territory such as high slopes and rockiness.
The HNVF concept developed in the early 1990's from the recognition that many of Europe's most endangered species and habitat types are strongly dependent on specific farming practices that evolved in the different regions of the continent; the secular application of these practices resulted in diversified agricultural systems composed by semi-natural pastures, meadows, orchards, large hedges and copses, providing effective ecological networks for wildlife conservation and guaranteeing numerous ecosystem services for the society (carbon storage, clean water, wildfire prevention, storage of genetic diversity and cultural values) (Opperman et al., 2012; http://www.high-nature-value-farming.eu/what-is-hnv).
Though both scientists and policy makers largely agree on its importance, the concept of HNV farming still remains for many aspects quite vague and not well defined, being strongly subjected to personal interpretations; this results in a lot of difficulties in characterizing and localizing HNV farmlands, which are often implemented by lack of data (or of their availability) and limitation in spatial, temporal and thematic resolution (data available on a regional level, for instance, might not be enough) (Lomba et al., 2014; Strohbach et al., 2015).
Modern tools for territorial analysis, such as GIS softwares, allow experts to access high amounts of information using open data about the territory (Burrough, 1986), thus avoiding the need to go on site, saving time and costs; this is especially true in the first steps of the analysis, when the suitability of the study areas for investigation has to be evaluated. This way, it is possible to obtain a solid knowledge for the planning and carrying out of the sampling survey. For these reasons, the usage of remote sensing and GIS tools has become common in environmental and ecological studies especially in recent years (Congedo et al., 2013; Capotorti et al., 2014; Marando et al., 2016).
Detecting the presence of HNV farmlands and investigating their features has recently been the subject of numerous works regarding landscape structure, wildlife and plant communities of HNV farmlands in several countries (Morelli et al. 2014; Boyle et al., 2015; Brunbjerg et al., 2016; O'Rourke et al., 2016; Fanfarillo et al., 2017a). Generally, these works have the common feature of requiring a high amount of information for the identification process, both needing data deriving from previous samplings and from new ones.
Thus, in the perspective of avoiding time and economic wastes when planning field surveys for such aims, in this work we propose a new method for the preliminary detection of areas suitable to host High Natural Value farmlands using free data in a GIS environment, applying it as a case study to a wide sector of central Italy (Latium and Abruzzo regions).

Materials and methods

Study area

Latium and Abruzzo are two neighbouring administrative regions located in central Italy (Figure 1).

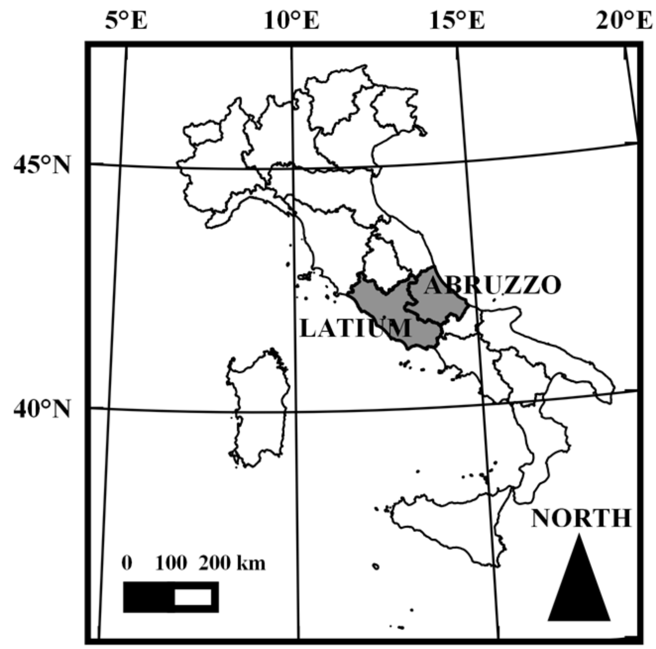

Figure 1. Location of Latium and Abruzzo in Italy.

The study area crosses the Italian Peninsula from the Tyrrhenian to the Adriatic Sea and is crossed by the Apennine chain, where the highest elevation is reached with Corno Grande (2912 m a.s.l.); the greatest part of the territory is hilly (47%) and mountainous (41%), with minor plains (12%) restricted to coastal Latium (www.istat.it/it/archivio/137001).
The area is remarkably heterogeneous in geomorphological, climatic and land use terms, and has extremely high floristic and vegetation diversity levels (Conti, 1998; Anzalone et al., 2010; Blasi, 2010; Conti & Bartolucci, 2015; Conti & Bartolucci, 2016); recent studies have proved floristic biodiversity to be particularly related to orography, with hills being the most important orographic feature that increases plant diversity (Abbate et al., 2016), and showed that agricultural and semi-natural areas are particularly rich in native woody taxa (Latini et al., 2017). Right here, most of the complex and highly valuable traditional agricultural systems, that shaped the landscape especially in the past, survive nowadays (Barbera et al., 2007).
The total agricultural surface covers 1,588,667 ha in the study area, occupying the 56.7% of its total surface, and is mainly

represented by arable land (31.7%) and woody agricultural plantations (12.8%); the latter are almost totally constituted by olive groves (54.5%) and vineyards (24.3%) (www.istat.it/it/censimento-agricoltura/agricoltura-2010). In this context, organic farming is playing a more and more relevant role, being practiced on an area of 140,277 ha as for 2015 (8.9% of the total agricultural surface) with an increase of 3.6% when compared to 2014 (http://www.sinab.it/content/bio-statistiche).

Though agriculture is widely practiced in both regions, in the last decades it has undergone a noticeable process of decline (www.istat.it/it/censimento-agricoltura/agricoltura-2010), this being a common event in many parts of Europe, including peninsular Italy (Terres et al., 2015). In particular, this phenomenon took place in areas that are not suitable for intensive agriculture, i.e. hills and low mountains (Manzi, 2012; Frattaroli et al., 2014), resulting in an extensive loss of century-old, traditionally managed agroecosystems.

Method description

For the identification of areas considered suitable to host HNV farmlands we used open data about the territory providing information, above all, on its geomorphology and land use; in fact, being the existence of extensively managed agricultural areas dependent on the impossibility of any intensification of practices, the coexistence of farmlands and rough portions (steep slopes, abundant rockiness) of territory highly increases the probability of the conservation of traditional agricultural systems.

All the used data are freely obtainable from several online sources and were processed using a free GIS software; thanks to this type of approach, the whole procedure was definitely low-cost.

The detection process consists in the following steps:

A. A 75 metres resolution Digital Elevation Model (DEM), which represents the ground's surface basing on terrain elevation data, is required;
B. From the DEM, the values of the Terrain Ruggedness Index (TRI, Riley et al. 1999) are calculated. The TRI is an index which provides a measure of the ground ruggedness based on the sum of the differences in elevation between a central cell (to which a TRI value is assigned) and the eight cells surrounding it in the DEM. A TRI map is so obtained and ruggedness classes can be determined; since the TRI extreme values strongly vary depending on the study area and its geomorphology, the ruggedness classes can be defined according to the needs of each study. Classes which are considered to be representative of areas potentially hosting HNV farmlands, i.e. the ones with higher TRI values, are then taken into account;
C. Information about land use is added through a map of agricultural surfaces derived from the CORINE Land Cover, which is overlaid to the TRI map in order to identify agricultural areas which fall into the formerly detected rugged areas as potential HNV farmlands;
D. A grid is then overlaid in order to obtain comparable portions of territory to be investigated with different kinds of field surveys, especially those aiming to detect the actual features of plant communities which shape the agroecosystems; all cells containing potential HNV farmlands are considered interesting for the study and suitable for further investigations, but the ones partially falling outside the study area (i.e. including sea surfaces and/or parts of territory of other regions) have to be excluded for comparability reasons;
E. Given a cell suitable for investigation, a full land use map (CORINE Land Cover, 4th and 5th levels) is overlaid to it, to get information about natural and semi-natural areas; then, through satellite images and, possibly, street view, the content of each interesting cell is checked in order to detect potential sampling sites for different specific purposes.

   The method can be easily adapted to the needs of different works, aiming for instance to identify intensively managed agricultural areas or the potentiality of a territory to host specific plant communities, by adding more layers for the discrimination of the study areas (geology, climate) and by varying the grid cells dimension according to the requested detail level.

Case study: data collection and analysis

We applied the method by selecting the territories of the regions Latium and Abruzzo, in central Italy (www.istat.it/it/archivio/124086).

Starting from a DEM (75x75 metres cells) of the whole Italian territory available online (http://www.geoviewer.isprambiente.it), we clipped the study area to obtain a DEM of the two regions (figure 2a).

Then, the TRI values (Riley et al., 1999) were calculated and a TRI map was obtained (figure 2b).

Information about land use was added using the CORINE Land Cover (http://www.sinanet.isprambiente.it/it/sia-ispra/download-mais/corine-land-cover/corine-land-cover-2012-iv-livello/view), clipped on the study area. All the agricultural CORINE land use categories were taken into account; then a shapefile was created selecting only these categories (figure 2c).

Next step consisted in checking for the presence of agricultural areas in rugged areas. Only two ruggedness classes needed to be determined for our purposes, so we established a $TRI > 3$ for rugged areas and a $TRI \leq 3$ for flat areas; then, using the raster calculator, we created a raster layer where

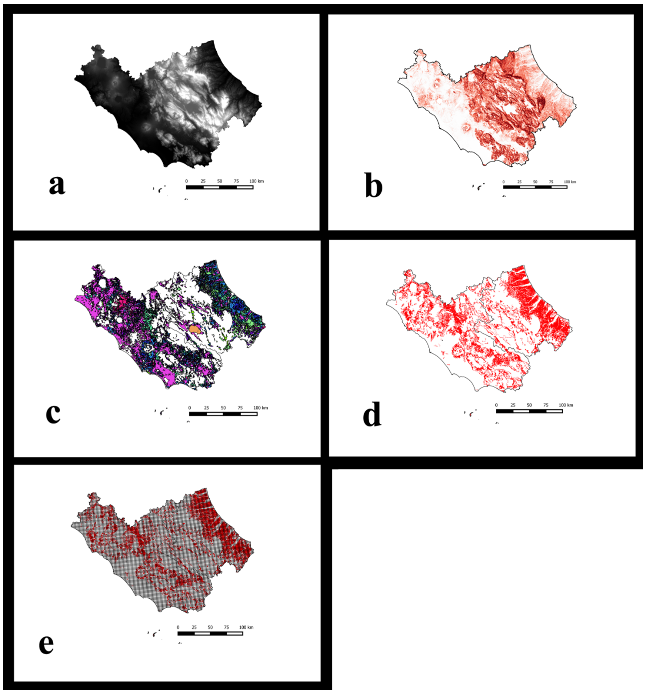

Figure 2. Digital Elevation Model of Latium and Abruzzo (a); TRI map of the study area: flat areas (TRI < 3) in white, rough areas (TRI ≥ 3) in red tones (b); distribution of agricultural areas across the study area (CLC) (c); distribution of potential HNV farmlands across the study area (d); the 2x2 km cells grid overlaid to potential HNV farmlands to obtain comparable portions of territory (e).

two ruggedness classes were defined: "rugged" (TRI > 3) and "not rugged" (TRI ≤ 3). We performed a simplification of this TRI map showing rugged and not rugged areas by eliminating very small patches: the layer was filtered applying a 500 pixel threshold (i.e. all patches smaller than 500 pixels were united with the biggest neighbouring patch) with a connection value of 4 (i.e., for each pixel, only the values of the four neighbouring pixels with common sides were considered for the unification process). We converted this new layer into a shapefile, then extracted from it a layer representing rugged areas. Next, we clipped the land use layer (agricultural categories of the CORINE Land Cover) on the one representing rugged areas; thus, we were eventually able to obtain a final layer showing areas potentially hosting HNV farmlands (figure 2d).
A grid of 2x2 km cells (Gargano, 2011) was then added, to subdivide the study area into comparable portions of territory (figure 2e); cells partially falling outside the boundaries of the two regions were excluded for having different extensions and being then not comparable. Thus, cells which are considered representative of different agricultural and environmental contexts can be selected for field surveys across the surface of the two regions.

We chose a cell containing potential HNV farmlands for further investigation and added the full CORINE Land Cover (4th and 5th levels); finally, we visualized its content through satellite images and, when possible, through street view images to check for accessibility (https://www.google.it/maps; https://www.google.com/streetview), being thus able to preliminary identify a significant number of sampling sites (figure 3).
All the analyses were performed using the free software Qgis 2.8.9 (Quantum GIS Development Team, 2016).

Results

In the study area the TRI values range between 0 and 34.8, thus showing a strong geomorphological heterogeneity in a sector of peninsular Italy in which agriculture is largely practiced, a fact that itself lays the foundations for the existence of HNV farmlands.
Through our method, we highlighted how agricultural areas which are suitable to host HNV farmlands occupy a considerable extension in the two regions (table 1). For the most part, these areas are located in the middle-elevation hilly belt, being agriculture mostly intensive in plains and absent at higher elevations.

Table 1. Evaluated extension of HNV farmlands and their percentage cover in the study area and in each of the two regions.

	Study area	**Latium**	**Abruzzo**
Agricultural areas	14,576 km^2 (52%)	9,863 km^2 (35.2%)	4,713 km^2 (16.8%)
Rugged areas (TRI≥3)	19,746 km^2 (70.4%)	10184 km^2 (36.3%)	9565 km^2 (34.1%)
Potential HNVF	8066 km^2 (28.8%)	4270 km^2 (15.2%)	3769 km^2 (13.5%)

Applying the 2x2 km grid, the study area was subdivided into 7366 cells; of these, 664 were excluded for not being entirely within the boundaries of the two regions. Between the remaining 6702 cells, 4881 contained potential HNV farmlands and resulted then suitable to be investigated; so far, more criteria can be taken into account (distance from urban areas and infrastructures, presence of protected areas) to perform a further discrimination and detect a number of particularly interesting cells, depending on economic resources and time availability. The cell of the grid we selected, as an example for further investigations, resulted to own, as expected, a highly differentiated land cover:

- The application of the CORINE Land Cover at the 4th and 5th levels showed how agricultural areas were surrounded by patches of natural and semi-natural vegetation, belonging to the following categories: 3112 (deciduous oaks woods), 3114 (Chestnut woods, representing a Natura 2000 habitat - http://www.minambiente.it/pagina/direttiva-habitat), 324 (evolving vegetation), and 31322 (mixed broadleaves/coniferous woods with mountain and oro-mediterranean pines);
- The usage of satellite and street view images allowed a better understanding of the structure of the territory, revealing a complex agricultural system being characterized by small and differently cultivated patches, with frequent hedges, small woods, shrubs, pastures and meadows which are not represented in the CORINE Land Cover;

These features eventually let us identify a high number of accessible potential sampling sites, to be investigated during the field survey (figure 3).

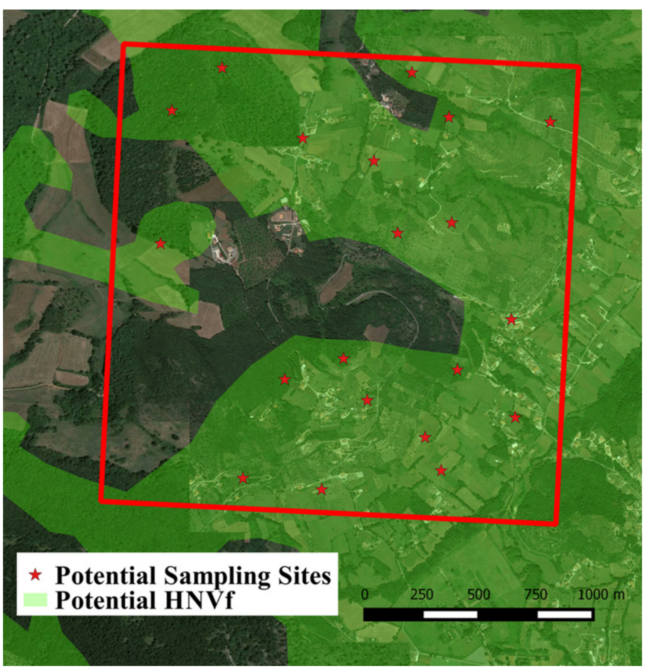

Figure 3. Satellite view of the 2x2 km cell selected as an example (centroid coordinates, WGS 84/UTM Zone 32N: 41°45’ N, 13°18’ E). Green-shaded areas represent potential HNV farmlands formerly detected; red stars represent possible sampling sites.

Discussion

Starting from the assumption that the practice of extensive agriculture mainly survives in rougher areas, where intensive agricultural techniques cannot be performed, we combined information about geomorphology and land use that eventually allowed us to discriminate those areas that were more likely to host the type of agroecosystems we were interested in.

The application of the method to a wide sector of central Italy characterized by high environmental heterogeneity, very high biodiversity levels and a complex agricultural landscape owing to a great historic and cultural value (Latium and Abruzzo regions) gave us the chance to prove its validity.

The agricultural areas we detected have a strong potential to be classified as HNV farmlands, being characterized by a high landscape heterogeneity, with small and diverse cultivated plots and frequent patches of natural and semi-natural vegetation (woods, hedges, shrubs and secondary pastures or meadows); besides, most of these areas fall into a middle-elevation zone which recent studies showed to be owning the highest floristic diversity levels in Italy (Abbate et al., 2016). The partition of the study area into sectors of the same extension through the overlap of a grid allows to obtain comparable portions of territory, especially useful when measuring biodiversity at different levels (α, β, and γ-diversity).

After selecting a target cell, using a more detailed land use map (4th and 5th levels of the CORINE Land Cover) we were allowed to identify the physiognomic features of natural and semi-natural stands surrounding the agricultural areas (in our case, even detecting the presence of Natura 2000 habitats), thus gaining more information about its species and community diversity.

In the perspective of carrying out field samplings to obtain information about the features of plant communities, we additionally used satellite images and street views to identify interesting sampling sites and then check their characteristics (including accessibility) in order to further reduce future efforts on field. In this phase, some difficulties may be encountered, mostly deriving from possible lack of street images; when so, satellite images can detect a suitable site with a good margin of safety, but in this case it is impossible to check if it can be easily accessed or not.

Conclusions

The preliminary evaluation of the suitability of a territory for a certain survey is a fundamental step in the study process, since it allows the avoidance of waste of time and economic resources; in this perspective, the new method here proposed proved to be an effective tool for the detection of potential HNV farmlands in a GIS environment.

In future studies the method can be applied to other sectors of Italy, even adding further information (e.g. about climate, geology, soil, urban fabric and infrastructures) to detect areas particularly valuable and/or representative of specific territorial contexts.

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