Use of Remote Sensing for the Assessment of Farmland Biodiversity

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Executive Summary

In many countries farmland represent the most relevant type of land use. The conservation and the enhancement of biodiversity within these areas is primary objective for the achievement of sustainable management of agro-ecosystems and the level of biodiversity can be used as agri-environmental indicator. The measure of biodiversity over larger territories however, can be very expensive and time consuming.

Earth observations have a rich history in characterizing and monitoring biodiversity and ecosystems. The possibility to use remotely sensed data for monitoring biodiversity was identified at the dawn of Earth observations and has been widely used for decades. Remotely sensed data can cost-effectively track changes in ecosystem distribution and status. The new generation of high-spatial and spectral resolution offers more hope for more direct monitoring of habitats and species.

Recent developments in satellite remote sensing and in geographic information system (GIS) combined with user oriented computer programs allow us to use ecological principles for biodiversity characterization at landscape level more efficiently.

This paper presents an approach for biodiversity characterization at landscape level using geospatial techniques. The present study hypothesizes that the complexity of the landscape is related to biological phytodiversity, and in turn phytodiversity can be considered a proxy of the overall biodiversity. The aim of the study is to estimate the farmland landscape complexity by using a remote sensing based approach. The approach has been validated in a Northern Italian agricultural area (Emilia-Romagna region).

Introduction: Background, scope objectives

Agriculture is the human activity occupying the largest share of the total land area for nearly all OECD countries; in Europe (EU 27) 44% of the territory is represented by farmland. The role of agricultural land in providing ecosystem services to the human society is essential. During recent years society asks the agricultural sector to provide additional services, other than the mere biomass production, and to reduce the pressure on the environment.

Conservation of biodiversity is one of the new challenges of modern agriculture. Agriculture can be considered at the same time key actor in biodiversity conservation within the developed countries, but also dependent on many services provided by the variety of organisms living in agricultural landscape.

The integration of environment into the Common Agricultural Policy (CAP) led to the development of Agro-Environmental Indicators (AEIs), as tools for monitoring and evaluating the achievement of the CAP goals. According to Priorr (2003), the AEIs role is:

• Supplying decision-makers and the general public with relevant information on the current state and trend in the environment as they affect the agricultural sector and rural development.

• Supporting decision-makers information on the cause and effect relationships between the choices and practices of farmers

• Supporting agricultural and environmental policy-makers, steering in the right direction any initiatives prompted by changes in the state of the environment.

• Assisting to monitor and assess the effectiveness of measures taken to promote sustainable agriculture.

In the development of AEIs indicators a key role was played by the OECD and by the European Union. The OECD reports on Environmental Indicators for Agriculture represent a milestone in this sector and the several projects, reports and activities carried out by the EU (IRENA , PAIS, SEBI 2010) are of paramount importance for the achievement of the goals of sustainable agriculture.

In the OECD report (2001), there are AEIs devoted to the evaluation of biodiversity status, but in many cases these indicators are difficult to apply, due to the lack of data on species or habitat distribution. In a research commissioned by RIVM (WCMC, 1995) it was concluded in that "good time-series data for global populations of individual species are very rare", and even twenty years later, in the occasion of the publication of “Natural Capital indicator for OECD countries”, the authors state that the situation remains the same. In 2001 OECD published also a specific report on the Agriculture and Biodiversity, where several approaches, based on field survey ro on the use of statiscal data, have been presented.

The application of landscape indicators is probably easier, because several metrics proposed can be easily produced from the available thematic maps and from remote sensing. There are several examples of the application of Corine Land Cover data for the production of AEIs indicators (EC, 2005). However if we are dealing with the agricultural land, the largest part of it is classified as Arable Land (Non-irrigated arable land 2.1.1, Permanently irrigated Arable Land 2.1.2 of CLC), even if large differences in terms of landscape structure and biodiversity can be present.

An essential contribute in the recognition of the role of agriculture in biodiversity conservation is represented by the inventory of HNV in EU (Paracchini et al.,2008). The aim of that activity however was focused on agricultural areas holding a high nature value; in such areas support and maintenance of biodiversity is linked to extensive farming practices, which is a type of land management often not characteristic of agricultural land classified in CORINE as arable land (2.1.1, 2.1.2). These two categories of land use however represents the largest part of the agricultural area, in many regions of Europe, and biodiversity contingent can be extremely differentiated (Gardi et al., 2003). Far to consider these land use classes HNV areas, however the agricultural policy agenda should take into consideration their biodiversity actual value and especially the potential of improvement.

In the EU the reform of the Common Agricultural Policy in 2003 introduced cross-compliance as a tool that creates a link between farm-relevant support and farm-relevant legislation: currently producer support depends on the respect of standards related to environment, food safety and quality, animal welfare and good agricultural and environmental conditions. Furthermore, agri-environment schemes in the framework of the Rural Development Policy aim at protecting and improving the environment, providing funding for farmers that adopt environmentally-friendly farming practices that go beyond legal obligations. The efficient use of these policy tools however, requires a deep knowledge of the rural areas. A necessary starting point to achieve the objective of preserving farmland biodiversity is to reach an adequate level of knowledge on its extent and on its spatial and temporal distribution.

Several attempts have been made trying to detect the biodiversity from remote sensing or from the landscape structure (Honnay et al., 2003; Turner et al., 2003; John et al., 2008). From the ecology we know that the measure of species diversity at a given site is expressed as α diversity, while the diversity of a given territory can be expressed as γ diversity. The theory of landscape ecology provides interesting relationship between the structure of the landscape and the biodiversity (Ortega et al., 2004).

The potential of remote sensing is to provide at the same time, information on the structure of the landscape (Patch shape and dimension, length and distribution of edges, fragmentation, etc), but also to provide information on the spectral characteristics of the objects lying on the soil.

In this paper is proposed a simple approach aimed to provide indirect estimate of plant biodiversity on the basis of parameters detected from remote sensed images (landscape structure, spectral signature). The objective of this approach is to provide a useful tool for decision makers, enabling them to better understand the state and the trend of agricultural land biodiversity.

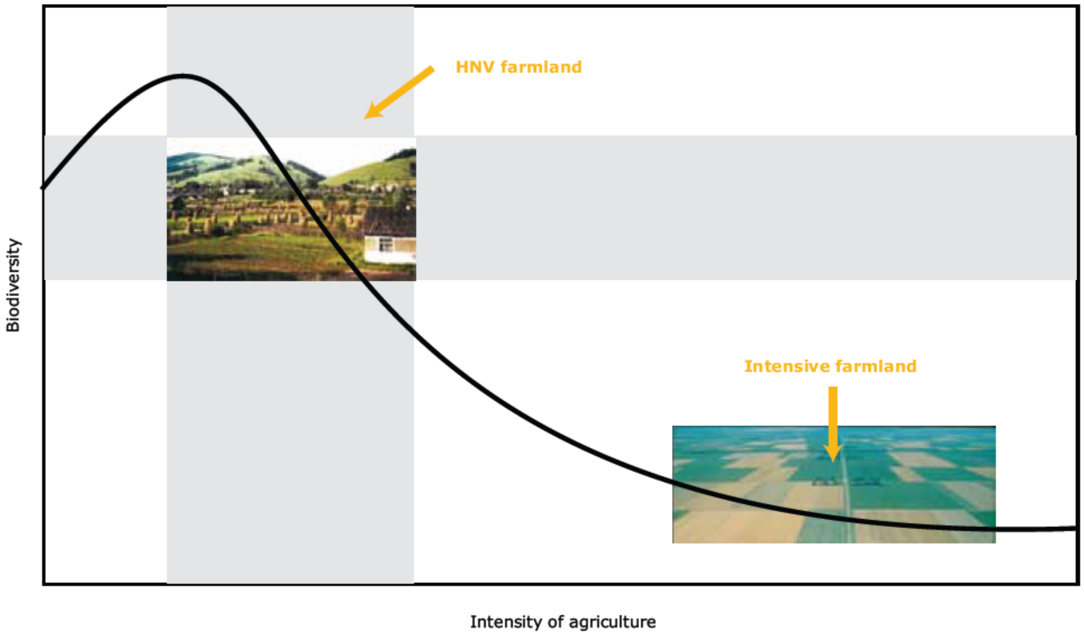
The proposed methodology has been tested in Emilia-Romagna region, as case study area, using different type of images. An economic evaluation of the proposed methodology, taking into account the cost of the images, the time required for processing, has been also made. It is important to consider that in several developed countries there is a large availability of good quality images, produced for controls related to agricultural policy (i.e. payments of CAP in the EU) that can be applied for this methodology.

Heterogeneity and potentiality of conventional farmland

In this context for "conventional farmland", it should be intended all the agricultural areas not classified as High Natural Values Farmlands. These type of areas in Europe accounts for more then 30% of the territory, and as it can be seen in the graphic of figure 1 (the white part on the right of the graph represents the conventional farmland), some variability in biodiversity level characterize also these areas. From our field survey data, referred to the number of vascular plants species found in the investigated sites (per unit area of 25 ha), these differences can be of one order of magnitude, ranging from 9 for the large monocropped fields, to 118 for the more complex mosaic including irrigated permanent grasslands, and several linear elements such as edges, tree rows, small patch of forests, wetlands or dry grasslands.

In a recent technical report published by the EEA (2009), an analysis of the potential of CAP expenditure for enhancing farmland biodiversity is presented; in this document most of the attention is focused on the farmland biodiversity hot spot, represented by HNV. It is important to consider however, that a better expenditure of the CAP could be finalized also to the improvement of biodidiversity within the conventional farmland, aiming to one of the following results:

- enhanche the biodiversity level of the areas below a given threshold;
- maintain the biodiversity level it the areas already rich in biodiversity.



Source: High Nature Value farmland — Characteristics, trends and policy challenges (EEA, 2004).

Figure 1. Graphical representation of the "conventional farmlad" (the white area on the bottom-right of the graph).

The level of biodiversity in farmland is the results of the interaction of several factors, such as landuse and crop types, landscape structure, management intensity, soil and climate characteristics. The possibility to increase biodiversity can be achieved modifying one o several of the above listed factors. For instance in high inputs agricultural systems biodiversity can be promoted adopting one of the following measures:

- increase the landscape diversity, introducing elements of the ecological networks, like corridors and stepping stones;
- reduce the management intensity;
- increase the complexity of crop rotation.

In order to reach the objective of the enhancement of biodiversity of this large part of European territory, that is represented by the conventional farmland, it is necessary to achieve an adequate level of understanding of its status and its variability in time and space. A possible objective for the political agenda, could be the establishment of a minimum biodiversity level (i.e. in terms of vascular plant species per a unit area), to be reached for the different territories, within a given deadline.

Proposed approach

Measuring the complexity of plant species in managed, semi-natural or natural ecosystems, as surrogate indicator of biodiversity is time consuming and expensive. The possibility to explore the use of remote sensing for the biodiversity assessment have been tested by several authors, evaluating different kind of relationships between diversity and other relevant processes. The basic idea of the proposed approach, is to calculate an indicator, related to gamma diversity of the agricultural landscape, using remote sensing.

The relationship between diversity and productivity has been the subject of a longstanding debate in ecology. According to the productivity hypothesis, when resources are abundant and reliable, species become more specialized, allowing more species per unit area (Skidmore et al.,). The use of this hypothesis by the remote sensing techniques, led to the use of NDVI (Normalized Difference Vegetation Index), and other vegetation indexes, as proxy indicators of both plant and animal species diversity, in natural or semi-natural ecosystems. Walker et al. (1992) correlated plant species richness to aggregated NDVI in California, while Jorgensen and Nohr (1996) related bird diversity to landscape diversity and biomass availability in the Sahel. In managed ecosystems however other factors can affect the productivity, and simplified systems (monocropping), can be highly productive. In the agricultural areas on the other hand, vegetation indexes can be used to assess whether vegetation cover of an area, is stable over a given period of time (indicating presence of permanent crops), or highly variable. For this purposes in the proposed approach, the average of fAPAR (Gobron et al., 2004) has been used as estimator of plant diversity.

Several authors described clear relationships between the patch complexity of farmland landscape and biodiversity. In the proposed approach the landscape complexity has been estimate, from the satellite images, by using edge detection techniques.

A third estimator has been the number of distinct spectral signature classes of surfaces, within a given area. The hypothesis is that each class should be related to a distinct entity represented by:

1) landuse;

2) crop or class of crops;

3) phenology;

and by the interaction of them.

Each entity could contribute with a distinct contingent of plant species, and consequently more complex is the assemblage of these entities, and higher would be plant biodiversity.

In order to propose a simple methodology, not requiring any ground truth validation, a unsupervised classification has been used. Detailed, supervised classification of large areas takes enormous effort and inputs in terms of time, manpower, and money (Fuller, 1994), while unsupervised classification is relatively faster and less expensive even if could lead to a compromise in terms of classification accuracy (Lark, 1995). Within the aim of the proposed approach, however, the unsupervised classification is the only option fast and cheap enough to allow the computation of a biodiviversity indicator of the agricultural land at large scale.

Study area

The study area is represented by the Emilia-Romagna, a region (NUTS 2) of Northern Italy. From physiographic point of view, the region is divided into 4 distinct units:

- Alluvial plain
- Coastal belt
- Hills
- Mountains

The study has been carried out on the alluvial plain area, that is characterised by the more than 80% of agricultural land use. Arable lands (2.1 CLC), represents the 55% of the investigated area (Fig.2). However strong differences in landscape structure (composition, configuration, natural and historical landscape feature), in biodiversity level and in agricultural management regimes exists, as can be seen in figure 3.

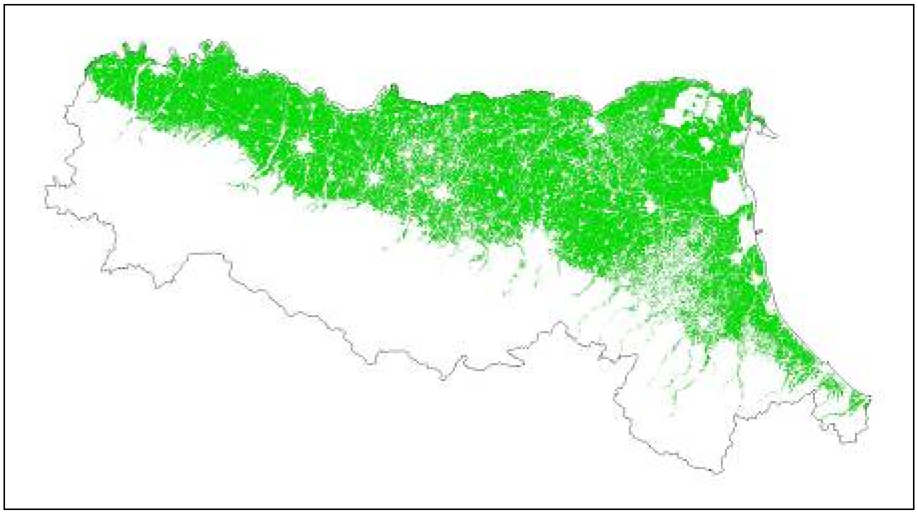


Figure 2. Distribution of arable land in the alluvial plain of Emilia-Romagna region.

Figure 3. Two different farmland landscape within Emilia-Romagna alluvial plain (same scale).

Materials and methods

For the application of the proposed methodology to the test area, two different data sets have been used:

- A 10-days time series of SeaWiFS images
- 2 Multispecrtal Landsat images

The SeaWiFS images have been used to calculate the average fAPAR (Fraction of Absorbed Photosynthetically Active Radiation), as index of plant diversity .

The Landsat images have been used to derive the following indexes, as partial estimators of plant photosynthetic activity indirectly related to diversity:

- the number spectral classes present in each area, considering this value related to the different nature of surfaces. This index was obtained performing an unsupervised classification for each Landsat frame, and then applying a focal operator, in order to assign the maximum number of classes within a 10 x 10 moving window, to the central pixel;

- the density of edges per unit area, as estimator of landscape complexity. This operation was performed using the a Laplacian algorithm for the detection of edges, and then applying a focal operator, in order to assign the maximum number of classes within a 10 x 10 moving window, to the central pixel;

The software used for the analysis and classification of the images was Envi 4.6, while for other spatial analysis ArcGIS 9.3 was used. The final indicator has been calculated as the sum of the three indexes described above. The calculated indicator value has been validated, in selected area, where floristic relevé have been made.

Discussion

The preliminary data of the Biodiversity Indicator, obtained in the test, area showed a good correspondence with the characteristics of the main agricultural districts of Emilia-Romagna region (Fig. 4).

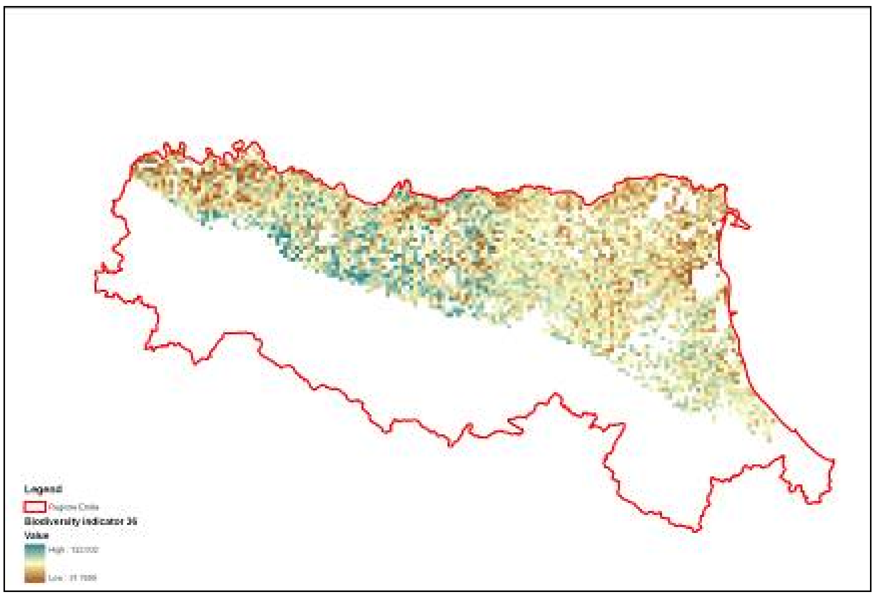


Figure 4. Variation of the Biodiversity Indicator within the investigated area.

In table 1 it is presented the comparison between the value of the calculated indicator and the number of vascular plant species per km^2 found in the surveyed areas. These numbers has been produced from the floristic check-list of the crop/land use type and landscape elements present in the area (edges, wood patches, etc.).

Further validation of the proposed indicator, the statistical analysis of the data should be performed, however they are beyond the scope of this contribute of the workshop. The main objective of this paper was to outline the existence of a high range of biodiversity statusalso in the conventional farmland of Europe and to present a possible approach, based on remote sensing, for the assessment of this biodiversity.

During this research we found that other metrics and sources of data currently available, such as the geospatial data related to CAP subsides, my allow a refinement of the proposed approach. Furtehrmore, from multitemporal series of satellite images, other indicators, aimed to the evaluation phenology, can contribute to a better distinction between high and low intensity agricultural areas.

It should be noticed that even in the hearth of high intensity agricultural areas, hot spot of biodiversity may be present. In the investigated area for instance, these hot spots, holding an interesting contingent of rare plant species, are associated to the conservation of traditional farming practices, such as the irrigated permanent grasslands ("prati stabili").

The detection of these hot spot throughout Europe and a better tuning of CAP expenditure, aiming to their conservation, can represent an important contribute to the enhancement of farmland biodiversity.

Table 1. Comparison between estimated values (indexes and aggregate indicator) and the number of vascular plant sepecies for selected sites

Description	Edge density index	fAPAR index	Spectral classes index	Aggregated Biodiversity Indicator	Vascular plant species (number)
Very simple landscape based on maize monocropping	7	0.27	3	37.45	9
Complex landscape structure, including permanent grasslands, shrub and tree edges	29	0.37	3	96.24	67
Very complex landscape structure, including permanent grasslands, wood patches, shrub and tree edges	21	0.48	4	109.63	118

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