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Environmental Evaluation and Monitoring of Agro-Ecosystems Biodiversity

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1. Introduction

Agroecosystems are open systems, whereby continual human intervention is needed for the maintenance of an equilibrium created by man himself with the aim of maximising the production provided by a few domesticated plant and animal species. In these systems, the equilibrium is maintained through energy input from outside that makes the operations possible, which are designed to create optimal conditions for the growth of the cultivated plants and the animals raised.
The individual agricultural systems can be very different depending on the pedoclimatic characteristics of the territories, the types of cultivation practiced, and the intensive practices used, although in all cases, to maintain specific productive characteristics there is the need for human intervention. If they are abandoned to their natural evolution, these systems tend to recover their natural state, with increases in the areas occupied by spontaneous vegetation and with substantial changes in the population dynamics of the various species that make up the wild fauna, obviously at the expense of the species that benefit from the human actions.
Despite being characterised by a specific level of structural simplicity and by a decrease in their natural state that is caused by the modifications to the original environment that had the aim of obtaining animal and plant production for mainly food and energy uses, these agroecosystems cover a large part of the Community area. For this reason, the conservation of the biodiversity on a large scale needs interventions that are aimed at the preservation of the contexts that are most hard hit by human activities.
As well as having less value with respect to the areas characterised by a higher natural state, in various situations, the agricultural systems can provide great heterogeneity of the environment, and in cases in which the actions of man have not had a great impact, they can contain and maintain a considerable biodiversity patrimony.
For extensive agricultural systems, which are generally more common in the medium-high hilly and low mountain areas and are associated with agricultural systems of low impact, with good diversity of cultivation and the presence of semi-natural elements, these can provide a reasonable variety of habitats and large areas of contact between environments with different ecological characteristics (the ecotones). In these cases, the animal and plant

biodiversity levels are high and their maintenance is strictly linked to the management practices adopted by man, whereby the traditional activities favour such biodiversity.

On the other hand, the agricultural systems that are subjected to intensive cultivation that are generically represented in the plain or low hilly areas are poorer overall in landscape elements that are useful for the protection, survival and reproduction of the wild animal and plant species.

Over the last ten years, a greater environmental awareness has guided public opinion towards a re-evaluation of the role of man in the management of the agroecosystems on which the maintenance of a satisfactory level of biological complexity depends. From the agricultural point of view, we have therefore passed from a largely productive approach to management strategies that are aimed at an increase in the quality of the products and the rural environment.

Today, the recovery of ancient cultivated varieties or autochthonous races is encouraged and has taken on crucial importance from the politico-economic and social points of view within specific rural contexts. The appreciation and commercialisation of these products, together with the official recognition that guarantees their quality, can return the original identity to the rural territories of high landscape value. Given their specific characteristics, such territories would have been progressively excluded from the commercial networks of intensive and industrialised agriculture.

The return of the original production and local traditions is allowed by the measures introduced with the regulatory practices that are a part of agriculture today. The Common Agricultural Policy that is applied at a regional level through the Regional Plans for Rural Development, and the regulation of the Cross Compliance favour the modernisation of the sector and of the individual farms, the improvement of the socio-economic conditions of the rural populations, and the protection of the environment within which these populations live and work.

In this sense, the farms take on a multifunctional role: as well as providing quality production, and in some cases services such as refection, or educational or recreational activities (e.g., holiday and educational farms), are especially required to manage and maintain their environment. This guarantees periodic maintenance of the non-productive infrastructure, the presence of which has fundamental importance in the correct ecological functioning of the agroecosystem.

This non-productive infrastructure of the agricultural landscape serves many functions, among which there is the conservation of biodiversity, the management and filtering of the water, the protection from pollution, erosion, and hydrogeological problems, and the fixation of CO_2. Moreover, these constitute an excellent indirect opportunity for the farms, because they allow the farms themselves to identify with a varied productive context that is rich in life and well maintained.

It is obvious that the actions of those who operate in agriculture must be evaluated periodically in order to verify the effective validity and efficacy of their practices. For this, there is the need for indicators or indexes that provide a sufficiently detailed measure of the quality of the rural environment.

With the present study, following on from a description of the main vegetation typologies of an agroecosystem context, we will illustrate a method for the evaluation of the functionality of the rural contexts that we have applied in past years to various territories examined. The system that we have adopted is based on vegetation analysis and on the application of

indexes specifically designed for this. This system allows precise measures to be carried out, which can be integrated with other fauna bioindicators. It has been applied at different scales, which go from hydrographic basins of individual farms to small herbaceous areas.
The analytical instrument that we present is particularly useful for the monitoring of the conservation state of agroecosystems, and in general it provides a tool for the better management of rural territories.

2. Vegetation of the agroecosystem

2.1 Study of the plant landscape

The study of the vegetation represents the best-suited method for interpretation of the ecological potential of a territorial context. The arrival and establishing of one specific vegetational typology rather than another are phenomena that are mainly linked to the particularities of the climate, pedology and use of a specific area. The phytosociological method is a rapid and efficient analytical procedure based on floristic and statistical measures that is widely used throughout the World (Westhoff & Van der Maarel, 1978; Gèhu & Rivas-Martinez, 1981).
It is based on phytosociological sampling that is carried out in the field following the individuation of an ecologically homogeneous area. It consists in the forming of a list of all of the plants that are found in the chosen site and the assignment of coverage and interactive values to all of these following specifically designed scales (range, + → 5 for the coverage, and 1 → 5 for the interactions). A re-evaluation of the relevés of the area then follows, through comparisons with Tables of previously defined relevés or through statistical analyses, with the aim of defining the plant associations.
The association is the basic unit upon which phytosociology is based, which is found within a unit of territory that is ecologically homogeneous and is represented by significantly repeated floristic components. The phytocoenoses are organised according to a hierarchical system. The upper level of the association is represented by the alliance, which in turn is included in an order. At the apex of the hierarchical organisation there is the vegetation class, which expresses the structure, evolution and phytogeographical significance of the various typologies that are referred to it.
The identification and description of the plant communities represents the first level of investigation, which goes under the name of classical phytosociology analysis. The study of the vegetation is, however, expressed according to two further levels: synphytosociological and geosynphytosociological.
The synphytosociological investigation is based on the identification of vegetation series. This phase studies the dynamic relationships between the various associations within the same sigmetum, which consists of a portion of the territory characterised by the same pedoclimatic particularities and within which there is therefore space for a single typology of potential vegetation (the climax). This level allows identification of the interactions between the different phytocoeneses, as evolutive or regressive, that occur within a "tessella" of ecologically homogeneous territory (Biondi, 1996). The tessella therefore represents the biogeographical environmental unit of a hypothetical mosaic and it is defined on the basis of various factors: the nature of the substrate, the altitude, the exposure, and the slope.
Within each tessella, the associations are organised in serial interactions and the areas occupied by the same plant communities are not constant with time, but can vary according to the management practices that are followed.

The third level of analysis is known as geosynphytosociology, and it studies the interactions between typologies of the vegetation across different geographical environmental units. In this case, these interactions are defined as chain interactions, and the evolution of a coenosis towards another in chain contact is never expected to occur, because two such coenoses occupy landscape tessellae with different vegetational potentials.

The method has an important predictive role in the ecological analysis of the landscape and has particular use in the planning and management of the territory. It can be used on different scales and allows generalisable results to be obtained. Depending on historic data, it allows the performing of diachronic analyses. It has been adopted by the European Community as the official means for identification and description of the habitats that warrant protection according to Directive 92/43/EEC.

This investigation system constitutes, moreover, the basis of our analysis of the functionality of the agroecosystems. This has been possible following the application of the floristic-vegetational indexes that are now presented (Taffetani & Rismondo, 2009; Rismondo *et al.*, 2011).

2.2 The rural ecomosaic

As already discussed in the introduction, the agroecosystem normally appears within a context that has been modelled and strongly influenced by man. Although recognising the existence of agricultural realities that are greatly different both from the point of view of the vegetational potentiality and that relative to the productive uses and the impact of man, it is still possible to say that generally the rural ecomosaic is formed by an alternation between various tesserae that can be differentiated one from the other as a function of their ecological significance.

In the agricultural landscape, a succession of areas can be seen that are cultivated with techniques that are more or less intensive, as the plots, alternating with diffuse semi-natural elements that gradually tend to occupy more space in passing on to contexts with less human impact. These are usually found in the zones that are less accessible and where mechanical tillage is less possible, and they are more frequent in the agricultural areas that are less intensively cultivated or are subjected to particular protection regulations.

The semi-natural elements are identified by formations such as rows of trees, hedges, small woods (either spontaneous or planted by man) and their ecotones, grasslands, abandoned fields, herbaceous strips along ditches, slopes, small farm tracks, edges of fields and ditches, and riparian formations.

The agricultural areas that are more variegated and richer from a naturalistic point of view usually occupy the zones in which the local population knew how to maintain and value traditional techniques and production in equilibrium with the potentiality of the surrounding environment. However, more and more often the areas that are disadvantaged from a productive point of view tend to be progressively abandoned; this allows evolution of grass coenoses, an increase in the areas of the shrub and tree communities, and the consequent loss of ecosystem variety. All of the units making up the agroecosystem mosaic take on their own functional significance within the context analysed. This significance is the fruit of all of the previous progressive productive uses, and it can be photographed in a clear and precise way, with the identification of the floristic-structural characteristics and with the subsequent syntaxonomic classification of the investigated areas.

In this section of the present study, the vegetation classes will be presented that are more represented in the rural systems that are under analysis. These last refer to the Adriatic

sector of the Italian peninsula, from the region of Fruili Venezia Giulia to Molise (Fig. 1). The geographical localisation and the pedoclimatic and morphological characteristics of the areas under study are summarised later. Brief descriptions of the ecological characteristics and the evolutive significance of the syntaxonomic classes are given. Moreover, the main orders are illustrated, and some of the vegetational typologies are described that can be typically seen in the agricultural ecosystems.
The classes are ordered according to their physiognomic and ecological characteristics: the serial typologies (therophyte vegetation, perennial grasslands, forest edges, shrub layers and mantles, woods) have been differeniated from the category relative to the acquatic azonal vegetation (both herbaceous and arboreal).

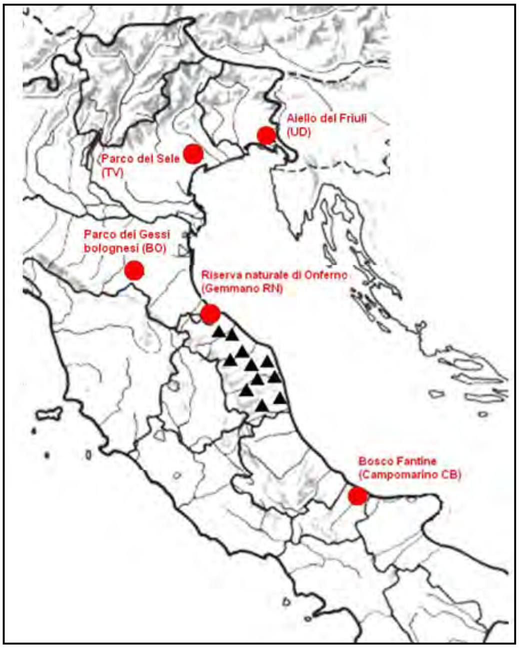

Fig. 1. Map of the study areas.

2.3 The therophyte vegetation

2.3.1 Class *Stellarietea*

The plant communities that have mainly therophyte species are referred to the class *Stellarietea*, and they are characterised by an annual cycle and reproduction by seed (Rivas Martinez et al., 2002).
This syntaxon includes phytocoenoses of commensals of annual-seeded crops, as both autumn to winter and spring to summer, and initial and immature grasslands that are seen under conditions of recurring disturbance, mainly by man. This disturbance can be caused by herbicides or by movement or removal of the surface layer of the soil.
In a serial context, the class *Stellarietea* occupies the first evolutionary step. The phytocoenoses of this syntaxonomic unit take on pioneering characters and tend to be the first to grow on bare substrata. In these communities, exotic species or species with a large

distribution that were accidentally introduced by man are often strongly represented, and these are distinguished by their high invasive capacity; in some cases, these same species have a dominant physiognomy and end up by taking over from the other species.

Stellarietea has a ruderal, nitrophilous or semi-nitrophilous character, and it is diffuse throughout the World, except in the tropical zones. Relative to the temperate zones and to part of the Mediterranean bioclimate distribution area, five different orders can be identified, as described below.

- *Centaureetalia cyani*: This syntaxon includes the infesting coenoses of the autumn to winter crops (cereals) without irrigation. This is well represented on marly-arenaceous or calcareous soils more or less rich in nutrients and alkaline or subalkaline, in the hilly and montane zones of the temperate bioclimate.

  Biforo testiculatae-Adonidetum cupanianae (Fig. 2): This is the reference association for the commensals of the autumn to winter seeded crops of the marly-arenaceous hilly sectors of central Italy. It can be found in the Mesomediterranean and temperate hilly bioclimate belts, and it belongs to the alliance *Caucalidion lappulae*. The species belonging to this association have relatively early flowering, and the characteristic species are *Legousia hybrida*, *Adonis annua* ssp. *cupaniana*, *Papaver hybridum*, *Bifora testiculata*, *Gladiolus italicus* and *Valerianella eriocarpa*.
- *Aperetalia spicae-venti*: This order groups the coenoses that are mainly found on the alluvial plains of the temperate zones, as commensals of autumn-winter annual-seeded crops. It is well represented on subacid, sandy or sandy-silty soils that are well supplied with water.
- *Solano nigri-Polygonetalia convolvoli*: The associations coming from this syntaxonomic unit are composed of infesting species that can colonise the sown spring-summer crops (both irrigated and not) or the rows between grapevines that have not been seeded. This syntaxon is distributed mainly in the temperate zones and in part in the zones with a Mediterranean bioclimate.

  Linario spuriae-Stachyetum annuae: This belongs to the alliance *Polygono-Chenopodion polyspermi* and it represents the infesting vegetation of spring-summer crops in the hilly clayey and marly zones that are not irrigated. It is diffuse in many sectors of the Italian peninsula south of the River Po, and it is mainly present in situations of strong edaphic aridity, interrupted only by the contribution of the limited summer rain. The characteristic species are *Linaria spuria*, *Stachys annua* and *Picris echioides* (Baldoni, 1995).
- *Chenopodietalia muralis*: This order represents the nitrophilous-ruderal vegetation of the Mediterranean area that is relatively mesophilous. It includes herbaceous pioneering coenoses, often dominated by exotic species, which grow on soils heavily enriched in nitrogen nutrients.
- *Sisymbrietalia officinalis*: This syntaxon includes the pioneer and ruderal plant communities of temperate Europe and the Mediterranean that grow along the edges of farm tracks and paths, which is also a habitat that is often subjected to compaction (and therefore on substrata that are particularly compact) and near to human habitation.

  Sinapidetum albae: This coenosis belongs to the alliance *Sisymbrion officinalis* (of the temperate zones) and overall it is dominated by the early flowering Crucifera *Sinapis alba*, which characterises the edges of the tracks and fields in March and April with its garish flowers. It has been described for the hilly Marche territories (Allegrezza Ballelli and Biondi, 1987) and prefers soils rich in organic deposits that are frequently disturbed or removed.

Aveno barbatae-Brometum diandri: This is an association of herbaceous margins that is relatively diffuse in the central Adriatic sector of Italy and it belongs to the alliance *Hordeion murini*. It is characterised by the species *Avena barbata* and *Bromus gussonei*. It has a spring development and it is easy to recognise in the month of April, while it tends to completely dry out with the advancing season; it is often found in situations where the soil is removed periodically to avoid invasion of the farm tracks by the vegetation and to keep the rain drains free (Biondi & Baldoni, 1991).

- *Thero-Brometalia*: This includes the nitrophilous-ruderal associations of a xero-thermophilous type that are limited to Mediterranean and Submediterranean territories. These coenoses are usually found where there are high nutrient concentrations in the soil.

Fig. 2. *Biforo testiculatae-Adonidetum cupanianae*.

2.3.2 Class *Polygono-Poetea*

The class *Polygono-Poetea* is diffuse throughout the World and includes the vegetation typologies that are characteristic of habitats that are compacted. It is linked to humanised and strongly compacted environments, as it has the ability to grow in environments such as the edges or centres of dirt tracks; some communities can colonise the spaces between the bricks of paved tracks or paths (Rivas-Martinez et al., 2002). The phytocoenoses in this class are ephemeral and are made up of annual plants, and in some cases, small perennials, which are anyway always characterised by the ability to grow in edaphic contexts with relatively high nitrate contents. In the agroecosystem, the communities that are included in this syntaxon can frequently be found where the tyres of farm vehicles have compacted the ground.

Although this is a vegetation class that has a strong human footprint, *Polygono-Poetea* does not tolerate excessive disturbance and reacts negatively to practices such as weeding or soil tillage, which, as already indicated, more favours species from the class *Stellarietea*. From an evolutive point of view, *Polygono-Poetea* is positioned a step higher than *Stellarietea*.

The only order recognised for this class is *Polygono arenastri-Poetalia annuae*.

- *Polygono arenastri-Poetalia annuae*: This order includes communities of grass, whether or not creeping, that can be found in temperate and Mediterranean climates, in sandy, silty and clayey edaphic contexts, and in some cases, rich in limestone. This order has a large ecological valence: some of the coenoses included in the order favour more wet and shady locations, others instead grow in more arid contexts.

Poetum annuae: These communities are dominated by the small Graminacea *Poa annua*, and they are part of the alliance *Matricario-Polygonion avicularis* and are found in contexts subjected to strong compaction and with soils that are not subjected to water retention. The dominant species is accompanied by many other entities of the same class that are particularly resistant to soil compaction. This coenosis is spread diffusely through the agroecosystems analysed, although it had not been previously noted for the territories investigated. Instead, it had been found in various locations on the Balcan peninsula Carni et al., 2002; Carni, 2005; Silc & Kosir, 2006).

Coronopodo procumbentis-Sclerochloetum durae (Fig. 3): This coenosis grows in situations under more intense impaction and it usually has a very low coverage index (50%-60%) and is dominated by the Graminacea *Sclerochloa dura*. It belongs to the alliance *Sclerochloo durae-Coronopodion squamati*, reaching its full development between the end of April and the beginning of May, and it is found along farm tracks. It has been described for the subcoastal territory of Marche (Biondi et al., 2002).

Fig. 3. *Coronopodo procumbentis-Sclerochloetum durae*.

2.4 The perennial grasslands

2.4.1 Class *Artemisietea*

This syntaxonomic unit includes pioneer associations that are mainly made up of biennial and perennial species, usually medium to tall (Rivas Martinez et al., 2002), that can be found in contexts affected by human activities, and that can rapidly colonise locations with uncovered soil or occupied by less evolved coenoses (of the class *Stellarietea mediae*).

Typical examples are represented by the plant communities of abandoned fields, of the calanchi, of the edges of fields and tracks, in the ruderal zones near to houses, and also in the urban environments or on the outskirts of cities. These coenoses grow under conditions of recurrent disturbance, although not excessive or systematic, and they represent the first evolutive stage towards perennial grass formations that are particularly stable. These last can grow in better conserved environments and are usually managed by periodic removal of the biomass or with pasturing, and they are included in the classes *Molinio-Arrhenatheretea* and *Festuco-Brometea*.

The class *Artemisietea* is found in territories with a Mediterranean-pluviseasonal and holartic-temperate climate and it definitely prefers substrata enriched in nutrients, and especially in nitrates. The syntaxa referred to this class grow on various types of substrata, mainly clayey and alkaline. From the evolutive point of view, they represent a higher level than the other two classes presented above. In the areas of temperate Europe and the Mesomediterranean, three orders are found.

- *Agropyretalia repentis*: This syntaxon includes the post-cultivation, ruderal grassland formations that are medium nitrophilous and are found in the Eurosiberian temperate and Submediterranean areas, on substrata that are mainly of the clayey type. The coenoses here are particularly diffuse in agricultural areas that have been abandoned, as they mainly characterise plots that have not been used for 3 or 4 years or the calanchi areas, with low or higher salt concentrations in the soil, that have been subjected to strong erosive morphological modifications.
  **Senecio erucifolii-Inuletum viscosae* (Fig. 4): This phytocoenosis is found in the abandoned fields of the central Adriatic hilly sectors with temperate or Submediterranean bioclimate (Biondi & Allegrezza, 1996). The diagnostic species are *Senecio erucifolium*, *Bellevalia romana* and *Cirsium italicum*. This community is included in the alliance *Inulo-Agropyrion* and it is usually physiognomically dominated by the Composita with a Euromediterranean distribution area, *Inula viscosa*. It prefers marly and clayey terrain and in situations that are more mesophilous it is enriched in species of the class *Molinio-Arrhenatheretea*, such as *Holcus lanatus* and *Agrostis stolonifera*.
- *Artemisietalia vulgaris*: This represents the central order of the class, and it includes ruderal and moderately mesophilous communities of the temperate areas. These coenoses often grow on soils that are sufficiently deep and wet, as well as being well supplied with nitrogenous nutrients, and they can also be found along the edges of water courses.
- *Onopordetalia acantii*: This order is represented by the ruderal and pioneering phytocoenoses of the meso-orotemperate or thermo-oromediterranean areas. These communities are usually dominated by species of thistles, and in particular of the genus *Onopordum*, and on average, they are more thermophilous than the formations included in the other two orders, They grow on soils of various natures: sandy, clayey and more or less calcicole.

Fig. 4. *Senecio erucifolii-Inuletum viscosae*

2.4.2 Class *Molinio-Arrhenatheretea*

Molinio-Arrhenatheretea is the vegetation class to which the regularly cut grasslands are referred, or in some cases pastured, that develop on deep, wet, neutral to subacid soils that are well supplied with nutrients, in territories with a prevalently flat or slightly sloped morphology (Rivas Martinez et al., 2002). The species of this class are mesophilous, nitrophilous, and well used as forage, and they are favoured by human practices, with the cutting and removal of the biomass.

In the agroecosystem, the communities of this syntaxonomic unit are spread in particular in the valley bottoms, along with grasslands or in strips of grassed terrain at the edges of ditches, fields or farm tracks. In some cases, they collonise contexts subjected to great human disturbance, such as the compacted environments or the grass areas by farm houses.

The phytocoenoses of *Molinio-Arrhenatheretea* can survive short periods of flooding, which frequently occur during spring, but they cannot tolerate periods of drought. This class has a Mediterranean, thermo-boreal and temperate distribution area, although it finds its optimum in the Eurasiatic area. From an evolutive point of view, the coenoses of this syntaxon can be considered among those herbaceous with intermediate maturity and stability levels. In the temperate and Submediterranean contexts, the hierarchical subdivision reveals the presence of six orders.

- *Molinietalia caeruleae*: This order has a central-European distribution area and includes temperate and mesophilous grasslands and pastures that are often cut and are linked to the presence of terrain that is almost always wet. They include both the communities of the non-fertilised and oligo-mesotrophilous grasslands and the fertilised and often flooded habitats that are found on the low-montane to montane zones.
- *Arrhenatheretalia eliatioris*: This includes fertilised grasslands and pastures with a Eurosiberian and Submediterranean distribution area. The communities are mainly dominated by *Arrhenatherum eliatius* or *Cynosurus cristatus*, and grow on deep and wet soils that have clayey or calcareous origins and good levels of mineral fertility, and that are well drained.
- *Plantaginetalia majoris*: This syntaxonomic unit includes the herbaceous communities that grow on wet eutrophic soils, which are sometimes flooded and are pastured and compacted, with a temperate and Medierranean distribution area. They are particularly well represented in the agroecosystem, on substrata that are mainly clayey or on alluvial plains, at the edges of ditches or at the sides of tracks, in edaphic contexts generally wet also in summer.

  **Lolio perennis-Plantaginetum majoris*: This association is dominated by *Lolium perenne* and *Plantago major*. It is included in the alliance *Lolio-Plantaginion*, and is linked to conditions of compact soil that is rich in nutrients and is wet. It is well enough spread in the investigation area, and in particular at the sides or along the centres of farm tracks, or in herbaceous areas subjected to intense impaction and enriched in nitrates due to the pasturing of animals.

  **Festuco fenas-Caricetum hirtae* (Fig. 5): The grasslands of *Carex hirta* of the alliance *Mentho-Juncion* find their ecological optimum in small depressions that are flooded and disturbed due to compacting, pasturing and ruderalisation (Ninot et al., 2000). Although they were not previously found in the area investigated, the association was found in some locations in Marche, along the banks of rivers and ditches, where it tends to grow on deep and wet substrata that are rich in nutrients and are periodically flooded.

  **Ranunculetum repentis*: Overall, these formations are dominated by *Ranunculus repens* and are characterised by their hygrophilous condition, as they can colonise the valley bottoms that are adjacent to water courses and often flooded, or plain areas that have slight depressions and with surface water. They belong to the alliance *Mentho-Juncion* and in the agroecosystem their presence is limited to the zones that are under good conservation.

- *Paspalo-Heleochloetalia*: This order includes grassland coenoses that are characeristic of the river banks that are sometimes flooded or submerged, or of the edges of small stagnant ponds or pools of water. These grow on muddy terrains that are rich in minerals and nitrogenous substances, and they are often characterised by being physiognomically dominated by stolonate exotic plants
- *Trifolio-Hordeetalia*: This syntaxon includes the permanent grasslands that grow on the previously lacustrine basins or on the alluvial plains. Its distribution area is limited to the Balcan peninsula and the central-southern Apennines, in which environment it is well represented by various associations that can be found on the karst high-plains, mainly in depressions that are particularly subjected to occasional flooding.
- *Holoschoenetalia vulgaris*: This includes grasslands with a dominance of rushes with a Mediterranean or Submediterranean distribution area and summer development. These coenoses are found on deep and muddy soils with a mainly silty and clayey fabric, although in other cases also on gravely or sandy sediments. They are well represented mainly corresponding to or near to bends in rivers with weak water currents.

Fig. 5. *Festuco fenas-Caricetum hirtae*

2.4.3 Class *Festuco-Brometea*

The class *Festuco-Brometea* includes the grasslands of human origins that in general are used for animal pasture. The communities included in this syntaxon are mainly composed of hemicryptophyte species characterised by good forage value; of the grasslands, these represent those with greater levels of stability and maturity. These formations are often particularly rich from a floristic point of view and they play host to numerous entities of great interest, among which there are various species of orchids.

The distribution area of this syntaxonomic unit includes the Eurosiberian and the western Mediterranean regions. From an edaphic point of view, the grasslands of *Festuco-Brometea* are baso-neutrophilous or, in some case, slightly acidophilous, and they generally prefer deep and rich soils, and anyway well drained, although they sometimes also grow on relatively superficial substrata (Rivas Martinez et al., 2002).

In the agroecosystem, the coenoses of this class are relatively diffuse in well conserved contexts that are under techniques of extensive cultivation, while their diffusion is lower in the zones that are more subjected to human influence. From the management point of view,

the abandonment of grasslands of *Festuco-Brometea* favours the recollonisaton of the pastures by shrub species, with the consequent floristic impoverishment and drastic reduction in the plant biodiversity. The associations that grow on calcareous substrata are protected according to the specific Community Directive 92/43/EEC, as habitat 6210, and therefore they need to be managed in such a way as to guarantee their conservation.
In the territories that were included in our analysis, the grasslands of this class can be included in the order *Brometalia erecti*.

- *Brometalia erecti*: This order includes the grasslands that substitute the forest vegetation and that are found on calcareous or marly-arenaceous substrata, which is more or less deep, in the temperate bioclimate areas, including the zones that fall within the Submediterranean variant. Its distribution area includes central and western Europe (Royer, 1991). The coenoses of this syntaxon are diffusely represented throughout the Italian peninsula.

  **Centaureo bracteatae-Brometum erecti* (Fig. 6): The grasslands attributed to *Centaureo-Brometum* are mesophilous continuous formations that to grow often as a post-cultivation stage and that are present on marly-arenaceous, arenaceous-clayey, and marly-calcareous substrata of the hilly slopes. These are widely diffuse in the northern and central Apennines (Biondi et al., 2006). They are included in the alliance *Bromion erecti* and their characteristic species are *Brachypodium rupestre*, *Galium album*, *Carex flacca* ssp. *flacca* and *Centaurea bracteata*.

Fig. 6. *Centaureo bracteatae-Brometum erecti*.

2.5 The vegetation of the forest edges
2.5.1 Class *Galio-Urticetea*

The class *Galio-Urticetea* is represented by the high-grass communities that grow along neutrophilous margins that are in contact with pre-forest or forest formations, and in some cases also near to artificial tree plantations, as for example the reforestation of conifers. Its distribution area includes territories with a thermoboreal, pluviseasonal Mediterranean and holarctic temperate bioclimate (Rivas Martinez et al., 2002).
The sites where it is possible to find vegetation of the class *Galio-Urticetea* are still today, or were in the past, under modifications attributable to human activities, which results in particular in enrichment of the soil with nitrogenous substances (Poldini, 1989). The plants

of the groups referred to this class are generally characterised by a good ability to live under shady conditions. They prefer deep soils with a good water content and rich in nutrients.
In the agroecosystem the plant associations of this syntaxon can be seen in sites such as the margins of ditches or the edges of copses, rows of trees, or hedges, and they can often be found also in human contexts, like in and around urban areas. They can grow on acidic substrata as well as on alkaline terrain.
From the serial point of view, the vegetation of this syntaxon can be identified as a pre-forest herbaceous stage that grows in the contact zones beween the herbaceous hemicryptophytic and shrub-arboreal vegetation. From the evolutive aspect, as it is mainly linked to the influence of man, and it is considered less mature with respect to the edge vegetation of the class *Trifolio-Geranietea*, which instead is found in contact with arboreal formations that are better conserved and structured.
Galio-Urticetea can be subdivided into two orders according to their ecological characteristics.

- *Galio-Alliarietalia*: This order is represented by the coenoses of the nitrophilous pre-forest or forest margins (Font et al., 1988). These can also be seen in small clearings, and they are linked to temperate and Mediterranean bioclimates, and require conditions of deep soil. The formations of this syntaxon can be more or less sciaphilous and their survival depends on good water availability of the soil also in summer; they are. However. never linked to situations characterised by stagnant water.
  **Galio aparines-Smyrnietum olusatri*: This association was described by Allegrezza et al. (1987). It is dominated by the *Smyrnium olusatrum* species, and it can be found at the edges of semi-natural and artificial arboreal formations, often along the sides of roads in shady and wet areas in and around urban zones. This coenosis is included in the alliance *Galio-Alliarion* and is particularly nitrophilous and distributed both on marly-calcareous substrata and on arenaceous and clayey hills. It is well enough represented in the rural landscape.
  **Alliario petiolatae-Chaerophylletum temuli* (Fig. 7): This nitrophilous edge association with *Alliaria petiolata* and *Chaerophyllum temulum* is also included in the alliance *Galio-Alliarion*, and has a sciaphilous character and grows in locations with soil rich in nutrients, e.g. in the zones next to the banks of rivers and edges of ditches, where the fine and rich soils are deposited (Hruska, 1988). Moreover, it is present at the edges of forest formations and in dense coenoses along the sides of roads. It is very well represented in the egroecosystem environment.
  **Petasitetum hybridi*: This association is characterised physiognomically by the large leaves of the species *Petasites hybridus*, and it is usually found on the external parts of the banks of the water courses, sometimes at the edges of riparian formations of *Salix alba*, generally under conditions of high atmospheric humidity (Baldoni & Biondi, 1993). The soil on which this grows is rich in organic matter and is constantly wet. This belongs to the alliance *Aegopodion podagrariae* and is well represented in the terriory analysed.
- *Calystegietalia sepium*: The phytocoenoses of this syntaxonomic unit are instead closely linked to the presence of water. Indeed, they can be found mainly on the banks of ditches and small pools of water, on soils with a high content of nitrates and water. Often, these associations can survive also under conditions of temporary stagnant water. The plants that form a part of these communities are climbers and moderately sciaphyle.

**Arundini donacis-Convolvuletum sepium*: The reed beds of *Arundo donax* are included in the alliance *Calystegion sepium* and are often associated with the fluvial margins that are degraded following the effects of remodelling of the banks and of herbicide use. The dominant species, which is almost always accompanied by the climbing Convulvulacea *Calystegia sepium*, was introduced for agricultural purposes and has become naturalised since. Today it is a constant element of the rural landscape, where it grows mainly on wet clayey terrain.
**Convolvulo sepii-Epilobietum hirsuti*: The formations dominated by *Epilobium hyrsutum*, which can also themselves be included in the alliance *Calystegion sepium*, grow on constantly wet soil, on various types of substrata. In the agricultural environment they can be found both on the borders of water courses with a permanent flow, in contact with more hygrophilous vegetation, and in the internal parts of ditches with periodic water flow, which are situated along the hilly slopes.

Fig. 7. *Alliario petiolatae-Chearophylletum temuli*.

2.5.2 Class *Trifolio-Geranietea*

This syntaxonomic class includes the plant communities of the margins of the pre-forest or forest formations of the Eurosiberian and Submediterranean regions (Rivas Martinez et al., 2002). The associations of this syntaxon are found in the hilly and montane bioclimate belts, both along the borders of the thermophilous oak and hornbeam woods as well as along the margins of the more mesophilous beech woods.
The phytocoenoses *Trifolio-Geranietea* can be seen on various terrains of calcareous, arenaceous and clayey origins. They usually prefer wet, deep-soiled sites with a good humus layer and constantly in the shade; in some cases they can even grow on particularly poor substrata. Some coenoses are more adapted to growing on acidic terrain, others in edaphic contexts that are more alkaline (Biondi et al., 2001).
The communities of this class are linked in contact with well-conserved forest environments and often show high floristic richness due to their growth in situations that are ecologically transitory; this last factor increases the plant biodiversity.
In the agroecosystem, this class is not widespread, both for its scarcity and for the often not optimal conservation state of the residual woods of the rural territory. Indeed, with these residual woods, the ecotone space of the transition towards contexts used by man, e.g. cultivated fields, is often missing; frequently the terrain in contact with the small wooded

areas found in the countryside are tilled right up to the margins of the wood, with the consequent destruction of the edge coenoses.

From the synphytosociological point of view, the class *Trifolio-Geranietea* can be considered as the herbaceous state with greater evolutive significance. The reference order for the coenoses found is *Origanetalia vulgaris* (Biondi et al., 2006).

- *Origanetalia vulgaris*: This order includes the coenoses of the edges of the woods that grow on mature soils that have a lot of humus and are mainly calcareous or marly-arenaceous. The coenoses are diffuse in the temperate and Submediterranean bioclimates, and the order is diffusely spread throughout the Italian peninsula, and especially in the Apennines, at the margins of both thermophilous and mesophilous woods

  **Buglossoido purpureocaeruleae-Glechometum hirsutae* (Fig. 8): This coenosis is the forest edge formations of downy oak or hop hornbeam of the areas with a temperate or Submediterranean climate. It has been described for a forest area of the Marche hinterlands (“Monaci Bianchi”Wood; Taffetani et al., 2009). It is included in the alliance *Trifolion medii* and it is not infrequent to see it at the margins of the residual woods of rural territories, in ecotone zones that are not greatly disturbed and in situations with deep and humus-rich soil. It is dominated by the species *Glechoma hyrsuta* and in the better preserved zones ìt can be noted for its good floristic richness and the presence of species of the upper heirachical levels.

Fig. 8. *Buglossoido purpureocaeruleae-Glechometum hirsutae*

2.6 The shrub and arboreal vegetation

2.6.1 Class *Rhamno-Prunetea*

The class *Rhamno-Prunetea* includes all of the coenoses of the forest and shrub mantle, which are composed mainly of nanophanerophyte or phanerophyte species that normally grow in contact with forest communities of the classes *Querco-Fagetea* and *Salici-Populetea*.

This syntaxon is mainly diffuse in the Eurosiberian and Mediterranean regions and the coenoses that belong to it can be more or less mesophilous or thermophilous (Rivas-Martinez et al. 2002). From the edaphic point of view, the class shows good ability for colonisation of various substrata. Among the communities that are a part of this class, some prefer fresh and deep soils, while others have adapted to also live on very poor and superficial substrata. In this last case, sometimes the shrub vegetation can take on the role as head of the series, due to a lack of the right ecological conditions for the development of mature forest formations.

In the rural landscape, the vegetation of *Rhamno-Prunetea* is well enough represented, both in the margins of woods or of riparian arboreal formations, and along rows of trees or in hedges. The shrubs colonise abandoned fields and pastures, and they represent the serial stage that precedes the return of the woods.

For the syntaxonomical classification, relative to the temperate and Submediterranean contexts analysed, the main reference order is *Prunetalia spinosae*.

- *Prunetalia spinosae*: This order collects the substitution phytocoenoses (mantles, shrubs, hedges) of the woods of the class *Querco-Fagetea* that grow mainly on well-structured soils that are often calcareous or calcareous-marly. Within this order, there are mesophilous coenoses that can be found on the hilly and montane zones of the temperate bioclimate, and others that are subthermophilous and thermophilous, which are typical of the Submediterranean areas.

  **Clematido vitalbae-Rubetum ulmifolii*: These coenoses with a dominance of *Rubus ulmifolius* are usually found as extended shrub layers that are almost impenetrable, among which there are brambles, with their ability to quickly expand due to their intense production of suckers, and which are associated with the Ranuncolacea vines of *Clematis vitalba* (Poldini, 1989). These shrub coenoses of the alliance *Berberidion vulgaris* are usually characterised by a floristic poverty, and they are indifferent to soils of different origins due to the wide ecological valance of brambles. In the rural landscape, they are very widespread, especially in the zones abandoned for longer times; they are frequenly found on post-cultivation grasslands (*Senecio-Inuletum*) and often show high stability, slowing the return of the wood, especially in situations particularly degraded and with a scarcity or absence of the propagules of arboreal forest species.

  **Symphyto bulbosi-Sambucetum nigrae* (Fig. 9): This mesophilous pre-forest formation of *Sambucus nigra* has been described for the hilly territory of Marche (Biondi & Allegrezza, 2004), and it prefers deep and fresh soils and makes up the pre-forest stage of elm coppices, both on sandy substrata and on alluvial substrata. It is ascribable to the alliance *Pruno-Rubion* and it is differentiated from analogous formations with elder of the northern Apennines and the eastern Alps by the presence of some Mediterranean and south European species, such as *Arum italicum*, *Symphytum bulbosum* and *Rubus ulmifolius*.

Fig. 9. *Symphyto bulbosi-Sambucetum nigrae*

2.6.2 Class *Querco-Fagetea*

This class includes the mesophilous woods that are spread over the hilly and montane zones of the areas with a temperate macrobioclimate, with penetration into zones with a Mediterranean influence (Rivas-Martinez et al. 2002).

The formations of the class *Querco-Fagetea* can be more or less structured depending on their previous management, and as with all woods, these are characterised generally by a multi-layered structure; indeed, they are composed of arboreal species, which characterise them physiognomically, as well low arboreal, shrub and herbaceous species.

The coenoses that can be included in this sytaxonomic unit can be found on various types of substrata, from those of calcareous origins to those marly, clayey and arenaceous, and they generally prefer soils with a certain depth, even if in some situations they can grow in relatively superficial edaphic contexts.

The vegetation of *Querco-Fagetea* represents the climax, i.e. the maximum evolutive expression found in a landscape context. In the agroecosysems, the woods have now become rare, but precious, elements, because of their richness in life forms and their complexity, and because of the possibility to provide autochthonous germplasm of nemoral arboreal, shrub and herbaceous species. These therefore need to be carefully managed according to their potential.

With regard to the sector of the Italian peninsula, as the object of this analysis, this class is represented by two orders.

- *Fagetalia sylvaticae*: This syntaxon has a central Europe and Caucasian distribution area and includes mesophilous forest phytocoenoses of deciduous trees of the montane and hilly zones of the areas with a temperate macrobioclimate. They have their optimum in fresh locations and with particularly deep and wet soils that have a good humus content. They include, in particular, beech, European hornbeam, lime and mountain ash woods.
- *Quercetalia pubescentis*: This order groups the wood formations that are essentially constituted of thermophilous broad-leaved trees, among which the most widespread are downy oak, turkey oak, bay oak, hop hornbeam and flowering ash. The spread of these coenoses that can be seen in the temperate and Submediterranean areas is limited to hilly zones.

  **Roso sempervirentis-Quercetum pubescentis* (Fig. 10): The woods of downy oak of this association are diffuse across the meso-Submediterranean thermoclimate belt of the hilly subcoastal territory of the central Adriatic region (Biondi & Allegrezza, 1996). These can be found on substrata of various origins, as arenaceous, clayey, and more or less calcareous, and they usually grow in the zones that are more exposed to the sun or with more superficial soil. They are characterised by the presence of various thermophilous species, like *Rosa sempervirens*, *Smilax aspera*, *Rubia peregrine* and *Laurus nobilis*. They are included in the alliance *Carpinion orientalis* and can usually be seen on the summit ridges of the hills.

  **Asparago acutifolii-Ostryetum carpinifoliae*: This neutrophilous hop hornbeam wood is included in the alliance *Carpinion orientalis* and it occupies soils derived from calcareous, marly and pelitic-arenaceous substrata of the lower mesotemperate bioclimate belt (Biondi et al., 2006). In the rural landscape of the territories investigated, it mainly occupies the fresh and usually north-facing slopes. Among the more representive species, as well as the hop hornbeam, there are *Asparagus acutifolius*, *Buglossoides purpureocaerulea*, *Smilax aspera* and *Acer obtusatum*.

**Lonicero xylostei-Quercetum cerridis*: The turkey oak woods of this association are included in the alliance *Carpinion orientalis* and they can be found in the central-southern sectors of the Italian Adriatic aspects. In particular, they occupy slopes with arenaceous-pelitic outcrops with a mainly sandy texture (Biondi & Allegrezza, 2004; Taffetani et al., 2005). Among the diagnostic species, as well as the hop hornbeam, there are *Lonicera caprifolium*, *Lonicera xylosteum*, *Sorbus domestica*, *Sorbus torminalis* and *Cyclamen hederifolium*.

Fig. 10. *Roso sempervirentis-Quercetum pubescentis*.

2.7 The herbaceous and arboreal hygrophilous vegetation

2.7.1 Class *Phragmito-Magnocaricetea*

The hygrophilous vegetation of the class *Phragmito-Magnocaricetea* grows in the marshy zones, at the edges of water courses, or ponds or lakes, in zones more-or-less constantly flooded. The class is well represented in territories with the temperate and Mediterranean macrobioclimate of continental Europe.

The communities that can be included in his syntaxonomic unit are often poor in species and composed mainly of helophyte plants, i.e. those characterised by their growth outside of the water although they are rooted in submerged soils. Among these, there are in particular the reeds, rushes, Carex sedges, and graminoid perennial species (Rivas-Martinez et al., 2002).

All of the coenoses of this class well tolerate long periods of submersion and soils that are very heavy or muddy, and deep. They grow both on clayey and silty soils, as well as on gravely alluvial plains that are typical of the valley bottoms. They cannot survive periods of drought, which can cause a decisive reduction in the water content of their soil. Some formations show from moderate to high resistance to the force of the water current.

In the rural contexts, *Phragmito-Margnocaricetea* characterises the more internal margins of ditches, channels, and small ponds or hill lakes, The presence of coenoses of this syntaxonomic unit within the rural territories contributes to the stabilisation and consolidation of the banks, and is an important index of good conservation: indeed, some of the species that characterise these communities can disappear if the level of human disturbance is high or in cases in which the concentration of nitrogen compounds in the water or in the soil are above specific levels.

From the syntaxonomic point of view, in the area under investigation, the coenoses seen can be referred to three main orders.

- *Phragmitetalia*: This syntaxonomic unit mainy concerns the marsh reed-beds and the *Typha* formations. These communities are characterised by the fact that the greater part of the biomass is produced by one, or a few, species (Poldini, 1989); usually these grow at the edges of water pools or along the banks of rivers and ditches where the water flows slowly (Rivas-Martinez et al., 2002).
  **Typhetum latifoliae*: The communities of *Typha latifolia* are included in the order *Phragmition communis*; these are poor in species and in the countryside they find the optimal conditions for their development in proximity to channels or ditches characterised by stagnant water that is present throughout the year. In general, they cannot survive conditions of high eutrofixation (Baldoni & Biondi, 1993) and they indicate a conservation level of the riparian environment that is sufficiently good.
- *Magnocaricetalia*: This order gathers the communities comprising the species of Carex of medium to high size that can be found on the edges of pools, ponds, lakes and water courses. These formations are often found interpositioned beween the coenoses of the order *Phragmitetalia* and riparian arboreal formations (Poldini, 1989).
  **Cypero longi-Caricetum otrubae*: These formations are physiognomically dominated by *Carex otrubae* and *Cyperus longus* and belong to the alliance *Magnocaricion elatae*, and they are found on heavy and constantly wet soils on the inside edges of channels and ditches. In central Italy, this has been reported for the wet environments of Lakeo Trasimeno (Umbria; Venanzoni & Gigante, 2000) .In the rural territory, these are becoming more rare because of intensive cultivation practices.
- *Nasturtio-Glycerietalia*: This syntaxon instead includes the plant communities at the edges of rivers or of small water courses that include the small rhizomatose pioneer plants and characterise a good level of resistance to the force of the water current. These pioneer plants grow in contexts where there are frequent variations in water flow (Rivas-Martinez, 2002).
  **Helosciadetum nodiflori* (Fig. 11): The formations of *Apium nodiflorum* are relatively diffuse in the the rural territory investigated, both in the high hilly areas and in the better conserved subcoastal zones. They form a part of the alliance *Glycerio-Sparganion* and they colonise the more internal parts of the banks of the rivers and ditches with sufficiently oxygenated water flow. They resist the impact of the current and periodic submersion well.

Fig. 11. *Helosciadetum nodiflori*.

2.7.2 Class *Salici-Populetea*

The class *Salici-Populetea* includes the riparian arboreal phytocoenoses of deciduous trees of the Eurosiberian and Mediterranean regions (Rivas Martinez et al., 2002). These plant formations are made up of species of willow and poplar, and they prefer soils of alluvial origin subjected to periodic flooding as a result of river overflow; some of these are located in close contact with the water, with others at greater distances, as a function of their decreasing ability to resist the force of the current. These same coenoses are frequently positioned in close contact with communities of the class *Phragmito-Magnocaricetea* and often it is possible to find various species of this last syntaxon within them.

The presence of coenoses of the class *Salici-Populetea* is relatively common along the banks of the more important rivers; instead, at the margins of small water courses, these communities are often very rare, if not completely absent.

In the agroecosystems analysed, the associations of this syntaxon are widely present, but in general little structured and reduced to thin strips positioned in direct contact with the water courses. This occurs because of the use of the major part of the terrain of the plains for the cultivation of annually seeded crops and as a function of the use of the soil that is determined by the development of commercial and industrial areas on river plains near to inhabited centres. Moreover, the arboreal riparian formations are always more often damaged extensively and heavily by badly designed reshaping and remodelling of the river banks, carried out to try to regulate the water flow of the main water courses.

Within this class, two orders can be distinguished, which include coenoses with different abilities to resist river flooding.

- *Populetalia albae*: This order includes the hygrophilous arboreal coenoses with a dominance of black poplar or elm that grow in zones not subjected to the continual influence of the water. These are usually located on alluvial terraces, on soils with a generally sandy texture and with good permeability, or in the bottom of the clayey gullies with deep and constantly wet soil.

  **Symphyto bulbosi-Ulmetum minoris* (Fig. 12): The elm coppices are found in the gullies with deep and fresh soil of clayey origins, or on the alluvial terraces with a superficial water table. These are included in the alliance *Alnion incanae*. The association illustrated here has been described for the hilly territory of a hilly sector of the central Adriatic (Biondi & Allegrezza, 1996), and it is a constant enough element of the hilly agricultural territory studied. In the herbaceous layer, the most represented species are usually *Symphytum bulbosum* and *Arum italicum*.
- *Salicetalia purpureae*: This syntaxon includes the riparian coenoses with a dominance of bushy willows that can be found in particular in the internal parts of the fluvial beds. The species that are part of these communities show high resistance to the impact of the water flow and they manage to rapidly recover their vegetative ability after the flooding of the river.

  **Rubo ulmifolii-Salicetum albae*: The riparian arboreal formations with a dominance of *Salix alba* are characteristic of the edges of the water courses which have a constant water flow. These are often seen as linear formations in direct contact with the adjacent cultivated fields. Those relative to the subcoastal hilly territory of the central-southern part of the Italian Adriatic sector are included in the association *Rubo ulmifolii-Salicetum albae* (Allegrezza et al., 2006). This coenosis belongs to the alliance *Salicion albae* and it is differentiated from analogous coenoses of white willow with a central European distribution area by the presence of species with a Mediterranean chorotype, such as *Rubus ulmifolius*, *Hedera helix* and *Laurus nobilis.*

Fig. 12. *Symphyto bulbosi-Ulmetum minoris.*

3. Evaluation of the quality and functionality of the agroecosystem

3.1 A system of floristic-vegetational indexes for the analysis of ecosystem functionality

Aspects of the ecological functionality relative to the agricultural systems can be evaluated and understood using the sysem of bioindicators introduced Taffetani & Rismondo (2009) and then updated (Rismondo *et al.*, 2011). It is based on the floristic-syntaxonomic particularities of the areas examined. In this type of analysis, the study of the plant landscape is examined with the aim of collecting and interpreting the effects caused by the diverse types of previous management.

The model of the study in question is based on two specifically formed databases:

- The floristic-syntaxonomic database collects the ecological information relative to each single species present in the Flora of Italy (Pignatti, 1982; Conti et al., 2005). Various indicators are associated with each taxon, among which there is the one relative to the syntaxonomic class to which it belongs (following consultation with various literature contributions: Guinochet et al., 1973; Rameau et al., 1989; Oberdorfer, 1990; Royer, 1991; Biondi et al., 1995; Biondi et al. 2005; Rivas Martinez et al., 2002), and those regarding the biological form, chorological type and the possible influences of the physical conditions of the terrain (edaphism).
- The database of the syntaxonomic classes includes the main classes of vascular vegetation found on national soil. A numerical value is given to every class (with a range of 0 → 9; Fig. 13) on the basis of the maturity level determined:

1. Commensal vegetation of the annually seeded crops;
2. Herbaceous pioneer vegetation;
3. Herbaceous ruderal nitrophilous vegetation of the margins and the abandoned fields;
4. Herbaceous perennial vegetation of the margins and the grasslands with cutting;
5. Herbaceous perennial vegetation of pastures and mature grasslands;
6. Mesonitrophilous herbaceous perennial vegetation of the ecotones of the arboreal formations;

7. Herbaceous perennial vegetation of the edges of the forest formations;
8. Vegetation of the forest mantle and the shrubs;
9. Arboreal forest vegetation.

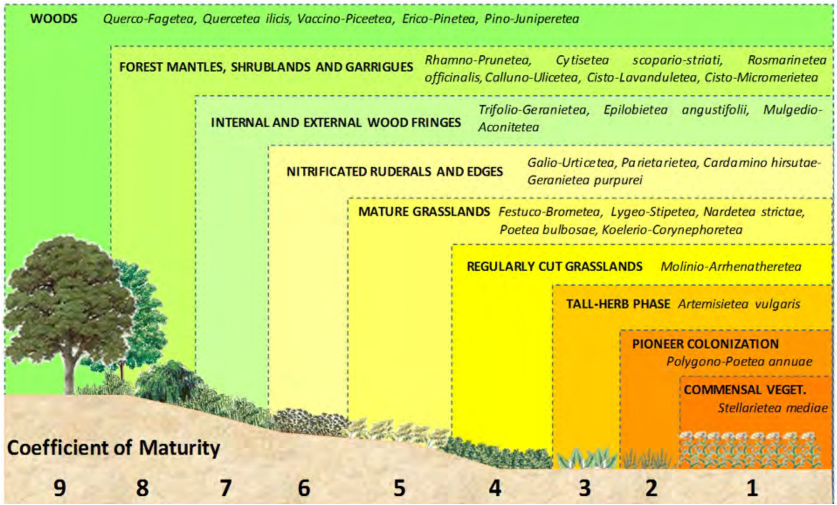

Fig. 13. Scheme which illustrates the maturity significance of each single community.

The numeric values introduced therefore increase bit by bit passing from pioneering vegetation typologies, like those relative to the commensals of annually seeded crops (*Stellarietea*), or to terophytic herbaceous formations (*Stellarietea*, *Polygono-Poetea*), to the herbaceous formations of the grasslands (*Artemisietea*, *Molino-Arrhenatheretea*, *Phragmito-Magnocaricetea*, *Festuco-Brometea*) and of the edges (*Galio-Urticetea*, *Trifolio-Geranietea*), and finally to the typologies identifiable with the pre-forest (*Rhamno-Prunetea*) or forest (*Salici-Populetea*, *Querco-Fagetea*) stages. This is in agreement with that which is illustrated in the section dedicated to the description of the agroecosysem landscape.

The classes characterised by a cerain type of edaphic determinism (adaptability of the vegetation to grow in contexts with soils always rich in water, or arid, or with high concentrations of salts) are distinguished by specific hygrophilous, xerophilous and alophilous coefficients; these last are functional in the calculation of the edaphic indexes, as well as for the calculation of the maturity indexes (see paragraph 3.1.1.).

The results of the vegetational investigations (relating to the presence and abundance of each taxon found) and the information contained in the two databases (ecological characteristics of every species) represent the applicative basis of the indexes used, through which numerical values are obtained that measure the conservation level of each individual coenosis (coenotic indexes) or of entire territorial contexts (cartographic indexes).

The system was specifically designed for the rural areas and as a consequence, its set-up is for areas mainly characerised by agricultural use of the territory.

The method is seen to be particularly efficacious in the analysis of the grassland formations, because a good part of the scale used for the quantification of the levels of maturity refer to the classes of herbaceous vegetation. This last is by far the most represented in the rural contexts than the mature elements of the landscape, such as shrubs, pre-woods and woods, as the herbaceous vegeation is characterised by being particularly susceptible and responsive to the ways in which it is used, which can also be observed even over short periods of time.

This makes the method particularly efficacious for the monitoring of environmental quality of contexts within which the ecomosaic is characterised by being influenced by human activities in an evident way. In the following paragraphs, the structure and significance of the indexes used in the analytical and applicative part of this study are described

3.1.1 Coenotic indexes

The indexes relative to the phytocoenoses allow the measuring of some ecological characteristics of the plant communities found in the field.

This information essentially regards the maturity, i.e. the evolutive level reached (Index of Maturity; *IM*), the biodiversity, expressed as the species number for each phytocoenosis (Index of Floristic Biodiversity; *IFB*), and various other parameters, like the edaphism (Indexes of Hygrophylia, Xerophylia and Alophylia; *IW*, *IX*, *IA*), the relative presence of the various biological forms (indexes of the terophytic, hemicryptophytic and non-hemicryptophytic perennial components; *IT, IH*, *IF*), and the relative presence of some of the chorological types (indexes of the endemic, wide distribution and exotic components; *IL*, *ID*, *IE*). The index of maturity is expressed in a range that goes from 0 to 9 (according to the maturity scale described in the previous paragraph), the index of floristic biodiversity is a simple number (of species per relevé), and all the others are as percentages.

In most cases, these indexes are calculated as a function of the coverage that can be attributed to each single species. The coverage can be considered within each single relevé or as the mean for a Table of relevés that are all attributable to one phytocoenosis.

The indexes that we have used with the greatest frequency for the functional characterisation of the herbaceous communities are the Index of Maturity, the Index of Floristic Biodiversity, and the edaphic indexes, with the Index of Hygrophylia in particular. Of these, the following provides brief descriptions of the formulas for their calculation.

- Index of Maturity: This allows the evaluation of the level of evolution of the coenoses analysed, which will be higher when there is a greater presence and coverage of species of the more evolved vegetation classes (e.g. shrubs, pre-woods, woods). For the herbaceous communities, the value will be higher as a function of the presence of perennial entities that are typical of mature grasslands or of ecotone coenoses.

$$IM = \frac{\sum_{i=1}^{n}(c_i \text{ x } y)}{C_{(tot)}}$$

where *IM* is the Index of Maturity; c_i is the coverage value for each single species, as an absolute value for single relevés or as a mean for groups of relevés in a Table; y is the value corresponding to m ($y = m$) for each single species and assigned on the basis of the information contained in the databases described above; and $C_{(tot)}$ is the value of the total coverage obtained from the sum of the coverage values for all of the species.

- Index of Floristic Biodiversity: This measure is the number of species relative to each of the coenoses, which are given as groups of floristic species that can develop in an ecologically homogeneous context. This does not depend on the coverage value of each single taxon (Puppi, 2008).

$$IFB = sp/ril$$

where *IFB* is the Index of Floristic Biodiversity; *sp* is the number of species of a given coenosis; and *ril* is the single relevé.

- Edaphic Indexes: These allow the qualtification of the weight of the hygrophilous, xerophilous and alophilous components of each coenosis and they are used to gather and measure the adaptability of each coenosis to develop under particular edaphic conditions regarding the availability of water and salts in the soil.

$$IW = \frac{\sum_{i=1}^{n}[c_{(sw)}]\ i}{C_{(tot)}} x100$$

$$IX = \frac{\sum_{i=1}^{n}[c_{(sx)}]\ i}{C_{(tot)}} x100$$

$$IA = \frac{\sum_{i=1}^{n}[c_{(sa)}]\ i}{C_{(tot)}} x100$$

where *IW* is the Index of Hygrophylia; *IX* is the Index of Xerophylia; and *IA* is the Index of Alophylia; $[c_{(sw)}]_i$; $[c_{(sx)}]_i$; $[c_{(sa)}]_i$ are the coverage values of each single species that belongs to the hygrophilous (*sw*), xerophilous (*sx*) and alophilous (*sa*) classes, as an absolute value for single relevé or as a mean for groups of relevés in a Table; and $C_{(tot)}$ is the value of the total coverage obtained from the sum of the coverage values for all of the species.

3.1.2 Cartographic indexes

The cartographic indexes come from the integration of the content of the maturity index with the data derived from the cartographic representations. This last is realised through the use of GIS (geographic information system). The cartographic analyses are carried out at a number of levels and allow thematic maps of different contents to be obtained.

The first phase is the photointerpretation of the territory under study, with the consequent attribution of each single patch to a specific category (previously defined). This allows the drawing up of the map of the use of the soil. Then, the cartographic investigation is deepened and the single polygons are assigned to defined vegetation typologies, inserted in their specific serial and landscape context. In this way, this provides the maps of the vegetation and the plant landscape, which illustrate the study area in a qualitative way.

The final level of the cartographic analysis is the assigning of the maturity values calculated for every coenosis to each of the corresponding spaces reported on the map. In this way it is possible to construct the maturity map, which provides a qualitative-quantitative vision related to the evolutive state and grade of conservation of the area investigated.

The ecological functionality of the hydrographic network of the agricultural areas can be measured with an analysis system based on the reconstruction of the graph of the fluvial segments and on the intersection of this with the vegetation map. This method, which will be considered more deeply in a following publication, allows a map of the conservation state of the hydrographic network to be obtained, as a predictive instrument that is useful for the identification of the part of territories that are potentially susceptible to erosion phenomena and hydrogeological problems, as characterised by high numbers of closed down ditches or with profoundly altered riverbank vegetation. In contrast to the previous example, in this case the map does not come from an analysis of the surface, but from a linear investigation, as the ditches are divided into segments to which a numerical value is associated, which is relative to the vegetational typology of the corresponding margin. The interpretation of the qualitative characteristics and of the management dynamics that can be revealed in the various contexts investigated is made possible by the superpositioning and the reading of the various cartographic representations presented.

The map of the maturity provides the foundation for the calculation of the so-called cartographic indexes, the index of synthetic maturity (*ISM*) and the index of the unproductive areas (*IUA*), expressed as a 1 → 9 scale and as a percentage, respectively, and as described in the following.

- Index of Synthetic Maturity: This is based on the area occupied on the map by each vegetational typology reported in the cartography and on the maturity value attributed to the same phytosociological typology.

$$ISM = \frac{\sum_{i=1}^{n}(IM_i \text{ x } \Omega_i)}{\Omega_{(tot)}}$$

where *ISM* is the Index of Synthetic Maturity; IM_i is the index of maturity relative to the ith vegetational typology from the cartography; $\boldsymbol{\Omega}_I$ is the area of the ith vegetational typology from the cartography; and $\boldsymbol{\Omega}_{(tot)}$ is the total area of the carography.

$$IUA = \frac{\sum_{i=1}^{n}[\Omega_{(u)}]\ _i}{\Omega_{(tot)}} x100$$

- Index of Unproductive Areas: This index is based on the distinction between cultivated or disturbed areas, characerised by *IM* ≤2, and unproductive areas with *IM* >2, and it is calculated as the relative presence of the cultivated or disturbed areas included in the cartography.

where *IUA* is the Index of the Unproductive Areas; $[\boldsymbol{\Omega}_{(u)}]_I$ is the area of the ith vegetation typology with *IM* >2; and $\boldsymbol{\Omega}_{(tot)}$ is the total area on the cartography.

3.2 Applying the indexes

In the following, there are some examples of the application of the system of the bioindicators just described. These refer to some of the territorial contexts described over the last few years and they are aimed at helping the reader in their understanding of the method presented here and in their appreciation of its potential use. The applications presented refer to both the coenosis indexes and the cartographic indexes.

3.2.1 Analysis of the ecological gradient in a vegetation transect

The application is based on the reconstruction of transects of the vegetation typologies that are revealed under particular conditions of morphology and use. These refer in particular to the edges of the water courses and of the dirt tracks. The schemes and the graphics that support the analysis allow the demonstration of how the method of bioindication on a floristic-vegetational basis provides precise and easily understood results regarding the influence of particular ecological or management conditions on specific phytocoenoses.

- Vegetation of the diches edges: Considering agroecosystems, the plant coenoses of the edges of the water courses often provide a high floral richness and an elevated naturalistic interest (as for the better-conserved edges of the fields and of the farm tracks) and perform multiple functions: they contribute to the protection of the soil from erosive phenomena, they act as connecting ecological corridors between semi-natural habitats, they host numerous forms of life and favour interactions between living and non-living organisms, and they absorb CO_2.

Unfortunately, the coming of intensive agriculture has favoured the practice of management techniques of rural territories that are particularly aggressive, such as the stripping of vegetation on a large scale and the tillage of areas previously not used, which have been performed with the aim of obtaining the maximum areas possible for cultivation. This has often resulted in the removal or alteration of a large part of the riverbank plant component.

In our studies into the understanding of the state of the biodiversity of the rural territories, following investigations of the countryside, we have been able to reconstruct the plant successions that can be potentially found along the edges of the primary and secondary water courses. The coenoses found can be referred to classes that are particularly hygrophilous, such as *Phragmito-Magnocaricetea* and *Salici-Populetea*, or to mesophilous classes, such as *Galio-Urticetea* and *Molinio-Arrhenatheretea*. To the reconstruction of the vegetation transects, we added the application of two of the floristic-vegetational indexes, as the maturity index (*IM*) and the hygrophilous index (*IW*), which allowed us to reveal interactions between the morphology of the soil, the gradient of available water, and the vegetation.

Scheme A of Figure 14 shows the succession of the coenoses seen at the edges of the main ditches with permanent water-flow throughout the seasons of the year (Rismondo *et al.*, 2011). The gradient of available water is shown by the progression of the hygrophilous index along the transect: it is higher for the coenoses that are in direct contact with the water, such as *Helosciadetum nodiflori* (*Phragmito-Magnocaricetea*), the *Carex pendula* communities (*Phragmito-Magnocaricetea*) and the association *Rubo ulmifolii-Salicetum albae* (*Salici-Populetea*), and lower for the ecotone formations, such as *Petasitetum hybridi* (*Galio-Urticetea*), and for the mesophilous grasslands of the external margins of the ditch, attributed to *Ranunculetum repentis*, *Festuco fenas-Caricetum hirtae* and *Lolio multiflori-Plantaginetum majoris Juncus bufonius* variant (all three of which are included in the class *Molinio-Arrhenatheretea*).

The grade of maturity is greatest for the riparian arboreal formation of willow, while it decreases for the herbaceous coenoses: it is lower for the vegetation with *Juncus bufonius* of the compacted and slightly depressed zones, as a function of the greater human disturbance (passing of agricultural machines, contact with the cultivated fields).

Scheme B of Figure 14 shows instead the sequence of coenoses of the ditches of the slopes with water flowing only during and immediately after rain events. The indexes of Maturity and Hygrophylia are higher for the formations within the ditch, such as *Convolvulo sepii-Epilobietum hirsuti*, and lower for the mesophilous coenoses of the external edges of the ditch, such as *Agropyron repens* and *Galium album* communities. In the agroecosystems the presence of these two plant formations (both of the class *Galio-Urticetea*) are seriously endangered by the profound alterations of the segments of the hydrographic network positioned in the hilly zones with the greater slopes.

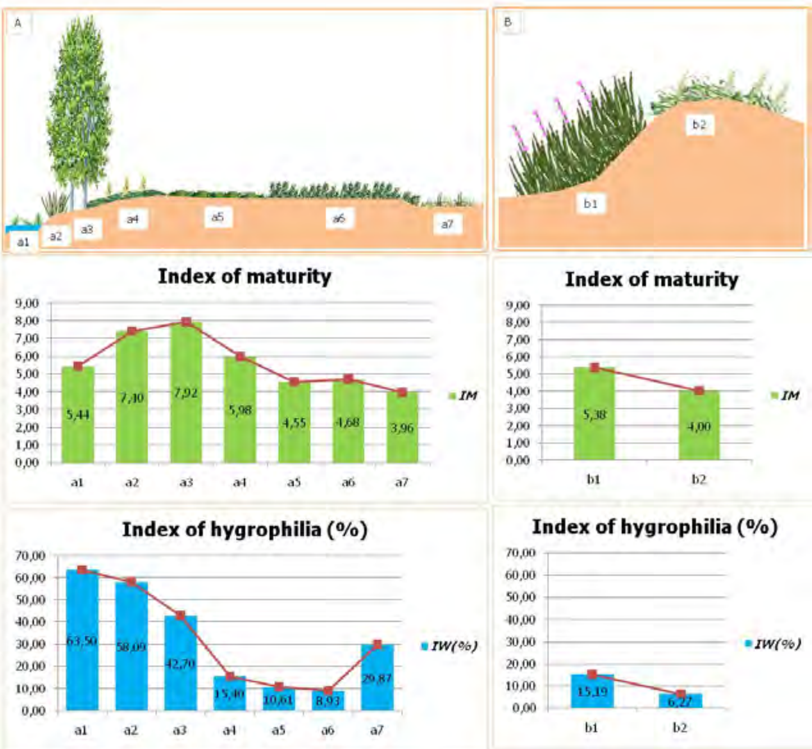

Fig. 14. Indexes of Maturity and Hygrophylia of the vegetation of the principal and minor ditches (Scheme B). Legend: a1=*Helosciadetum nodiflori;* a2= *Carex pendula* communities; a3=*Rubo ulmifolii-Salicetum albae*; a4=*Petasitetum hybridi*; a5=*Ranunculetum repentis;* a6=*Festuco fenas-Caricetum hirtae*; a7=*Lolio perennis-Plantaginetum majoris Juncus bufonius* variant; b1=*Convolvulo sepii-Epilobietum hirsuti*; b2= *Agropyron repens and Galium album* communities.

- Vegetation of the dirt tracks: The farm roads made of beaten earth provide the connections between the farms and their fields and they are used mainly for the passage of agricultural machinery. These have little traffic, but are anyway subjected to high compaction of the terrain. The particular ecological conditions that are created corresponding to these secondary communication tracks allow the development of vegetation that is well adapted to this mechanical disturbance and the alterations to the structure of the terrain, which is little aerated. The coenoses that can be found mainly belong to the class *Polygono-Poetea*, although in some cases also to the classes *Stellarietea* or *Molinio-Arrhenatheretea*. These habitats are also today decreasing, mainly due to the vegetation stripping that also affects the environments outside of the cultivated fields, and to the extreme simplification of the network of tracks between the fields and houses in the countryside (as a function of the depopulation of the countryside, which has resulted in the abandoning of many houses in the countryside, and the incorporation of small plots in the larger cultivated fields). In some situations, however, the state of conservation is still sufficiently good and our study allowed the reconstruction of an example that illustrates the vegetation variation and the relative maturity level as a function of the level of compaction of the soil.

In Scheme C of Figure 15, it can be seen how the coenoses of the class *Polygono-Poetea*, which are *Coronopodo procumbentis-Sclerochloetum durae* and *Poetum annuae*, are positioned. The first of these is found in the individual tracks left by the passage of the agricultural machinery, and the second is in the centre and at the margins of the dirt track; *Lolio perennis-Plantaginetum majoris*, of the class *Molinio-Arrhenatheretea*, is instead found at the more external margins. In the transect, it can also be seen that there is an inverse relationship between the level of compaction of the soil and the evolutive level of the phytocoenoses: indeed, this last decreases going from the margin to the centre of the dirt track (in particular under the tracks of the tyres of the tractors).

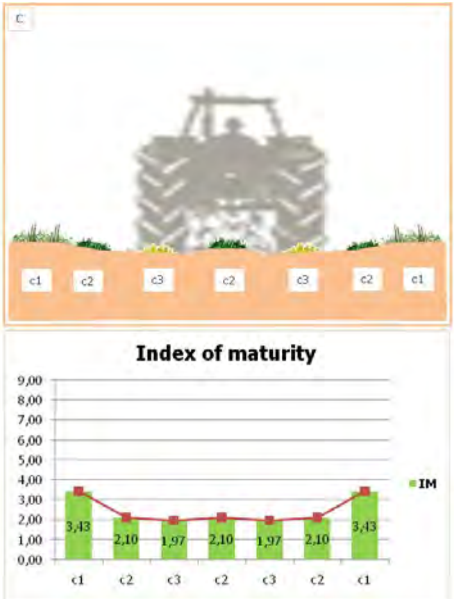

Fig. 15. Indexes of Maturity of the vegetation of the dirt tracks (Scheme C). Legend: c1=*Lolio perennis-Plantaginetum majoris*; c2=*Poetum annuae*; c3=*Coronopodo procumbentis-Sclerochloetum durae*.

3.2.2 Evaluation of the environmental quality of the territory at different scales of enquiry

The example reported is based on the calculation of the maturity index of the coenoses found within determined territory contexts, on the construction of the maturity maps (derived from the vegetation maps), and on the calculation of the consequent cartographic indiexes. The analysis system is shown to be an excellent means for comparison of the areas characterised by different management modalities that can influence the state of conservation of the habitats. The following presents applications relative to the different scales of investigations.

- Analyses of the state of conservation of small herbaceous areas: This example concerns the characterisation of the threshing grounds surrounding an abandoned farmhouse (named as C2) located in the rural territory in a medium hilly area of Marche. The study has involved various threshing grounds of country houses located beween the provinces of Ancona and Macerata (inside Musone River Basin), and it involved the definition of all of the vegetation typologies present for every location analysed, the drawing up of the vegetation map, and the subsequent calculations of the coenosis indexes. Following this, the maturity map was constructed and the cartographic indexes were calculated on the basis of the area occupied by each coenosis and their maturity values.

The investigations carried out allowed us to see how these herbaceous areas represent habitats rich in biodiversity and definitely worth further investigation from the point of view of the relationships that exist beween the flora and the historic usage. The threshing grounds are mainly characterised by coenoses of the class *Molinio-Arrhenatheretea*, grasslands that are regularly cut and that develop, as illustrated, on soils well supplied with nutrients and water. These communities are however on the road to extinction in the agroecosystem environment, due to the abandoning of the traditional management methods.

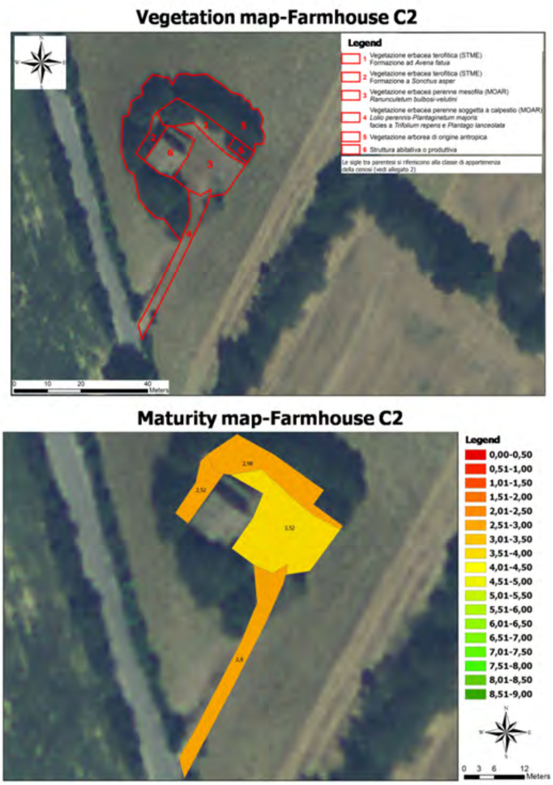

Fig. 16. Vegetation and maturity maps of Farmhouse C2.

The maturity map shown in Figure 16 reveals how the method allows the obtaining of high-precision data regarding the conservation state of the plant communities and of the entire area (as a function of the values of the indexes; Table 1) and provides the possibility of monitoring possible subsequent variations in the floral composition and the level of maturity due to changes in the type of management of the areas involved.

Vegetation community	**Area (m^2)**	***IM***	***IFB***	***IW(%)***	***IX(%)***	***IA (%)***
Avena fatua community	47,78	2,52	20,00	0,00	0,00	0,00
Sonchus asper community	136,41	2,98	18,00	0,00	0,00	0,00
Ranunculetum bulbosi-velutini	245,76	3,52	23,00	0,00	0,00	0,00
Lolio perennis-Plantaginetum majoris Trifolium repens e *Plantago lanceolata* facies	141,52	2,80	33,00	0,00	0,55	0,00
	Area (m^2)	***IMS***				
Farmhouse 2	571,47	3,13				

Table 1. Coenosis indexes and IMS of Farmhouse C2.

- Comparison of the functionality of the agroecosystems at the territory scale: This example refers to two agricultural territories of medium hilly areas of Marche, located in the province of Ancona: the Spescia and Bottiglie sub-basins (municipality of Serra de' Conti; Taffetani & Rismondo, 2009). The two areas are located a few kilometres from each other on soils that originated from sedimentary rock and on clayey, silty-clayey, marly, silty and sandy substrata of various grades of compaction. The reference bioclimate is of the Submediterranean variant of the temperate region.

The Spescia sub-basin shows extreme simplification of the landscape and a lack of semi-natural structures like herbaceous strips, small woods, or rows of trees and shrubs. It is cultivated in an intensive way according to conventional agricultural techniques. The whole of the territory is divided into only two properties and as a consequence the cultural diversification is minimal, also because the plots cultivated with seeded crops are very large and there is no tree growth. The study of the vegetation, the application of the indexes, and the obtaining of the relative maturity map (Fig. 17) reveal a very low level of conservation, as can be seen by the large area covered by coenoses of a very low grade of evolution and by the high homogeneity of use of the areas.

The Bottigle sub-basin instead presents a more diverse plant landscape and its area is subdivided into many small properties. The agricultural use of the terrain includes annual seeded crops, forage crops and polyphytic grasslands; some of the owners operate following the regulations of organic production. The variety of the environments is also favoured by a good level of semi-natural environments, such as herbaceous strips at the edges of the farm tracks, rows of trees and shrubs located at the limits of the fields, riparian vegetation and a small, well structured, turkey oak wood. These residual environments are characterised by vegetation with a good level of maturity; e.g. along the edges of the access tracks there are grasslands of the class *Festuco-Brometea*, the conservation of which is favoured by the periodic cutting. When the maturity map is compared to that of the Spescia sub-basin (Fig. 17), it clearly reveals higher environmental diversification and a good presence of semi-natural marginal coenoses, with *IM* ≥2.

What can be easily noted graphically from the maturity map can be translated into numerical data through the use of the cartographic indexes. As can be seen from Table 2, both the Index of Syntetic Maturity (*ISM*) and the Index of the Unproductive Areas (*IUA*) are a lot higher for Bottiglie sub-basin with respect to the agricultural territory of Spescia.

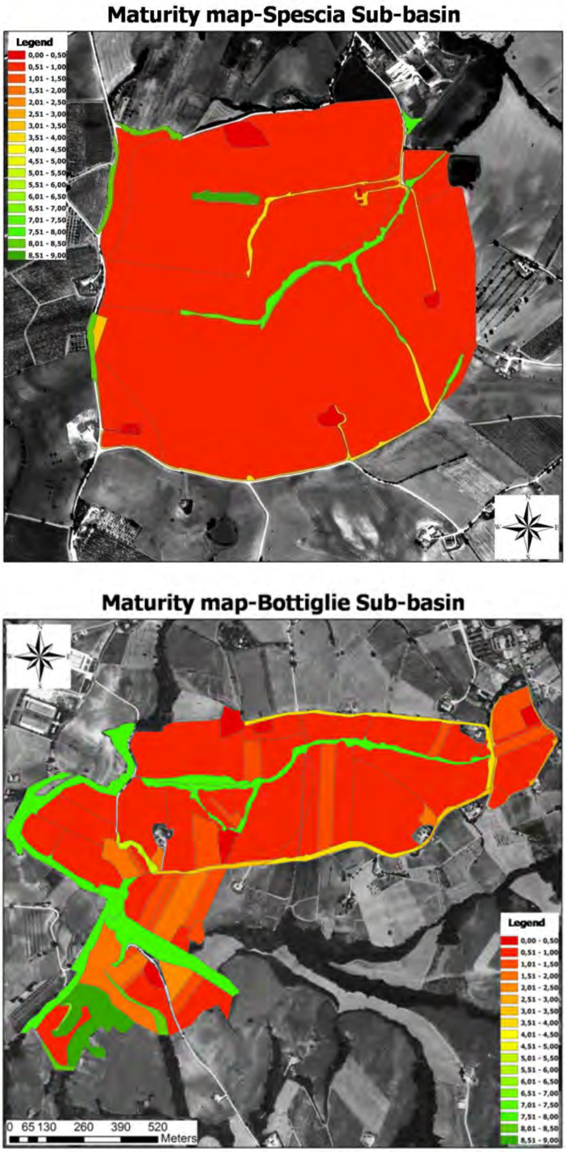

Fig. 17. Maturity maps of Spescia and Bottiglie Sub-basins.

Area	Area (Ha)	*ISM*	*IUA*
Spescia Sub-basin(AN)	84,74	0,96	5,49%
Bottiglie Sub-basin (AN)	107,32	2,31	22,12%

Table 2. Cartographic indexes of Spescia and Bottiglie Sub-basins.

4. Conclusions

4.1 Directives and Regulations for the conservation of biodiversity in agricultural environments

Today, the normative instruments to promote eco-sustainable management of rural territories have a fundamental role for the realisation of conservation strategies for the biodiversity of agricultural environments. The ecosystem services produced by the correct use of the rural territory cannot indeed be given a direct monetary value and therefore cannot be paid to the farmers. Due to this, the introduction of norms and of incentives and financing applicable to specific forms of management represent the only way to give an effective and concrete value to these positive ecosystem benefits.
In the following paragraphs, we consider the main Community legislative references connected with the planning and conservation management of agrobiodiversity.

4.1.1 Rural Development Programme and cross compliance

The Rural Development Programme (RDP) is an economic and policy tool of the European Union for non-urbanised areas. The normative framework to which it refers and its financial funding are known as FEARS. Every region had to take on Regulation (EC) 1698/05, to prepare an RDP for the period of 2007-2013 (the preceding one referred to 2000-2006), and to send it to the European Commision, which needed to evaluate and approve it. The main aims that need to be followed with the RDP regard the improvement of the competitivity in the agricultural and forestry sectors, the improvement in the quality of the rural environment, and the improvement in the quality of life and in the economic opportunities connected to the rural territories.
In exchange for the high levels of public resources directed to the agricultural sector, the intervention priorities according to the second of the objectives just introduced are dictated by the opportunity to guarantee the attribution to agriculture of a role that goes beyond the simple production of foods. This should extend to the function of providing environmental services directed at the protection of the territory and the regeneration of the basic elements, like air, water and soil. Every single farm can have access to funds provided by the RDP following their participation in specific funding applications. Among the measures considered by the RDP, there is, for example, the possibility of access to agro-environmental payments for those who take on the implementation of farm management models that focus on the conservation of the environmental quality (regulations for organic production with low environmental impact).
The Cross Compliance involves all of the farmers who from the start of 2005 intended to benefit from funding made available by the European Union through the Common Agricultural Policy itself, obviously including the payments planned by the RDP. Indeed, from that date, the farmers had to assure that they would respect a series of obligations for the correct agronomic management of the terrain, the protection of the environment, public health and animal health, and animal welfare. Non-conformity with these obligations results in the activation of a mechanism for the reduction of the direct payments to which each of farmers would have the right.
The obligations to which every farmer must make reference are subdivided into two large categories.

- Obligatory Management Criteria, as provisions of law, indicated as Acts already in force and deriving from the national implementation of the corresponding Community arrangements.
- Good Agronomic and Environmental Conditions, indicated as norms set up at a national level to guarantee reaching five priority objectives fixed by the European Union, as: protection of the soil through the use of appropriate measures; maintenance of the levels of organic matter in the soil through the use of appropriate practices; protection of the structure of the soil through the use of adequate measures; assurance of a minimum level of maintenance of the ecosystem and avoidance of deterioration of the habitats; and protection and management of the water resources.

The Cross Compliance is based on the Regulation (EC) 1782/03, subsequently abrogated by Regulation (EC) 73/09.

4.1.2 HNV Farmland Areas

The politics of rural development at the European level proposed the specific objective of the conservation of the agricultural areas of High Natural Value (HNV Farmland Areas) according to Regulation (EC) 1257/99. These had to be identified by 2008, and then be subjected to management modalities aimed at the conservation of biodiversity. Unfortunately, Italy is still today behind also in the determination of the HNV Farmland Areas. These HNV Farmland Areas were defined by Baldock et al. (1993, 1995) as systems of low input and with good levels of biodiversity that are characterised by the application of agricultural practices of low intensiy, a high proportion of semi-natural elements, and a high diversity in the soil coverage. Andersen et al. (2003) identified three typologies of HNV Farmland Areas:

- Type 1: Agricultural terrain with a high coverage of semi-natural vegetation;
- Type 2: Agricultural terrain dominated by low intensity agriculture or by a mosaic of semi-naural and cultivated territories;
- Type 3: Agricultural terrain where there are rare species or a high proportion of a population of a European or World animal or plant species.

For the identification of each typology, they indicated three types of approach:

- Approach 1: soil coverage (Corine Land Cover, not applicable to type 3).
- Approach 2: investigation of the farming system (system of agricultural accountability, RICA, not applicable to type 3).
- Approach 3: species and habitat (Natura 2000, IBA, PBA, IPA).

The method is based on the application of a series of indicators and indexes that have the function of assigning to every specific context a value as a function of characteristics relative to the coverage of the soil, cultivation practices, and the presence of rare species.

The limit of this method is determined by the fact that this is essentially based on large-scale cartographic data, while not making reference to the need for detailed territorial analyses, such as floristic-vegetational investigations. These last would be a valid instrument of support both for the definition phase of the areas and in the course of the successive stages of the planning and the implementation of the management measures.

4.1.3 Habitat Directive

Directive 92/43/EEC, known as the Habitat Directive, relates to the conservation of natural and semi-natural habitats and wild flora and fauna, and it was approved by the European

Commission on 21 May, 1992. Each Member State then had the job of accepting and implementing this Community Normative. The man aim of the Directive is to promote the protection of biodiversity through the conservation of the natural habitats and of the wild flora and the fauna of the European territory of the signing Member States, taking into account also the economic, social, cultural and regional needs.

In Article 1, the significance of the SCI and SAC were defined:

- A SCI (Site of Community Importance) is a site that contributes in a significant way to the maintenance or restoration of a type of natural habitat (Attached I) or a species (Attached II) in a satisfactory state of conservation.
- A SAC (Special Area of Conservation) is a site of Community importance designated by the Member States through an administrative Act where conservation measures are applied that are necessary for the maintenance or restoration in a satisfactory state of conservation of the natural habitats and/or populations of species for which the site is designated.

Each Member State identified the sites in their own territory that are fundamental for the conservation of the species and habitats of Community interest and proposed to the European Commission their own list of pSCIs (as stated in Article 4 of the Directive). On the basis of this list, the Commission drew up the list of SCIs. Within six years from the declaration of an SCI, a specific area is declared an SAC by the Member State.

Instead, the SPAs (Special Protection Areas) were created according to the Bird Directive (79/409/EEC), with the aim of protecting in a rigorous way the sites in which ornithological species live, as contained in attachment I of the same Directive.

The combination of the SCIs (which will anyway become a SACs according to the procedure indicated above) and the SPAs form the European ecological network known as Natura 2000 and defined in Article 3 of the Habitat Directive. The Natura 2000 Network is a combination of sites characterised by the presence of habitats and species of both animals and plants that are of Community interest (indicated in attachments I and II of the Directive), the function of which is to guarantee the long-term survival of the biodiversity, in all of its components, present on the European continent, recognising the interdependence of the biotic, abiotic and anthropic elements.

Article 6 of the Directive defines the management of the sites of Natura 2000 (including the ZSPs). The obligation derived from the Directive is that of adopting opportune measures to avoid the following:

1. The degradation of the habitats of Attachment I.
2. The degradation of the habitats of the species for which the zones were designated.
3. The disturbing of the species for which the zones were designated where this can have negative effects on their conservation.

The instrument of implementation of the Habitat Directive within the SCIs and SPAs is represented by the management plan. The Habitat Directive assumes great importance in the rural environment because with a large part of the sites identified by the Member States there are agricultural territories that are more or less extensive. These areas are often identifiable as HNV Farmland Areas, in which the presence of man and of agro-forestry-pastural activities have favoured the creation of a mosaic of environments, which are characterised by a high level of biological variety. Within these areas, the protection of the traditional cultural systems based on extensive agricultural techniques should be favoured. These considerations must be examined and evaluated carefully at the moment of the drawing up of the management plans.

4.2 Applications of the indicator system

As already illustrated, the analysis and evaluation system described in this study allows the acquisition of numerical data starting from qualitative information of the description of the ecological characteristics of every single phytocoenosis. The integration of these data with those obtained by the cartographic procedures then allows a measurement to be provided of the level of conservation of entire territories, which can also be operated on different scales of investigation. The model is well suited to be used as a means of decisional support in the politico-administrative and management fields, and it has numerous other potential applications, many of which can be applied to the legislative instruments illustrated above, which can be synthetically summarised as follows:

- Support for the definition of naturalistic values, of the state of conservation of the hydrographic network, and of management measures of the agroecosystems more appropriate to guarantee the conservation of the habitats within the SCIs and SACs. The measures should then be included in the specific management plans.
- Identification of the HNV Farmland Areas (agricultural areas of high naturalistic value) by means of the integration of the indexes in use (diversification in the use of the soil, proportion of semi-natural elements present, intensity of the impact of agricultural practices) and the data derived from studies of the plant landscape and the application of the floristic-vegetational indexes.
- Determination of the conservation level of the agricultural territories, from a hypothetical starting situation, to be used as a basis for subsequent monitoring.
- Evaluation of the respecting of the Cross Compliance regulations on the part of the single farms, with the aim of the reaching of the objective of increasing the verifiability and the efficacy of the Norms imposed by the same Cross Compliance.
- Supporting the determination of the economic value linked to the positive ecosystem benefits and measuring the ecosystem services (Finco et al., 2007) produced by specific management practices.
- Determination of the value linked to activities that can be potentially funded within the terms of the RDP.
- The possibility for single farms to autocertificate the quality of their own practices.
- Comparison between farms that adopt different management models (e.g. organic *versus* conventional agriculture; Lazzerini et al., 2004) and the choice of the culture to practice on the basis of the vegetational potentialities identified.
- Certification of the quality of the agricultural ecosystems in the districts of quality production.

In conclusion, it can be stated that the realisation of such a system of investigation on a large scale will represent an excellent tool for the acquisition of useful data for the planning and implementation of management practices that are functional for the protection of the residual habitats of greatest value present in the agroecosystem.

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