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Impact of land ownership and altitude on biodiversity evaluated by indicators at the landscape level in Central Italy

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ABSTRACT

This study analyzed the ecological role of agroecosystems in maintaining landscape diversity and sustainability using selected indicators and indexes in Central Italy. The study focuses on analysing ecological systems at the landscape level to assess the environmental sustainability in terms of land cover composition and diversity. We used geographical information systems, landscape fragmentation and heterogeneity to determine the ecotone types and patch characteristics and gather useful information based on ownership (private and public areas) and altitude (plain, hilly, and mountain areas).

The results showed that private areas had major landscape heterogeneity, which increased both the presence of ecotones and land cover diversification. There was a higher level of landscape heterogeneity and land cover diversification in plain and hilly areas, where agriculture was mostly present. There was also an increase of margins and/or hedgerows. Publicly owned areas generally had permanent land cover types, such as woods and pastures with low human influence, that induce biodiversity conservation. Privately owned areas were mainly characterized by cultivated land with high human influence that requires careful biodiversity management. However, most important ecological structures, such as ecotones, occurred where human land use intensity was at its highest level (plain-hilly areas and private ownership areas), and this could help to maintain and increase the biodiversity of the agricultural landscape. In Central Italy, there is an acceptable level of landscape sustainability achieved by integrating both private and public types of management.

Introduction

Over the last century, many environmental problems have emerged, and agriculture is becoming a disturbing factor for environmental sustainability in developed countries. Modern intensive and conventional agriculture violates the ecological principles of closed cycles, the spatial and temporal dimensions of cycles, and the diversity and complexity of agroecosystems (Jorgensen and Nielsen, 1996; Lin, 2011). To reverse this trend, it is advisable to change from a reductionist approach to an ecological approach (holistic, systemic, and interdisciplinary) when choosing a type of agricultural management. Agriculture plays an active and positive role in preserving and protecting agroecosystem sustainability (Caporali et al., 2003) by properly organizing a territory (Ghersa and Leòn, 1999).

Biodiversity means the variability among living organisms from all sources, including inter alia diversity of ecosystems within species and between species (UNCED, 1992). Therefore, it is possible to associate biological diversity with ecosystem diversity and landscape diversity. Biodiversity contributes to security, resiliency, social relations, health, and freedom of choice and actions (OECD, 2001, 2002).

One way to increase biodiversity in agroecosystems where natural vegetation patches have been virtually eliminated is to establish different types of field margin vegetation and/or hedgerows that serve as biological corridors to guarantee the sustainability of the systems (Altieri, 1999).

Land management choices directly and indirectly affect biodiversity and environmental sustainability (e.g., in time and space crop diversification favours an equilibrium in associated biodiversity, such as weeds, insects, etc., that increases the integrity of the ecosystem) (Altieri, 1999; Forman, 1995a, 1995b). Furthermore, important ecosystem services are provided by biodiversity in farm systems and associated agricultural landscapes (Tscharntke et al., 2012). Landscape and biodiversity are ecologically connected and mutually dependent (Thies and Tscharntke, 1999). Additionally, there are mutual interdependencies among land cover, land use and biodiversity (Haines-Young, 2009). Biodiversity exists in a matrix

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of habitat patches, including managed and natural environments. Thus, habitat change is the most important cause of biodiversity change and loss in the ecosystem (MEA, 2005).

Activities that support and increase landscape heterogeneity, biodiversity and ecological sustainability in agroecosystems include the following: the development of biocentres (permanent existence of flora and fauna), biocorridors (allow migration of flora and fauna among biocentres), heterogeneous crops, crop structuring (organization of growing areas), polyculture and intercropping, crop rotation, biocontrol introduction, and modification of pesticide use (Caporali et al., 2010). It is known that habitat fragmentation affects biodiversity and is generally defined as a landscape-scale process involving both habitat loss and separation. However, habitat fragmentation per se does not necessarily have a strong impact on biodiversity. Therefore, if agriculture is managed in a sustainable way, it can play an important role in landscape sustainability because biodiversity should be preserved in protected agricultural areas (Donald and Evans, 2006). There are areas in the Mediterranean where the evolution of agroecosystems has produced a typical and diversified landscape, such as in Central Italy.

Indicators are essential for evaluating biodiversity. The "indicators" and the "indexes" (UNCED, 1992) are able to translate large quantities of information into simple numbers and permit the quantification of biodiversity, evaluation of sustainability and quick comparisons of various situations far in space and/or in time (Ghersa et al., 2002). In the scientific literature, the words index and indicators are occasionally confused. In this research, an index is considered to be a numerical synthesis aggregating several indicators to gain further information. Consequently, the indicator is a measure of an environmentally relevant phenomena (direct indicators considered interesting for the aim of the study). The index is the indirect quantification obtained through the aggregation of several indicators of significant phenomena relating to the state of the agroecosystem.

The use of biodiversity indicators and indexes enables us to evaluate agroecosystem sustainability at the landscape level (Moonen and Bàrberi, 2008). Ecosystem biodiversity indicators can be observed and measured in terms of composition (species richness and distribution) and variation in structure (e.g., fragmentation, ecotones, number and size of the patches) and function (flow paths relative to system processes at scale level) (Noss, 1990).

In this study, the biodiversity of an area of Central Italy was evaluated at the landscape level using indicators elaborated from data collected by remote sensing images, cartography, and fieldwork.

The main objectives of this research were the following: (i) to evaluate biodiversity at the landscape agroecological level using structural biodiversity indicators and indexes and (ii) to determine the influence of territorial characteristics, such as ownership and altitude in land cover patterns.

Materials and methods

Approach adopted

The methodology used in this study was based on the analysis of landscape hierarchical levels according to the concepts of landscape (Halffter, 1998), ecomosaics (Forman, 1995b) and integrated organization levels (Caporali et al., 2010). The landscape analysis was based on photograph interpretation, cartographical analysis, and fieldwork. All of the information obtained was used to build a database to determine the core set of selected indexes and indicators (Table 1) needed to evaluate agroecosystem sustainability in terms of biodiversity.

The aerial photography was classified according to vegetation type (described below) and provides an excellent source of data for performing the structural studies of a landscape (Sachs et al., 1998). Simple measurements of patterns, such as the number and size (area and perimeter) of patches, were taken because they can indicate the functionality of a land cover type better than the total area of the cover alone (Forman, 1995a). High-resolution aerial imagery is also effective for extracting individual objects and permits the detailed classification of lands. These types of images have previously been used to analyze landscape patterns (Dunbar et al., 2003).

In this study, the GIS analysis technique was applied (Balram et al., 2004). Aerial photos (imagery acquired in the year 2000 – 1 pixel = 1 m^2) were used to construct a land cover map (at the same resolution) for the entire study area (Forman, 1995a, 1995b). After photograph interpretation, the data (4% of mapped units) were verified directly on the field according to a method used by Congalton and Green (1999) and Cozzi and Ferretti (2003). The patches are small ecological landscape features that represent relatively homogeneous, spatially explicit landscape functional units. The number, area, and perimeter of the patches and the length of other landscape characteristics, such as streets and rivers, were used in this study according to Odum and Turner (1990) and Forman (1995a, 1995b). Each patch was classified into categories based on land cover. The land cover classes (LCs) selected for the study area were herbaceous crops (HC), tree crops (TC), woods (W), hedges (H), grassland (G), shrub-grassland (SG) (areas with shrubs scattered or widely distributed over fields of native herbaceous species), and buildings (B) in terms of surface and rivers (Wa) and roads (Ro) in terms of length. Consequently, it was possible to assess some important features of the landscape, such as heterogeneity, starting from structural information and described using the landscape indicators reported by Magurran (1988). The structural information refers to the use of natural resources, such as land, and affects the composition and the organization of these system components.

The landscape analysis was also distinguished by the ownership of the patches (private and public) and the altitude of the patches (plain, hill and mountain). These parameters were defined by national maps because they are a principal driving force of landscape composition and management.

Diversity consists of richness and abundance components. Diversity can be measured by one of these components or by measures incorporating both factors. Moreover, methods for evaluating the diversity of a high ecological hierarchical level, such as landscape, are closely related to techniques for measuring species diversity (Magurran, 1988).

In this study, the selected core set includes both new and existing indicators and indexes. Ecotones are transition zones between different ecosystems or patches and are generally characterized by a large variety of species and properties that at times do not exist in either of the adjacent systems (Odum, 1993). Particular attention is given to the core set construction. According to Duelli (1997), ecotones with high structural heterogeneity, such as forest edges and hedgerows, enhance regional biodiversity and the abundance and diversity of beneficial organisms. According to Marshall and Moonen (2002), ecotones (or field margins) in farmland play an important role in biodiversity by interacting with adjacent farmlands.

Each indicator refers to a specific characteristic. Several indicators and indexes were combined to understand the various agroecological aspects and different relationships among the components and important agroecosystem processes. The indicators and indexes used were the following (Table 1): the complementary of the Simpson index [S′], Margalef index [MAR], Menhinick index [MER], McIntosh index [*U*], Berger–Parker index [BP′], patch complexity index [PC], ecotope diversity index [*d*] (patch as ecotope)