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Methodological aspects for the evaluation of the quality of agro-ecosystems and landscapes that give rise.

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Abstract
Agriculture is a sector where current efforts for conservation of biodiversity at international and national levels are focussed, according to the requirements of the sustainable policies. Agricultural intensification and concomitant land abandonment in the less favoured areas have impacted strongly on the environment, and consequently, have had worrying effects on biodiversity. In Europe, the Habitats Directive (92/43/EEC) is a valuable tool for the preservation of biodiversity, while the reformed Common Agricultural Policy provides important instruments towards the direct management of biodiversity. In the future, the reformed Common Agricultural Policy is going to be based on a first "greener" pillar that is more evenly shared, with a second pillar that will focus on competitiveness and innovation, on climate change, and on the environment. Thus the assessment of the quality of agro-ecosystems through the use of the bioindicators that indicate their status becomes a fundamental need for the monitoring of farmlands at the European Community level. This study defines a methodology that provides cartography-based estimations of the quality of agro-ecosystems (using ArcGIS 9.1). This methodology uses information relating to the quality of the soil and the vegetation types in the area under study (here, the Conero Regional Natural Park). The Synvegetation Naturalness Index and the Simpson's Diversity Index are here combined and integrated, to allow the evaluation and implementation of management decisions based on the values of these indices. These choices must necessarily be compared with the dynamic serial processes, for which a simulation of farmland transformation over time is presented.

Key words: Phytosociology, Synvegetation Naturalness Index, Simpson's Diversity Index, Revised Universal Soil Loss Equation, management of rural landscape, Conero Regional Natural Park, dynamic processes.

Riassunto
L'agricoltura è un settore su cui si focalizzano attualmente gli sforzi per la conservazione della biodiversità in ambito internazionale e nazionale, secondo i presupposti di politiche ecosostenibili. L'intensificazione delle pratiche agricole e il concomitante abbandono dell'agricoltura nelle zone più svantaggiate hanno determinato infatti forti impatti sull'ambiente che hanno avuto ripercussioni preoccupanti sulla biodiversità del paesaggio rurale. A livello europeo la Direttiva habitat (92/43/CEE) rappresenta un valido strumento per la salvaguardia della biodiversità che trova nella PAC riformata importanti mezzi per la diretta gestione. La PAC riformata dovrebbe infatti poggiare in futuro su un primo pilastro "più verde" e più equamente ripartito e su un secondo pilastro maggiormente incentrato sulla competitività e l'innovazione, il cambiamento climatico e l'ambiente. Valutare la qualità di un agroecosistema mediante l'uso di bioindicatori in grado di rappresentarne lo stato diviene pertanto un fondamentale atto di controllo dei territori agricoli a livello comunitario. Il presente studio definisce una metodologia in grado di stimare lo stato di qualità degli agroecosistemi di tipo cartografico (software arcGIS 9.1) che si basa sulle informazioni inerenti la qualità dei suoli (Revised Universal Soil Loss Equation) e le tipologie vegetazionali, di tipo fitosociologico, del territorio indagato (Parco Naturale Regionale del Conero). L'uso degli indicatori di naturalità sinvegetazionale (Biondi & Colosi) e di diversità (Simpson), tra loro integrabili, consente di implementare e valutare le scelte gestionali con rapporto al valore degli indici. Tali scelte vanno necessariamente confrontate con i processi seriali di tipo dinamico dei quali si presenta una simulazione di trasformazione dell'area agricola nel tempo.

Parole chiavi: fitosociologia, Indice di Naturalità Sinvegetazionale, Indice di diversità di Simpson, Revised Universal Soil Loss Equation, gestione del paesaggio rurale, Parco Naturale Regionale del Conero, processi dinamici.

Introduction

Agricultural activities have always been predominant in the modification of the landscape, and they have been associated with the creation of natural habitats that can support high levels of biodiversity and provide for species and habitats of conservational concern (Baldock *et al*., 1993; Beaufoy *et al*., 1994; Bignal & McCracken, 2000). However, with the advent of agricultural mechanisation and of the Common Agricultural Policy (pre-1990), the dynamics of change in rural environments quickened in pace. This had a considerable impact on the depletion of the natural biodiversity that remained in rural areas, which had already replaced the more natural habitats. Thus agricultural intensification and concomitant land abandonment in the less favoured areas (and its consequent fragmentation) have indeed had a strong impact on the environment, and consequently, also have worrying effects on biodiversity (MacDonald *et al*. 2000; Plieninger *et al*. 2006; Dover *et al*., 2011).

In this context, a radical reform of the sector policies became essential to reduce this loss of biodiversity. Agenda 2000 thus gave to agriculture the important role of landscape conservation and biodiversity, as well as promoting the production of standard commodities (e.g., food and fibre). This introduced the concept of agricultural multifunctionality (Jordan *et al*., 2007) and established the foundations for the development of sustainable and competitive agriculture.

The American Society of Agronomy (ASA, 1989) uses the term "sustainable agriculture" to denote an agricultural practice that can fulfil certain conditions, including improvements to the quality of the environment and to the natural resources upon which it depends. Such agricultural practices must ultimately be closely connected with the conservation of biodiversity (Parris, 2002).

According to the Convention on Biological Diversity that was adopted at the Earth Summit in Rio de Janeiro in 1992, and to the European Commission (EC; DG AGRI 1999), the term "biodiversity" refers to the variability of the life, in all of its forms, and of the biological complex within which all species take part. It is, therefore, also an aggregate vision of the quality of the life, which can assume different characters that will depend on the scientific interpretation, on the organisation of this life within the biosphere, and on the effects that human interventions have on this organisation, both directly and indirectly.

Governmental associations like the United Nations Organisation (ONU), United Nations Environment Programme (UNEP), Food and Agriculture Organisation (FAO), Organisation for Economic Cooperation and Development (OECD) and other non-governmental organisations have launched projects that are aimed at halting the loss of biological diversity at all levels, from genetics to the territorial organisation of agro-ecosystems (International Treaty on Plant Genetic Resources for Food and Agriculture, 2001).

In Europe, the Habitats Directive (92/43/EEC) is a valuable tool for the preservation of biodiversity. Here, the reformed Common Agricultural Policy also provides important instruments for direct management of habitats and their biodiversity. Indeed, in the future, the reformed Common Agricultural Policy is going to be based on a first "greener" pillar that is more evenly shared and on a second pillar that will be focussed more on competitiveness and innovation, and on climate change and the environment. This will allow the European agricultural sector to unleash its latent production potential, particularly within the new Member States, to achieve the goals of European Strategy 2020 (European Commission, 2010).

Biological diversity in agriculture has been defined as "a subset of the general biological diversity", according to both the Convention on Biological Diversity and the National Strategy for Biodiversity (Italian Ministry for the Environment, Land and Sea, 2010). Maintenance of this biodiversity within an agro-ecosystem is necessary to ensure the continued supply of goods and services. This thus requires the definition and use of bioindicators for the assessment of the balance and quantity of the habitats within an agro-ecosystem, and for the monitoring of the changes these undergo over time.

On this basis, the study of the plant landscape is proposed as a valid method of analysis that is based on the documented abilities (Biondi *et al*., 2004) of the plant associations to assume the role of bioindicators. These macroindicators can be defined spatially and then mapped with the support of geographic information system (GIS) methodologies. This can thus provide thematic maps, such as the vegetational map (the phytosociological map) and the map of the plant landscape (the geosynphytosociological map), from which it is possible to define further needs and definitions.

The Conero Regional Park, located in central-eastern part of the Italian peninsula, is the territory that was chosen as case study for the assessment of agro-ecosystem quality. The presence of farmlands in the study area is important for the sustainability of the ecosystems, even when they are non-managed, semi-natural terrain (i.e. forests and grasslands). This is also because they provide an important food source for many wild animal populations that enrich the biodiversity of this Natural Park. Moreover the variety of the microhabitats that are interposed between the fields (the ecotonal areas) further increases the presence of different species in this study area.

The study area

The Conero Regional Natural Park is situated in the central-eastern section of the Italian peninsula, and it covers an area of about 6.000 ha. It is a coastal area that is characterised by a hilly morphology, within which there rises the promontory of Mount Conero (572 m above sea level).

The wide floristic and biocoenotic biodiversity that characterises the study area is determined by its central position with respect to the basin of the Adriatic Sea, by the height of the Mount Conero promontory and by the diversity of the geological, geomorphological and climatic conditions of the territory enclosed in this Natural Park (Brilli-Cattarini, 1967; Biondi, 1986; Biondi *et al*., 2002; Biondi & Colosi, 2005).

Over the years, the human activities of agriculture, animal grazing and forestry have further helped to shape this territory of the Natural Park. This has resulted in a diversified landscape, both in terms of its structure and is functions, and has promoted an increase in its original biodiversity (Biondi *et al*., 2002). Indeed, farmlands are the predominant component of the landscape of this study area, and for this reason their management becomes essential for the conservation of the biodiversity in this Natural Park. Currently, this agriculture-induced biodiversity is threatened by the abandonment of some of the previous agricultural practices, such as the cutting of the grasslands and sheep farming, which involve the development of the natural dynamic processes of vegetation recovery (Biondi *et al*., 2002).

As far as the geological aspects are concerned, the study area is mainly composed of limestone rock that is a part of the formations of the Umbria-Marche series, that arise from the Cretaceous to the Pliocene (Coltorti *et al*., 1991). The structural setting is provided by a dome-shaped anticline that has numerous faults of an Apennine–anti-Apennine orientation, which have been attributed to different tectonic phases (Pliocene, Pliopleistocene and Pleistocene phases) (Coltorti *et al*., 1991).

From the geomorphological point of view, four main areas can be defined that have specific characteristics (Cello & Coppola, 1983). The first of these is represented by the coastal belt, which is greatly indented by little bays, and is composed of various lithological and structural typologies: marl and sandstone, limestone and sedimentary deposits. The hilly section of the inland areas is shaped by several gentle hills that are characterised by an average height of about 250 m above sea level. The lithological substrata of these hills are mainly of pelitic-arenaceous and marly deposits of a Mio-Pliocene age. The third zone includes the Mount Conero promontory, which is the highest peak in the area, and which has an almost vertical slope towards the sea, and a more rounded shape towards the western, inland areas. Finally, the fourth zone comprises the plains that are formed by the pebble and pebble-sand alluvial deposits, and by lenticular formations of various extents, with fine silt-sand and silt-clay deposits of a few metres in depth (Coltorti *et al*., 1991; Nanni, 1997; Biondi *et al*., 2002). The climatic and phytoclimatic characterisation of the study area was carried out on the basis of data from the thermo-pluviothermic stations of Ancona, Ancona-Falconara and Ancona-Torrette. The thermo-pluviothermic diagrams highlight the Mediterranean character of the climate, with an arid summer through July and August (Fig. 1).

On the basis of the bioclimatic indices of Rivas-Martinez *et al*. (1999), the Mount Conero territory belongs to the Mediterranean macrobioclimate, with an oceanic pluviseasonal bioclimate, of an upper mesoMediterranean thermotype, and a low subhumid ombrotype. It is also evident that the vegetation is influenced above all by the meso-climatic and micro-climatic conditions that are linked to the geomorphological characteristics of this study area.

The vegetation of the study area

The landscape of the Conero Regional Natural Park is extremely heterogeneous, due to the geological and geomorphological complexity that characterises this region.

The forests consist mainly of holm oak woods, referred to the associations *Cyclamino hederifolii-Quercetum ilicis* Biondi, Casavecchia & Gigante 2003 and *Cephalanthero longifoliae-Quercetum ilicis* Biondi & Venanzoni ex Biondi, Gigante, Pignatelli & Venanzoni 2002, and of downy oak woods, referred to the association *Roso sempervirentis-Quercetum virgilianae* Biondi 1986 corr. Biondi & Casavecchia 2010. Also present, although as smaller percentages, there are hornbeam woods (*Asparago acutifolii-Ostryetum carpinifoliae* Biondi 1986 e *Scutellario columnae-Ostryetum carpinifoliae* Pedrotti, Ballelli & Biondi ex Pedrotti, Ballelli, Biondi, Cortini & Orsomando 1980), elm woods (*Symphyto bulbosi-Ulmetum minoris* Biondi & Allegrezza 1996), poplar and willow woods (aggr. a *Populus nigra* o *Populus alba* o *Salix alba* e *Rubo ulmifolii-Salicetum albae* Allegrezza, Biondi & Felici 2006) and *Fraxinus oxycarpa* woods (*Rubio peregrinae-Fraxinetum oxycarpae* [Pedrotti & Gafta 1992] Biondi & Allegrezza 2004).

Most of this territory is covered by anthropogenic vegetation, which consists mainly of *Pinus halepensis* and *Quercus ilex* mixed reforestation, and of the growth of crops.

Shrub vegetation is well represented in this territory, and this is seen as dense *Arundo pliniana* reeds (*Arundinetum plinianae* Biondi, Brugiapaglia, Allegrezza & Ballelli 1992) and thermophilic formations dominated by *Ampelodesmos mauritanicus* and *Coronilla valentina* (*Coronillo valentinae-Ampelodesmetum mauritanici* Biondi 1986). Other vegetation types occupy much smaller areas, which include very small grassland areas that can be referred to several coenoses, including the endemic *Convolvulo elegantissimi-Brometum erecti* Biondi 1986 (Biondi 1986; Biondi *et al*., 2002). There is also the typical

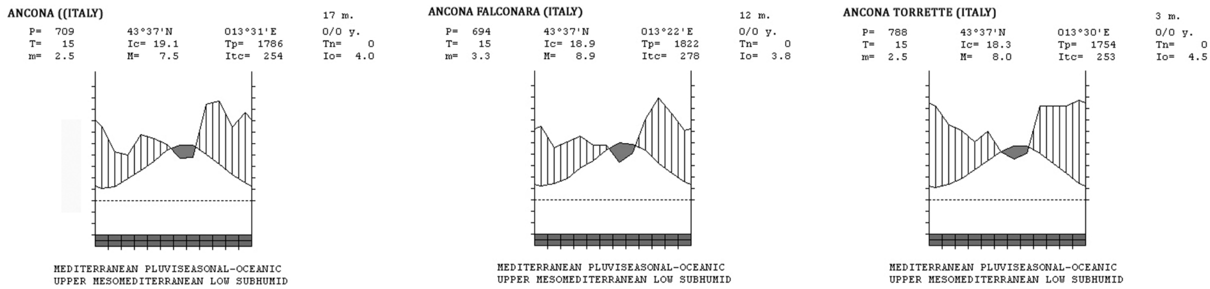

Fig. 1 - Bioclimatic diagram and classification of the Mount Conero area defined in this study.

vegetation of sandy and gravely coastal environments, with reefs and typical water and marsh environments that are important from a conservation point of view, and that are included in Annex I of the Directive 92/43/EEC.

The analysis of the vegetation and plant landscape was carried out in the study area of the Conero Regional Natural Park through phytosociological methods (Rivas-Martínez, 2005; Géhu, 2006; Biondi, 2011; Blasi *et al*., 2011; Pott, 2011). This has allowed the identification of, and discrimination between, the different plant coenoses, with the construction of thematic maps on a 1:10.000 scale.

Material and methods

The methodology used in this study was designed for the assessment of the agro-ecosystem quality of the study area based on land use and vegetation types. The analysis was completed through the processing of the vegetational, or phytosociological, map, the plant landscape, or geosynphytosociological, map, and the vegetation series map. All of these thematic maps were carried out within the Marche Ecological Network project (Biondi *et al*., 2007).

The processing of these maps was performed using the ArcGIS 9.1 ESRI software and the data in the computerised geographic database that forms the Marche vegetation information system (Pesaresi *et al*., 2007). In this way, the phytosociological map (Biondi *et al*., 2008), the geosynphytosociological map (Biondi *et al*., 2008), and the habitat map of the Natura 2000 sites included in the park (Biondi *et al*., 2008) were carried out. All of these maps are freely available and downloadable from the Marche Region website (http://www.ambiente.regione.marche.it/Ambiente.aspx), and from the "*Selva di Gallignano*" botanical garden of the Polytechnic University of Marche website (http://www.ortobotanico.univpm.it).

On the basis that an assessment of environmental quality of an area cannot be implemented using only a single indicator to express the complexity of the ecosystem, we chose to use multiple indicators that can be integrated with each other. These multiple indices were derived from the available data on the vegetation and plant landscape, and provide estimations of the quality levels that characterise the ecosystems of the study area.

The state of naturalness was evaluated following the Biondi & Colosi (2005) approach, whereby a naturalness level is assigned to each vegetation type. These degrees of naturalness (α_t) are computed on the basis of the floristic-vegetation knowledge of the *syntaxa* and of the dynamic stages for each vegetation type within every vegetation series (*sigmetum*). Using these α_t values, the naturalness of the entire vegetational series was evaluated according to the Synvegetation Naturalness Index (NSI; Biondi & Colosi, 2005, revised by Zivkovic, 2009):

$$NSI = \sum_{t=1}^{n} A_t/A_s * \alpha_t$$

where A_t is the area of the t^{th} stage of the series, t is the number of stages, A_s is the total surface of the vegetational series, and α_t is the naturalness degree of each *sigmetum*, the values of which lie between 1 and 32.

The range of variation of α_t was modified from that originally described by Biondi & Colosi (2005) to give greater weight to the final stages of the series. Therefore, the value 1 was assigned to areas subjected to a high human impact, such as urbanised and cemented areas, and 32 was assigned to the vegetation types with the highest levels of naturalness (i.e. forests). These index values thus vary between 1 and 32, and they are similar to the values of the naturalness degree of the individual vegetation stages.

The landscape diversity was calculated using the Simpson's Diversity Index (1949), which expresses the probability that two randomly chosen patches belong to the same vegetation type. This index takes into account not only the number of selected vegetation types present in the territory, but also how these are evenly distributed in an environment. To estimate this Simpson's Diversity Index, a 500-m-squared grid was overlaid on the topographical map of the territory of the study area (Fig. 2). Then, in each grid cell, the average slope was estimated and used to divide up the territory of the study area into different zones according to three classes of slope: a flat sector (S <3°), a medium slope sector (3° <S <10°) and a high slope sector (S >10°). These slope zones correspond to areas that are more or less suitable for crops, and for each one, the Simpson's Diversity Index (D) was calculated using the following formula (McGarigal & Marks, 1995):

$$D = 1 - \sum_{i=1}^{n} (p_i)^2$$

where p is the frequency relative to the i^{th} phytocoenosis and i is the number of the vegetation type from the whole of the territory. The frequency p_i is determined by calculating the ratio between the patch surface of the same vegetation type included in each grid cell and the total area of the grid cell. The D value is between 0 (all patches belong to the same phytocoenosis; landscape homogeneity) and 1 (the maximum level of landscape heterogeneity).

Assessment of the soil quality was carried out using the Revised Universal Soil Loss Equation (RUSLE; Renard *et al*., 1997), which estimates the potential average loss of soil, expressed as A = R * K * LS * C * P, in tons per hectare per year. This factor is the result of the integrated assessment of this variety of parameters that impact directly on the soil. Thus we evaluated the soil erodibility factor (K), which was derived from geological map of the study area on a 1:20.000 scale, the slope length and its degree of slope (LS), which was derived from a digital elevation model on a 1:10.000 scale, and the land cover (C), which was derived from the phytosociological map on a 1:10.000 scale. The rainfall run-off erosivity factor (R) and the support practice factor (P) were considered as constant (unit values) because of the absence of specific data and as they were deemed to be homogeneous throughout the territory.

Finally, a long-term (15-30 year) model of the management planning that we developed for a hilly sector of the Conero Regional Natural Park is described. This is based on the knowledge of the natural dynamics of the vegetation (*sigmeta*), and it allows the creation of simulation models of changes in the ecomosaic composition and configuration, which can then be used to evaluate the required management alternatives.

The simulations were implemented through the use of GIS technology, and they allow predictions of the future territorial transformations according to changes that can occur in the land management of a sample area. The potential vegetation of this sample area is represented by *Quercus virgiliana* woods referred to the association *Roso sempervirentis-Quercetum virgilianae* (*Roso sempervirentis-Querco virgilianae*

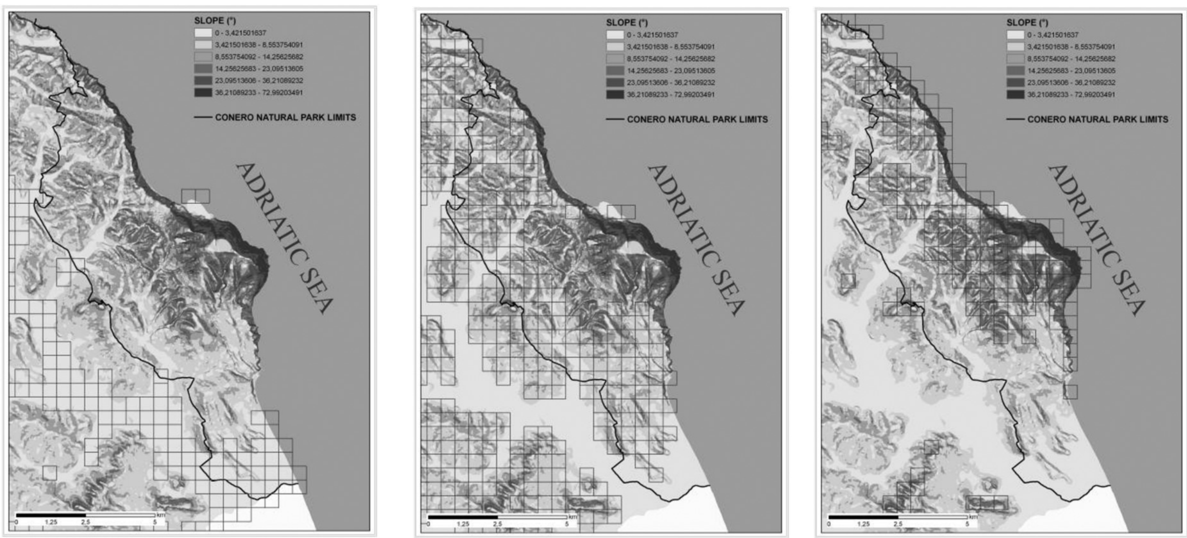

Fig. 2 - Representation of the three geographical areas divided according to the three classes of slope. From the left: flat sector (S <3°), medium slope sector (3° <S <10°), and high slope sector (S >10°).

Σ). According to this interpretation of the plant landscape, a dynamic model of the management of the study area is proposed.

Results

The landscape composition in terms of the use of the land was derived from the phytosociological map of the Conero Regional Natural Park, and it highlights the importance of this agro-ecosystem (Fig. 3). The human influence occupies more than half of the Park, and is seen as 49% farmland and 6% tree crops (vineyards and olive groves). Reforested and urban areas are also important (8%, 12%, respectively). It is understandable therefore that the naturalness of the park is relatively poor. Indeed, the naturalness map illustrates this situation clearly (Fig. 4), showing how the lower values of the naturalness (NSI) are distributed mainly across the farmlands, as well in the urban areas, as expected. We can make the same assessment for the habitats (*sensu* Directive 92/43/EEC), which although diversified, occupy only 10% of the study area (Table 1).

With this in mind, it is clear that the conservation status of the park depends, in particular, on the quality status of the agro-ecosystem. This can be improve by using the most correct and suitable management measures, and by promoting the inclusion of popular elements of the agriculture landscape (e.g. hedges, rows of trees, scattered trees, herbaceous and shrub ecotone) as well as the elimination of the use of herbicides and chemical fertilisers.

The landscape diversity map was constructed from the processing of the Simpson's Diversity Index in the three different slope sectors (Fig. 5). This shows that the high slope sector (D between 0.31 and 0.85) is the most diversified. This result does not define the quality of a territory by itself, and it is based on the frequency of each structural element already mentioned. So,

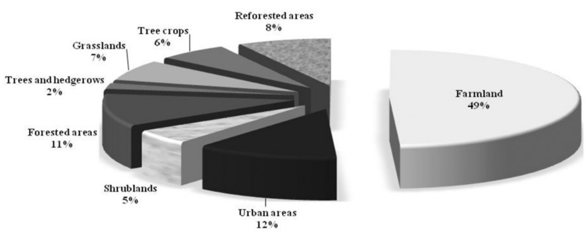

Fig. 3 - Structure of the vegetation cover in the Conero Regional Natural Park in terms of the land use. This map was constructed as a simplification of the phytosociological map.

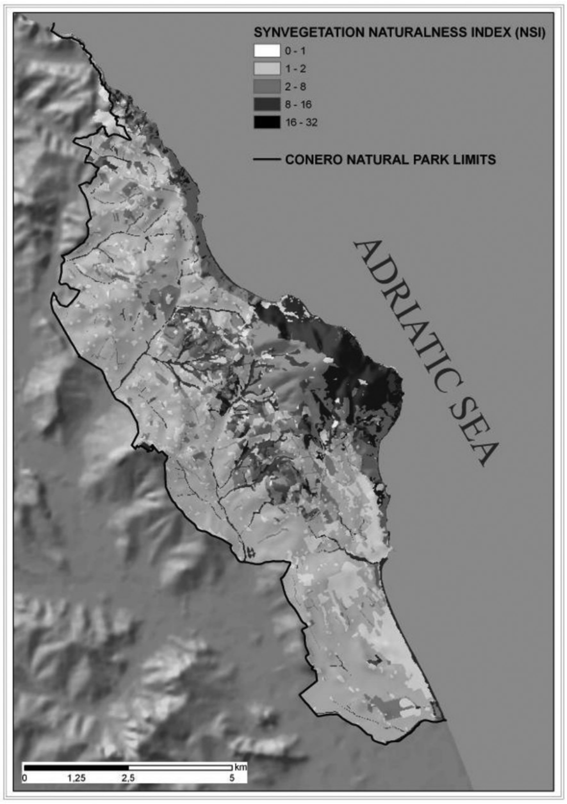

Fig. 4 - The naturalness map of the Conero Regional Natural Park. This map was constructed through spatial visualisation of the NSI values (from 1 to 32).

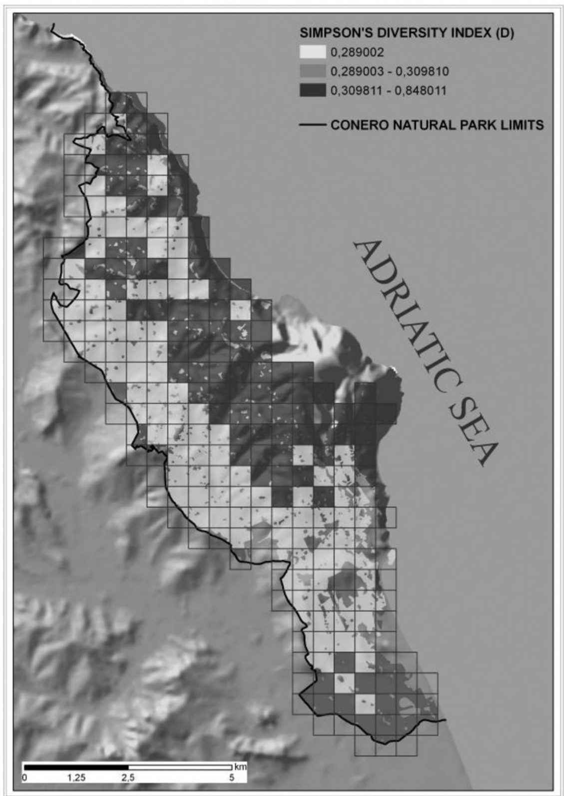

Fig. 5 - The landscape diversity map in the three different slope sectors of the study area.

Habitat Code	Percentage %	Present in the glade of
1160	0,11	
1210	0,90	
3270		*Aggr. a Popolus nigra*, *Popolus alba* e *Salix alba* e *Rubo ulmifolii-Salicetum albae* (92A0)
5130	0,22	
5310	0,02	
5330	0,67	
6110		*Asperulo aristatae-Fumanetum thymifoliae* Allegrezza, Biondi, Formica & Ballelli 1997
6210	0,51	
6220		*Cephalanthero longifoliae-Quercetum ilicis* var. a *Laurus nobilis* (5310), *Coronillo valentinae-Ampelodesmetum mauritanici* e *Coronillo valentinae-Ampelodesmetum mauritanici* var. a *Spartium junceum* (5330), *Convolvulo elegantissimi Brometum erecti* e *Centaureo bracteatae-Brometum erecti* (6210)
6430		92A0
91AA	1,86	
91B0	0,01	
92A0	1,58	
9340	5,36	
Totale	11,24	

Tab. 1 - The habitats of Directive 92/43/EEC that characterise the study area and the Park territory, the relative percentages for the whole territory, and the presence of a few habitats in the glades of other type of vegetations are shown. The last column indicates the type of vegetation (association) where a habitat is present, with the habitat code to which the association is referred given in brackets.

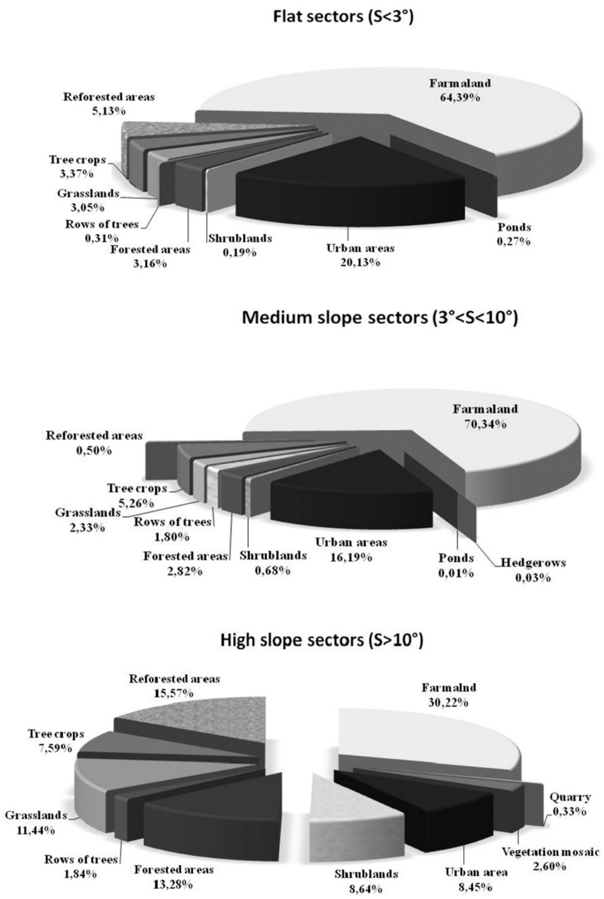

Fig. 6 - The structure of the vegetation cover in the three different slope sectors in the study area of the Conero Regional Natural Park, in terms of the land use.

in the flat and medium slope sectors, the Simpson's Diversity Index value is lower (between 0.29 and 0.31), as almost all of this zone comprises farmland and urban areas (flat sector, 64% and 20%; medium slope sector, 70% and 17%; respectively). The composition of the plant landscape in the high slope sector is rich in numbers and is well distributed (Fig. 6).

The assessment of the average soil loss was obtained according to the RUSLE, and it was mapped for the study area (Fig. 7). This shows a particularly high risk of erosion in the medium slope areas. Although the formula would be extremely sensitive to the topography of the area, in this context, the vegetation has a key role. Indeed, the average soil loss is greater in the areas under agricultural practices than in the high slope sectors, where farmlands are less frequent.

The predictability for agro-ecosystem management

The knowledge of future scenario simulations, in terms of the ecosystem composition, is one of the major problems concerning the ecological landscape. Synphytosociology has greatly developed this field of study, which is based on the vegetation series and the vegetation potentiality of the landscape unit (*geosigmeta*) (Biondi & Nanni, 2005; Biondi *et al.*, 2005; Biondi, 2011). Through this knowledge, we can assume management alternatives for the study area (e.g. absence or introduction of grazing management, abandoned farmland and grazing management at the same time), and we can estimate both the spatial and temporal changes over time compared to a starting state, which is as in the vegetation map. Defining the goals to be achieved with any type of intervention is therefore essential to the choice of the most suitable management method to be implemented, according to the dynamic processes of the vegetation recovery. These dynamic processes follow progressive and regressive paths that are already well known for the national territory, and in particular, mainly in central Italy. It should also be kept in mind that as a paradigmatic principle, land abandonment (as non-intervention) where specific types of potential vegetation are absolutely not present corresponds to a management choice. In addition, the more we know

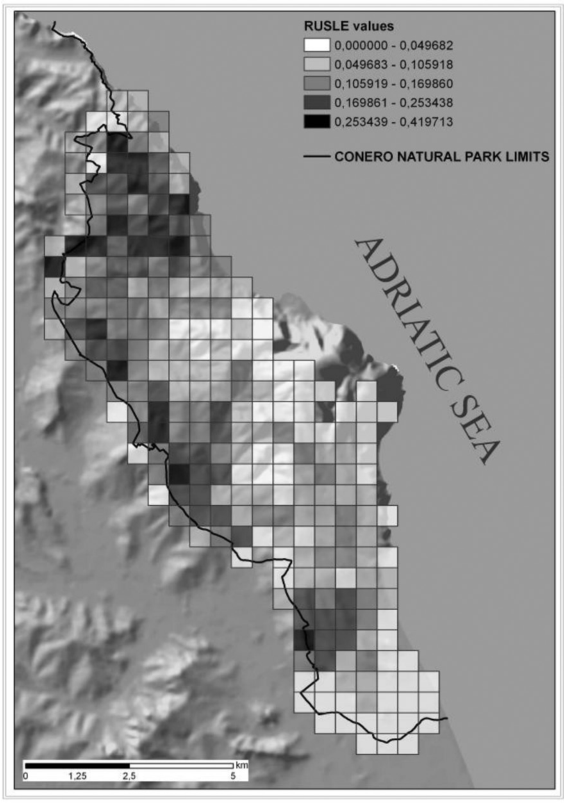

Fig. 7 - Cartographic representation of the average soil loss, obtained by processing the RUSLE formula within each grid cell.

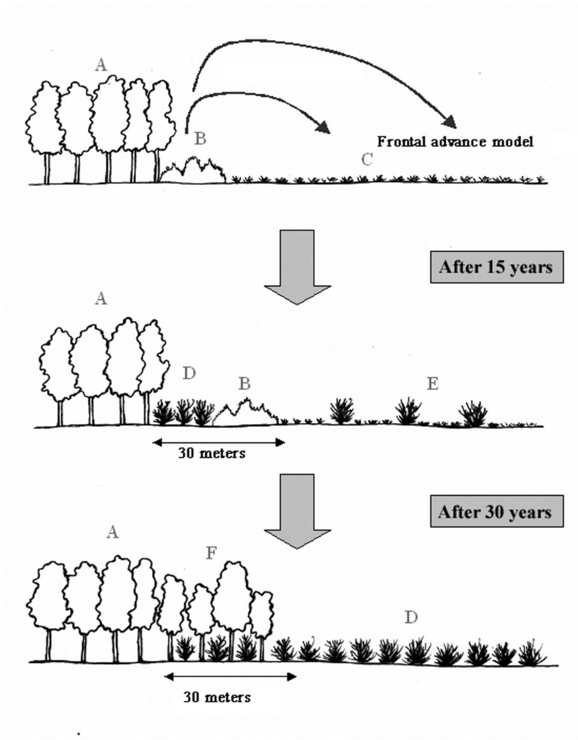

Fig. 8 - The frontal advance model of the forest in a hilly area of the Conero Regional Natural Park. The scheme shows the intercorrelated connections among the vegetation mantle, the wood, and the grasslands (or abandoned fields) and the forward spreading of the woods. *A* represents *Quercus virgiliana* woods (*Roso sempervirentis-Quercetum virgilianae*); *B* represents the mantle that serves as a centre for the spreading of the seeds of the shrub species, as common broom (*Spartio juncei-Cytisetum sessilifolii*); *C* represents the grasslands or abandoned fields; *D* represents the high-density shrubland; *E* represents the low-density shrublands; and *F* represents the pioneer wood plants.

about the vegetation dynamics, the better will be the predictability of the model chosen.

The management model presented here is characterised by a forecast that is considered valid for a period of 30 years. Thus, this represents a useful tool to describe the changes in the spatial arrangement of the vegetation in the plant landscape. This simulation relates to the hilly area sample, which belongs to the series *Roso sempervirentis-Querco virgilianae* Σ, when grasslands and abandoned fields are not managed (with the absence of grazing and mowing).

This model hypothesises a frontal advance of forest by 30 m (Fig. 8). This will be triggered mainly by the common broom (*Spartium junceum*), which is particularly active in vegetation recovery processes (Biondi *et al*., 2006). These data are from an experimental study where direct sampling was carried out for the plant populations that cover an Apennine area substantially similar to that of the Mount Conero area (Biondi *et al*., 2000; Ballerini *et al*., 2002; Ballerini & Biondi, 2002). The simulation, which considers the geological, pedological and bioclimatic settings of the area, and the vegetation types and their dynamic processes, assumes the conversion from abandoned fields and grasslands to low-density and high-density shrublands in the first 15 years, and then to the development of pioneer woods by the end of the first 30 years (Fig. 9).

This transformation will certainly increase the naturalness index (NSI), because of the spread of the forest-type coenosis, although it will also compromise the biodiversity as a result of the greater homogeneity of the area.

These two indices are therefore closely linked, and it is important to use them in an integrated way for the evaluation of the quality and conservation of an area to be more complete. Moreover, the integration of these indices with management models allows the complete assessment to be consistent with the landscape features, and to be functional in the choosing of the best management strategies.

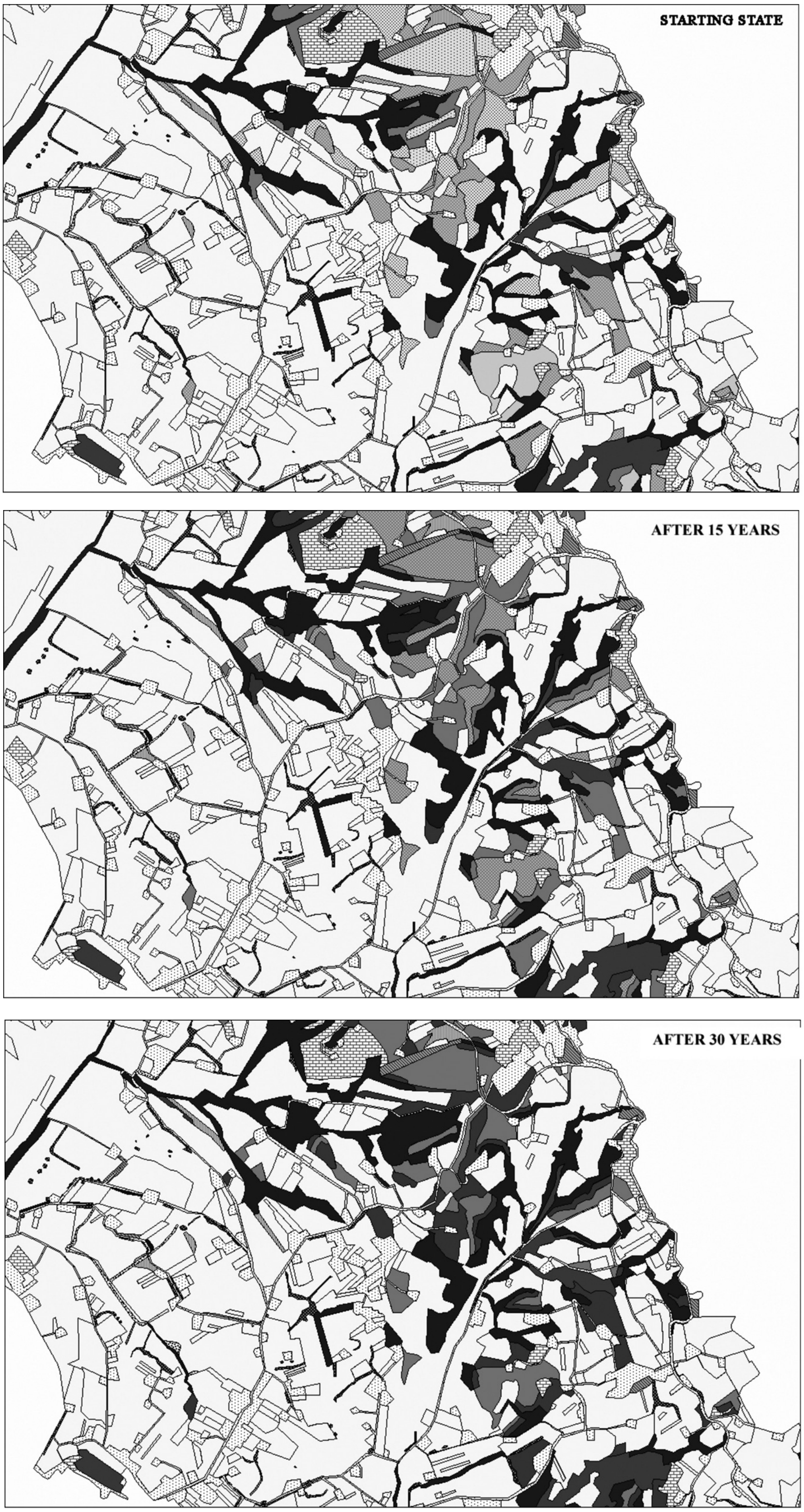

Fig. 9 - Representation of the changes in the plant landscape composition due to the interruption of grazing and mowing. The dark polygons represent the *Quercus virgiliana* forests, the grey coloured areas represent the *Spartium junceum* shrubs, and the light coloured polygons represent the grasslands and abandoned fields. The starting state (top) is the current composition of the plant landscape mosaic and was constructed from the vegetation map. The central panel represents the ecomosaic of the plant landscape after the first 15 years, and the bottom panel after the first 30 years.

Conclusions

The application of the naturalness (NSI) and landscape diversity (D) indices have highlighted how the zones of the study area subjected to farming practices are characterised by lower qualities than the areas covered by natural coenoses. Even the average soil loss analysis contributes to emphasise that the agro-ecosystem is more sensitive to erosion, which will inevitably reflect on the ecosystem quality.

These findings are, however, consistent with the kind of land use and farm types that are implemented in some of the zones of the study area, rather than in others. In these zones, farming is mainly concentrated in areas that are characterised by the best morphological conditions (e.g. optimal slope of the substratum), although this is mostly marginal farming because of its focus on consumption by the farming families (Russino, 1991). Therefore, natural elements related to rural environments, such as rows of tree, residual forests, hedgerows, and patches of vegetation, are still identifiable as they are closely related to traditional farming practices and to a type of rural landscape that still shows signs of share-cropping management (Paci, 1979; Anselmi, 2000).

The abundant presence of these elements, referred to as the "spread" by the Marche Rural Development Programme, ensures the quality of the agro-ecosystems, as these have an important protective function in terms of reducing soil erosion. The same structures assure a more biodiverse ecosystem that is rich in animal and plant species. Thus, management decisions aimed at increasing the density of these elements will result in overall soil quality improvements, and consequently in an increase in the phytocoenosis number (Taffetani & Rismondo, 2009).

In addition, the rural elements have the particular merit of working as an ecological network: they have an important role in the mobility of the wildlife species, they are habitats for numerous plant and animal species, including some that are of interest for hunting, and they are elements that improve the visual perception of the landscape and represent structural and the functional transition zones (ecotones), the importance of which has been well defined from an ecological point of view. Indeed, together with the ecotonal belts that originate through the contact between woods and farmlands, these elements become important targets and tools for managing and enhancing of the ecosystem quality (Biondi *et al.*, submitted).

The Rural Development Programme, 2007-2013, for the Marche Region stresses the importance of maintaining "a strip of land from the border of the woods, with a width of at least 5 m" (section 2.1.3), a measure that is already part of the Management Plan of the Conero Regional Natural Park (Biondi *et a*l., 2001). In this way, it is possible to create functional ecotonal belts that will promote increases in the biodiversity levels by creating transitional micro-ecosystems, such as vegetation edges and mantle, that are particularly rich in flora and fauna species. This measure would also increase the grassland areas within the Park, which are referred to as a habitat of community interest (Habitat 6210(*) "Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (*important orchid sites)". This issue is far from insignificant if we consider that the grasslands in the Park are characterised by very important coenoses from a conservation point of view, among which there is the endemic association *Convolvolo elegantissimi-Brometum erecti* Biondi 1986. These vegetational formations cover a small portion (12%) of the whole of the Park. This is an area that is significantly lower than those seen in the map attached to the volume describing the association (Biondi, 1986). This reduction is related to the natural proliferation of shrubs (mainly *Juniperus oxycedrus*) that have started to colonise the grasslands in the absence of farming and grazing.

It should be emphasized that the application of these management strategies must take into account the dynamic processes inherent in the vegetation itself. An abandoned field, where spontaneous renaturalisation processes can occur, will inevitably be affected by floristic and structural transformations: a progressive colonisation of the shrubs that take over the grasslands, the subsequent development of pioneer wood plants, and finally, the spread of the forest formations according to the vegetation potentiality that characterises the landscape unit considered. It is therefore necessary to know the ways, where possible, under which these transformations occur (Biondi *et al.*, 2005; 2006). Although the simulation model applied is a generalisation that simplifies the processes of the recovery of the vegetation, it remains a valid tool that can be used to estimate the changes in the eco-mosaic over the long term as a result of the implementation of different management choices.

The obtaining of an understanding of these mechanisms of recovery of the vegetation and the development of integrated models, like the one described here, form the scientific basis for the design of the intervention that a specific area might need, especially where this is a protected area where the recovery of biodiversity and natural ecosystems are the primary goal.

With these considerations and evaluations in mind, some important aspects on which to focus the management strategies can be identified. These strategies should coherently found the necessary economic resources in the measures provided by the Rural Development Plan of the Marche Region, as in agreement with the aims set out by the EC legislation on biodiversity (Habitats Directive 92/43/EEC) and in full compliance with the management goals as defined by the Management Plan of the Conero Regional Natural Park.

References

Anselmi S., 2000. Agricoltura e trasformazione dell'ambiente. Diboscamento e politica del grano nell'area marchigiana, secoli XIV-XVIII. In S. Anselmi (a cura): "Chi ha letame non avrà mai fame" Studi di storia dell'agricoltura. Quaderni di Proposte e Ricerche, n. 6, Ancona.

Baldock, D., Beaufoy, G., Bennett, G. and Clark, J., 1993. Nature Conservation and New Directions in the Common Agricultural Policy. IEEP, London.

Ballerini V. & Biondi E., 2002. Dinamica di popolazioni arbustive e preforestali nell'Appennino umbro-marchigiano (Italia centrale). Fitosociologia 39 (1) suppl. 2: 175-183

Ballerini V., Neri D., Zucconi F. & Biondi E., 2002. Il modello architettonico di *Spartium junceum* L. Fitosociologia 39 (1) suppl. 2: 163-173.

Beaufoy, G., Baldock, D. and Clark, J., 1994. The Nature of Farming: Low Intensity Farming Systems in Nine European Countries. IEEP, London.

Bignal, E. M. and McCracken, D. I. (2000) The Nature Conservation Value of European Traditional Farming Systems. Environmental Reviews, 8, 149-171.

Biondi E., 1986. La vegetazione del Monte Conero (con carta della vegetazione alla scala 1: 10.000). Regione Marche, Ancona.

Biondi E., 2011. Phytosociology today: Methodological and conceptual evolution. Plant Biosyst 145 Suppl. 1: 19–29.

Biondi E. & Colosi L., 2005. Environmental quality: an assessment based on the characters of the plant landscape. Plant Biosystem 139 (2): 145-154.

Biondi E. & Nanni L., 2005. Geosigmeti, unità di paesaggio e reti ecologiche. In: Carlo Blasi, Adriano Paolella (a cura) "Identificazione e cambiamenti nel paesaggio contemporaneo" Atti del Terzo Congresso IAED (Roma, 4/6 dicembre 2003): 134-140.

Biondi E., Bagella S., Casavecchia S., Pinzi M. & Calandra R., 2001. Analisi geobotaniche integrate per l'elaborazione del piano di gestione naturalistica del Parco Naturale regionale del Conero. Inform. Bot. Ital., 33 (1): 130-133.

Biondi E., Baldoni M. & Loiotile A., 2000. Utilizzazione del territorio e successioni diacroniche della vegetazione in un'area dell'Appennino umbro-marchigiano. In: a cura di E. Biondi & R. Colantonio "La pianificazione del paesaggio tra ri-naturazione ed iper-antropizzazione". Atti del Convegno - Ancona, 27-28 novembre 1997 - Accademia Marchigiana di Scienze Lettere ed Arti: 103-159. Tip. Trifogli, Ancona.

Biondi E., Casavecchia S. & Pesaresi S., 2006. Spontaneous renaturalization processes of the vegetation in the abandoned fields (Central Italy). Ann. Bot. (Roma), 6: 65-93

Biondi E., Casavecchia S., Nanni L., Paradisi L., Pesaresi S. & Pinzi M., 2005. Methodologies and processes for the analysis, conservation and monitoring of plant biodiversity. Ann. Bot. (Roma), V: 205-221

Biondi E., Casavecchia S., Nanni L., Paradisi L., Pesaresi S. & Pinzi M., 2005. Methodologies and processes for the analysis, conservation and monitoring of plant biodiversity. Ann. Bot. (Roma), V: 205-221.

Biondi E., Casavecchia S., Pesaresi S., Zivkovic L., submitted. Natura 2000 and the Pan-European Ecological network: a new method for data integration.

Biondi E., Casavecchia S., Pinzi M., Bagella S. & Calandra R., 2002. Excursion to the Conero regionale natural park. Fitosociologia 39 (1) Suppl. 3: 5-32.

Biondi E., Catorci A., Pandolfi M., Casavecchia S., Pesaresi S., Galassi S., Pinzi M., Vitanzi A., Angelini E., Bianchelli M., Cesaretti S., Foglia M., Gatti R., Morelli F., Paradisi L., Ventrone F. & Zagaglia C., 2007. Il progetto di "Rete Ecologica della Regione Marche" (REM): per il monitoraggio e la gestione dei siti Natura 2000 e l'organizzazione in rete delle aree di maggiore naturalità. Fitosociologia 44 (2) suppl. 1: 89-93.

Blasi C., Biondi E. & Izco J., 2011. 100 years of plant sociology: A celebration. Plant Biosyst 145 Suppl. 1: 1–3.

Brilli-Cattarini A. J. B., 1967. Il Monte Conero: aspetti floristici e fitogeografici. Esercitazioni Acc. Agr. Pesaro, 1: 11-32.

CBD (Convention on biological diversit)y, COP 10 Decision X/2-Strategic Plan for Biodiversity 2011-2020, 19 December 2010 (http://www.cbd.int/decision/cop/?id=12268).

Cello G., Coppola L., 1983. Aspetto geologico-strutturale dell'area anconetana e sua evoluzione plioquaternaria. Boll. Soc. Geol. It., Roma 10: 1-13.

Dover J. W., Spencer S., Collins S., Hadjigeorgiou I. & A. Rescia, 2011. Grassland butterflies and low intensity farming in Europe. J. Insect Conserv., 15:129-137. DOI 10.1007/s10841-010-9332-0.

European Commission, 2010. Report from the Commission to the Council and the European Parliament: the 2010 assessment of implementation of the EU biodiversity action plan. COM (2010) 548. Brussels: European Commission.

Géhu J-M., 2006. Dictionnaire de Sociologie et Synecologie végétales. Berlin-Stuttgart: J Cramer. p. 900.

Jordan N., Boody G., Broussard W., Glover J. D., Keeney D., McCown B. H.., McIsaac G., Muller M., Murray H., Neal J., Pansing C., Turner R.E., Warner K., Wyse D., 2007. Sustainable Development of the Agricultural Bio-Economy. Science, 316 (5831): 1570-1571. DOI: 10.1126/science.1141700.

MacDonald D, Crabtree JR, Wiesinger G, Dax T, Stamou N, Fleury P, Lazpita JG, Gibon A (2000) Agricultural abandonment in mountain areas of Europe: environmental consequences and policy response. J Environ Manage, 59: 47–69.

McGarigal, K. & Marks B. J., 1995. Fragstats: spatial pattern analysis program for quantifying landscape structure. Gen. Tech. Rep. PNW-GTR-351. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 122 pp.

Miller D.R., Rossman A.Y., 1995. Systematics, Biodiversity, and Agriculture BioScience, 45 (10) The Diversity of Systematics: 680-686.

Nanni T., 1997. Caratteri geologici del bacino idrografico del Fiume Musone. In Nanni T. (ed.): "Il bacino del Fiume Musone: geologia, geomorfologia e idrogeologia". Arti grafiche Scarponi di Osimo (Ancona): 15-47.

Paci R., 1979. Sedimentazioni storiche nel paesaggio agrario. In Sergio Anselmi (a cura): "nelle Marche centrali. Territorio, economia e società tra Medioevo e Novecento: l'area esino misena", Jesi.

Parris, K., 2002. Sustainable agriculture depends on biodiversity. OECD Observer No. 233 .

Pesaresi S., Biondi E., Casavecchia S., Catorci A. & Foglia M., 2007. Il Geodatabase del Sistema Informativo Vegetazionale delle Marche. Fitosociologia, 44 (2) suppl. 1: 95-101.

Plieninger T., Hochtl F., Spek T., 2006. Traditional land-use and nature conservation in European rural landscapes. Environ. Sci. Policy, 9: 317–321.

Pott R., 2011. Phytosociology: A modern geobotanical method. Plant Biosyst 145 Suppl. 1: 9–18.

Renard, K. G., Foster G. R., Weesies G. A., McCool D. K., & Yoder D. C., 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). Agriculture Handbook N° 703. U.S. Department of Agriculture Research Service, Washington, District of Columbia, USA., 404

Rismondo M., Lancioni A. & Taffetani F., 2011. Integrated tools and methods for the analysis of agro-ecosystem's functionality through vegetational investigations. Fitosociologia 48 (1): 41-52.

Rivas-Martínez S., 2005. Notions on dynamic-catenal phytosociology as a basis of landscape science. Plant Biosyst 139: 135–144.

Rivas-Martínez S., Sanchéz-Mata D. & Costa M., 1999. North American boreal and western forest vegetation. Itinera geobotanica 12: 5-316.

Simpson E. H., 1949. Measurement of diversity. Nature 163: 688.

Taffetani F. & Rismondo M., 2009. Bioindicator system for the evaluation of the environmental quality of agro-ecosystems. Fitosociologia, 46 (2): 3-22.

Zivkovic L., 2009. Analisi fitosociologiche e geosinfitosociologiche per la realizzazione delle reti ecologiche: il caso studio della Provincia di Ancona. Università Politecnica delle Marche, Doctoral Thesis, 2008/2009.