Bioindicator system for the evaluation of the environmental quality of agro-ecosystems

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Abstract
One of the most important scientific contributions to the application of the Landascape Ecology's disciplines is represented by the development of indicators to assess environmental quality. In particular, the use of bio-indicators based on flora and vegetation allowed a better classification of threatened species and habitats, together with a development of specific environmental politics. Despite this, many of the analysis and methods used in several conservation actions showed some important application limits, especially inside modified ecosystems such as farmlands and urban areas. This work presents a method to assess environmental quality inside agro-ecosystems; it is based on a system of bioindicators used as an analysis tool able to take advantage of all potential information brought by different bio-coenoses. Starting from the innovations of the phytosociological dynamic approach, the main objective is to take into account the results provided by vegetational analysis, concerning the description of land units and phyto-coenotic mosaics, and to improve their information capacity through an integration with quantitative data. These data can be obtained by the application of specific vegetation bioindicators created to be used inside agro-ecosystems.
This kind of interpretation of landscape dynamics, especially inside agro-ecosystems, is coherent with the application of European Agro-environmental politics (CAP, RDP, Habitat Dir.), and with the main objective of biodiversity conservation (Countdown 2010). The importance of a knowledge base for the assessment of politics effectiveness is also necessary to evaluate sustainable systems for environmental management inside both natural (protected areas) and agricultural systems within which there are important reservoirs of biodiversity and residual habitats that need to be preserved.

Keywords: Agro-ecosystems, Bioindicators, Maturity, Biodiversity, Environmental quality, Territory management, Vegetated strips.

Riassunto
Un importante contributo fornito dai numerosi approcci scientifici allo studio dell'ecologia del paesaggio è rappresentato dall'elaborazione di indicatori per la valutazione della qualità ambientale. In particolare l'utilizzo di bio-indicatori basati su flora e vegetazione ha permesso la classificazione, la valutazione e lo sviluppo di politiche di conservazione di specie e di habitat naturali e semi-naturali minacciati. Per contro, però, l'applicazione di tali tematiche in ambito prevalentemente conservazionistico ha fatto sì che le metodologie di analisi e di valutazione utilizzate comportassero limiti di applicabilità soprattutto in ecosistemi fortemente modificati come le aree agricole o quelle urbanizzate.
L'esigenza di un sistema per la valutazione della qualità ambientale negli agroecosistemi nasce dalla necessità di predisporre uno strumento di analisi che utilizzi al massimo il potenziale informativo delle biocenosi, sfruttando le prerogative del metodo fitosociologico e del suo approccio dinamico più innovativo. L'obiettivo principale del sistema di bio-indicatori proposto nel presente lavoro è quello di utilizzare le informazioni di tipo qualitativo fornite dall'analisi vegetazionale, inerenti la ricostruzione del mosaico fitocenotico e la descrizione delle unità di paesaggio, e di esaltarne la capacità descrittiva attraverso l'integrazione con analisi quantitative basate sull'uso di indici vegetazionali appositamente concepiti per la loro applicazione all'interno dei sistemi ad elevata artificializzazione.
Questo tipo di lettura ed interpretazione del paesaggio, e nello specifico dell'agroecosistema, trova riscontro nell'applicazione delle attuali politiche agricole ed ambientali (PAC, PSR, Direttiva Habitat) all'interno delle quali l'obiettivo primario di conservazione della biodiversità (Countdown 2010) impone una base di valutazione precisa dei risultati di tali scelte, insieme con l'individuazione delle più adeguate tecniche di gestione degli ecosistemi non solo in contesti naturali ed all'interno delle aree protette, ma anche in ambienti antropizzati, dove risiedono importanti serbatoi di biodiversità ed habitat residui da preservare.

Parole chiave: Agroecosistemi, Bioindicatori, Maturità, Biodiversità, Qualità ambientale, Gestione del territorio, Fasce vegetate.

Introduction

The study and ecological characterisation of the landscape have been the objects of numerous scientific approaches (Forman & Godron, 1986; Naveh & Liebermann, 1987; Klijin & deHaes, 1994; Forman, 1995; Zonneveld, 1995, Sims *et al.*, 1996), for which the common characteristic is the attempt to provide a holistic synthesis in which the landscape is considered as the result of the interactions between the abiotic and biotic components of an ecosystem. In this context, the phytosociological method, which is based on the modern synecological, synchorological and syndynamic concepts of the vegetal component (Braun-Blanquet, 1964; Géhu e Rivas-Martínez, 1981; Rivas-Martínez, 2005), is the most effective and appropriate instrument for integration of the landscape approach using structural and functional analyses of a territory. Vegetation analyses allow the definition of interpretative models that are based on dynamic relationships among coenological units (associations) that are part of a hierarchical system through which it is possible to connect and compare wider vegetation complexes both from a geographic and an ecological point of view (Rivas-Martínez, 1987; Rivas-Martínez *et al.*, 1987; Biondi, 1996; Blasi *et al.*, 2001; Biondi *et al.*, 2004). In this way, the landscape mosaic is described in a functional, ecosystem-relevant and dynamic fashion, and it is proposed as a coherent application of the heterogeneous landscape approach that goes under the name of 'landscape ecology' (Forman & Godron, 1986; Forman, 1995; Blasi *et al.*, 2000; Blasi, 2007).

Indeed, phytosociological analysis of the landscape begins as a method of punctual observations, but it is organically inserted in a generalisable system that is integrated (it includes information about geology, geomorphology, bioclimate, and bio-coenological interactions of both natural and artificial origins) as well as hierarchical, and not exclusively perceptive (as in the architectural-landscape approach) or reductionist (as in the physiological-ecological approach).

At present, many lines of research are experimenting with methodologies for the integration of various environmental disciplines in order to correlate the study of vegetation with other complementary naturalistic and ecological researches. The aim is thus to develop a system of descriptive indicators that can be simply and rapidly measured, while providing sensitive and implementable results.

Vegetation as a bioindicator

As with the indices of Ellemberg (Ellemberg, 1974) and Landolt (Landolt, 1977), and the Plant Strategies of Grime (Grime 1979), ecological indices with a floristic basis have been investigated in Italy in applicative environmental studies (Lucchese & Monterosso, 1994; Pignatti, 1998; Biondi, 1999; Pignatti *et al*., 2001; Fanelli 2002; Onori *et al*., 2002; Celesti-Grapow *et al*., 2005; Pignatti, 2005; Taffetani & Rismondo, 2009). Based on the phytosociological method, the evolution of the concept of vegetation as a 'super-indicator' has allowed the elaboration of vegetational indices, like the biogeographic value, the richness of the endemism, the biodiversity, the naturalness, the maturity, the structural diversity, and the potential of the phytocoenoses and of the vegetation series. These have been used to quantify the biological/naturalistic value of an area and its conservational interest (Géhu & Géhu-Franck, 1988; Poldini *et al*., 1989; Feoli & Zuccarello, 1996; Izco, 1998; Ferrari *et al*., 2000; Biondi & Colosi, 2005), and in particular with the application of the Habitat Directive in Italy and in Europe (Ricotta *et al*., 2000; Buffa *et al*., 2005; Penas *et al*., 2005; Biondi *et al*., 2005; Blasi *et al*., 2007; Loidi *et al*., 2007; Poldini *et al*., 2007; Biondi *et al*., 2007).

Conservation of agro-ecosystems

Up to a few years ago, the importance of agro-ecosystems for the conservation of biodiversity inside human-influenced territories had been conceptually emphasised, but was underestimated in actuality, both in agro-environmental politics and by the scientific community. In the agronomic sector, research has been aimed mainly at the production dynamics within cultivated areas (cultivation techniques to improve yield quality and quantity), and in some cases at mitigation of the impact of cropping systems on the environment, particularly from the physico-chemical point of view. In the environmental research sector, attention has instead been focussed on conservation of the areas of greatest naturalistic value that are considered as the main biodiversity reservoir. This has thus neglected wide territories with intense agronomic use that are characterised by a much reduced level of biodiversity. Taking into account the scientific production of the last 30 years at the national level, vegetational studies indeed confirm this tendency, with a small number of papers regarding specifically the commensal vegetation of cultivated fields (Lorenzoni, 1979; Ferro, 1990; Baldoni, 1996; Ferro *et al*., 1997; Poldini *et al*., 1998; Baldoni *et al*., 2001; Covarelli, 2002), the post-cultivation ruderal vegetation (Ubaldi, 1976; Hruska & Dell'Uomo, 1981; Ubaldi *et al*., 1982), and the nitrophilous vegetation of the herbaceous margins (Brullo & Marcenò 1983; Hurska 1986; Allegrezza *et al*., 1987; Biondi *et al*., 1990; Biondi & Baldoni 1991; Hruska 1996).

Today, we are witnessing a change in the approaches to problems dealing with the protection of agro-ecosystems, which recognize the importance of interactions between artificial and natural systems (Baudry *et al*., 2000; Marshall & Moonen 2002; Le Coeur *et al*., 2002; Müller *et al*., 2004; Roschewitz *et al*., 2005; Jackson *et al*., 2007; Moonen & Bàrberi, 2008), while the introduction of the concept of an ecological network has allowed the re-evaluation of the semi-natural areas for conservation of biodiversity.

Materials and methods

The need for a system to evaluate environmental quality of agro-ecosystems arises from the need to develop an analytical instrument that uses the maximal informative potential of the vegetal component, taking advantage of the characteristics of the phytosociological method (a floristic, quick and statistical method) and of its more innovative dynamic approach. The bioindicator system proposed in the present study has the main aim of providing an evaluation of the phytocoenotic quality of an area at a determined moment. Starting from the study of the vegetation, and in particular, from the data contained in phytosociological tables, the system is designed to use the information regarding species,

life-forms, chorological types, soil coverage, and the dynamic characterisation of the syntaxa. Indeed, this information allows evaluation of biodiversity of phytocoenoses and provides an understanding of their relationships with the vegetational mosaic at different levels of complexity and maturity. A mature wood, for example, can have a biodiversity that is lower than the herbaceous margins, such as grasslands or edges. This should have great influence on management and conservation choices, in particular within the agro-ecosystem.

The basic phytosociological analyses have been carried out in study areas characterised by agricultural systems that are representative of central-northern Italy[1], and specifically of three lower catchment basins in the hilly environment near the Municipalities of Serra de'Conti (AN) and Ozzano dell'Emilia (BO), an area at the base of the Esino River basin in the Municipality of Chiaravalle (AN), and two flat areas in the Municipalities of Aiello del Friuli (UD) and S. Canzian d'Isonzo (GO), which are characterised by intensive cultivation regimes that have resulted in massive modifications to the territory (Taffetani et al., 2002). The data used also come from areas characterised by a higher level of naturalness (Taffetani et al., 2006), which have been mostly identified in the surroundings of the Sibillini Mountains Park (in the Region of Marche, Province of Macerata and Ascoli Piceno), and which include the Municipalities of Montemonaco (AP), Amandola (AP) and Sarnano (MC).

The vegetational study was developed through the phytosociological method of the Sigmatist School of Braun Blanquet (Braun-Blanquet, 1964), with modifications from the integrated Phytosociological School of Rivas-Martínez (Géhu and Rivas-Martínez, 1981).

Moreover, two databases have been constructed, in which have been collected the data arising from the vegetational analyses of the above-mentioned study areas, and through which it has been possible to carry out the calculation of the indices of these systems.

[1] The study starts from the results of the vegetational analyses carried out as part of the two "Research Programmes with a National Interest" (PRIN), with the titles, "Vegetated strips for the sustainability of the agro-ecosystem" (2001) and "Ecological networks in agriculture" (2003), conducted by the botany section of the Department of Environmental Sciences and Vegetal Production of the Polytechnic University of Marche, in collaboration with the Department of Vegetal Production and Environmental Agronomics of the University of Padua, the Department of Vegetal Production and Agricultural Technologies of the University of Udine, and the Department of Agro-environmental Science and Technology of the University of Bologne.

THE FLORISTIC-SYNTAXONOMIC DATABASE

The floristic-syntaxonomic database contains the floristic list of all of the species included in the "Flora of Italy" (Flora d'Italia) (Pignatti, 1982). These have been provided with their numerical codes, specific binomial names, life-forms and chorological types. From the comparisons of the different contributions of the main European authors (Guinochet et al., 1973; Rameau et al., 1989; Oberdorfer, 1990; Royer, 1991; Biondi et al., 1995; Rivas Martínez et al., 2002), every taxon has been univocally attributed to a specific syntaxonomic class. This has been done according to the criterion of choice that has taken account of the frequency of the attribution of the various authors and of the ecological and biogeographic significance of every species in the territory investigated. In its present form, the attribution of the syntaxonomic classes has been carried out only for the species found within the present study area; one of the main future objectives of the study is to implement and update the database for various sectors of the national territory, also in collaboration with other researchers.

THE MATURITY OF THE SYNTAXONOMIC CLASSES DATABASE

The database for the maturity of the syntaxonomic classes includes the main classes of vascular vegetation found in Europe, and it has been constructed following the ecological synthesis proposed by Rivas Martínez et al. (2002)[2], although reduced to the only classes of the Italian territory. On the basis of the interpretation of ecological and dynamic relationships of the heirarchical synphytosociological system, a maturity value has been attributed to each class, according to a logic that describes its evolutive dynamism. In this context maturity is considered as the grade of dyamic evolution of each coenosis inside a tessera (patch), within a range of values that go from the initial condition, with no vegetation coverage (for example a tilled filed or an active quarry), to the final condition, with vegetation corresponding to the equilibrium stage (climax). This kind of concept of maturity is quite overlayable to the naturaleness concept (Géhu & Géhu-Franck, 1988; Poldini et al., 1989; Feoli & Zuccarello, 1996; Biondi & Colosi, 2005; Loidi et al., 2007), but it has been kept separated on the basis that agro-ecosystems, as well as other highly disturbed areas, represent simplified

[2] With the exception of the class Salici purpureae-Populetea nigrae (Rivas-Martínez & Cantó ex Rivas-Martínez et al. 1991) Rivas-Martínez et al. 2002, for which it has been decided to maintain the denomination and classification of the lower levels previously described and included in the class Salicetea purpureae Moor 1958.

ecosystems where mature vegetations (series heads) are often missing. For this reason it becomes more coherent to evaluate the dynamic grade reached by each coenosis (maturity), instead of its distance to a reference climax (naturaleness) wich is fundamental for the evaluation of naturaleness but is not always easely representable in these contexts.

The values have been assigned by attributing to each class a coefficient of maturity (m) between 1 and 9. This quantifies the degree of maturity of the syntaxa at the physiognomic-structural, synecological and syndynamic levels, with maximum values for climatophilous coenoses (usually woods), and minimum values for the therophytic communities (annual species, weeds). Tab.1 summarises the ecological significance of these difference vegetation typologies from the evolutive point of view, in relation to the m attributed to the classes that describe them[3].

The syntaxonomic classes that describe the azonal vegetation comprise communities linked to particular environmental and ecological conditions, such as the presence of water (hygrophilous successions: e.g., *Isoeto-Nanojuncetea*, *Phragmito-Magnocaricetea*, *Salicetea purpureae*), lithosoils (xerophilous successions; e.g., *Tuberarietea guttatae*, *Sedo-Scleranthetea*, *Asplenietea trichomanis*), or elevated saline concentrations (alophilous classes; e.g., *Pegano-Salsoletea*). These have been given edaphic coefficients (s) that separate these three limiting factors (w = hygrophilia; x = xerophilia; a = alophilia), and that only take account of the physiognomic-structural aspects of the vegetation (Tab.2).

Tab. 1 - Coefficients of maturity (m) of the syntaxonomic classes on the basis of their position in the dynamic series

Coefficient of maturity (m)	EVOLUTIVE STAGE (vegetational typologies) and synaxonomic classes
Serial vegetation classes in a dynamic-evolutive order	
1	**SPONTANEOUS IN THE CULTIVATED PLOTS** (Commensal vegetation of cultivated fields) *Stellarietea mediae*
2	**POINEER COLONISATION** (Annual pioneer grasses and trodden herbaceous communities) *Polygono-Poetea annuae*
3	**TALL-HERB PHASE** (Perennial nitrophilous ruderals of grassy margins) *Artemisietea vulgaris*
4	**REGULARLY CUT GRASSLANDS** (Grasslands and perennial herbaceous margins subjected to cutting) *Molinio-Arrhenatheretea*
5	**MATURE GRASSLANDS** (Pastures and grasslands of herbaceous perennials) *Festuco-Brometea, Lygeo-Stipetea, Nardetea strictae, Poetea bulbosae, Koelerio-Corynephoretea*
6	**NITRIFICATED RUDERALS AND EDGES** (Nitrophilous and mesophilous herbaceous perennials and ruderal vines) *Galio-Urticetea, Parietarietea, Cardamino hirsutae-Geranietea purpurei*
7	**INTERNAL AND EXTERNAL WOOD FRINGES** (Edges and forest glades of herbaceous perennials) *Trifolio-Geranietea, Epilobietea angustifolii, Mulgedio-Aconitetea*
8	**FOREST MANTLES, SHRUBLANDS AND GARRIGUES** (shrubbery and chamaephyte vegetation) *Rhamno-Prunetea, Cytisetea scopario-striati, Rosmarinetea officinalis, Calluno-Ulicetea, Cisto-Lavanduletea, Cisto-Micromerietea*
9	**WOODS** (generally climatophilous forest vegetation) *Querco-Fagetea, Quercetea ilicis, Vaccino-Piceetea, Erico-Pinetea, Pino-Juniperetea*

[3] It needs to be mentioned here that the secondary grasslands of the class *Molinio-Arrhenatheretea* tend to develop (in particular in montane environments) on deeper and more evolved soils compared to the coenoses of the class *Festuco-Brometea*, resulting in communities that are presumably more mature from the dynamic point of view. On the other hand, however, within the herbaceous coenoses that are cut or used as pasture in hilly environments, which are generally characterised by the presence of species of the class *Molinio-Arrhenatheretea*, the species of the class *Festuco-Brometea* tend to gradually prevail in situations of abandonment or non-use, according to evolutive dynamics that are influenced by the "use factor".

CALCULATION OF THE SYNTHETIC INDICES AND ECOLOGICAL SIGNIFICANCE

All of the indices reported below, with exception of the biodiversity index, were calculated according to the coverage value (c) of each single species present within a phytosociological table. This value is relative to a single relevé or to the results of a mean value of relevés from a single table. The value of c is attributed on the basis of the method proposed by Braun-Blanquet (1964) and modified by Pignatti (1982) (Tab. 3).

Tab. 2 - Edaphic coefficients (s) of the azonal vegetation classes based on the ecological gradient

Edaphic coefficient (s)	VEGETATION CLASSES WITH AN EDAPHIC DETERMINISM
sw – Hygrophilous vegetation classes	
1	Oryzetea sativae
2	Charetea fragilis, Potametea, Lemnetea
4	Bidentetea tripartitae, Isoeto-Nanojuncetea
6	Scheuchzerio palustris-Caricetea nigrae, Oxycocco-Sphagnetea, Montio-Cardaminetea, Phragmito-Magnocaricetea, Utricularietea intermedio-minoris, Adiantetea, Isoeto-Littorelletea
8	Salicetea purpureae, Nerio-Tamaricetea
9	Alnetea glutinosae
sx – Xerophilous vegetation classes	
2	Tuberarietea guttatae
5	Festuco-Seslerietea, Sedo-Scleranthetea, Asplenietea trichomanis, Thalspietea rotundifolii
sa – Alophilous vegetation classes	
2	Thero-Salicornietea, Cakiletea maritimae, Saginetea maritimae
5	Pegano-Salsoletea, Juncetea maritimi, Crithmo-Limonietea, Spartinetea maritimae, Sarcocornietea fruticosae

Tab. 3 - Quantification of the coverage value (c)

COVERAGE (Br.-Bl.,1964 mod. Pignatti, 1982)	% max value	Coverage value (c)
+ = coverage < 1%	1	0.05
1 = coverage 1%-20%	20	1
2 = coverage 20%-40%	40	2
3 = coverage 40%-60%	60	3
4 = coverage 60%-80%	80	4
5 = coverage 80%-100%	100	5

INDEX OF MATURITY

Through the integration of the database described above, it is possible to attribute to each species a value (y) that corresponds to the coefficient of maturity (m) or to the edaphic coefficient (s) according to the phytosociological class that they belong to. Once the value y has been associated to each of the species found or present in a phytosociological table, it is possible to calculate the Index of Maturity (IM) using the following formula:

The IM provides a measure of the actual stage of maturity of a vegetal community in relation to the distribution and soil coverage of all the species that are present. The m represents the qualitative data as the basis of the IM, and it was constructed in such a way as to amplify the role of the herbaceous vegetation classes (margins, grasslands, edges), as these are more sensitive to disturbance in environments with human influence, such as agro-ecosystems.

Based on the attribution of the IM to all vegetation typologies present in a defined area, an *Index of Synthetic Maturity (ISM)* can be calculated at different territory scales, by using data related to the areas occupied by all vegetation units mapped with the GIS (Geographical Information System), or the information contained in the Vegetation Maps. From the same data it is also possible to calculate the *Incidence of Unproductive Areas* (*IUA*), based on the distinction between cultivated/disturbed areas (vegetation communities with $IM \leq 2$) and unproductive areas with semi-natural and natural vegetation ($IM \geq 2$).

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

where:

IM = Index of Maturity

c_i = coverage value of each single species, given as the absolute value relative to a single relevé, or as a mean value of relevés from a table;

y = value corresponding to m ($y = m$) for species of the classes described in Tab. 1 (m = maturity coefficient), or to s ($y = s$) for species of the classes described in Tab. 2 (s = edaphic coefficient);

$C_{(tot)}$ = total coverage value, obtained by summing the values of c for all of the species present, according to the formula [$C_{(tot)} = \Sigma\ c_i$]

The ISM and IUA are calculated according to the following formulas:

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

where:

ISM = Index Synthetic Maturity

IM_i = Index of Maturity relative to the i-th mapped vegetation typology

Ω_i = area of the i-th mapped vegetation typology

$\Omega_{(tot)}$ = total mapped area

$$IUA = \frac{\sum_{i=1}^{n} [\Omega_{(u)}]_i}{\Omega_{(tot)}} \times 100$$

where:

IUA = Incidence of Unproductive Areas

$[\Omega_{(u)}]_i$ = area of the i-th mapped unproductive vegetation (IM≥2)

$\Omega_{(tot)}$ = total mapped area

EDAPHIC INDICES

The calculation of the edaphic indices follows the same procedure as the *IM*. In this case, the values of *c* are derived from the vegetation classes, as subdivided into xerophiles [$c_{(sx)}$], hygrophiles [$c_{(sw)}$] and alophiles [$c_{(sa)}$]. The calculations must therefore be carried out by separately taking into consideration the species belonging to the classes described above (Tab.2), following the formulas:

$$IX = \frac{\sum_{i=1}^{n} \langle [c_{(sx)}]_i \times s \rangle}{C_{(tot)}}$$

$$IW = \frac{\sum_{i=1}^{n} \langle [c_{(sw)}]_i \times s \rangle}{C_{(tot)}}$$

$$IA = \frac{\sum_{i=1}^{n} \langle [c_{(sa)}]_i \times s \rangle}{C_{(tot)}}$$

where:

IX = Index of Xerophilia

IW = Index of Hygrophilia

IA = Index of Alophilia

$[c_{(sx)}]_i$; $[c_{(sw)}]_i$; $[c_{(sa)}]_i$ = coverage values of each species of the xerophilous (*sx*), hygrophilous (*sw*) and alophilous (*sa*) classes, given as absolute *c* values relative to a single relevé, or as a mean value of the relevés from a table;

s = edaphic coefficient;

$C_{(tot)}$ = total coverage value, obtained by summing the values of *c* of all of the species present, according to the formula [$C_{(tot)} = \Sigma c_i$].

These edaphic indices of Xerophilia (IX), Hygrophilia (IW) and Alophilia (IA) indicate the presence of species adapted to environments that are conditioned by these limiting factors. These values provide useful information for the evaluation framework of development conditions of the phytocoenoses, and they influence the IM, which indeed represents the synthesis of IM,IX, IW and IA.

INDICES OF THE LIFE-FORMS

The indices of the life-forms, according to Pignatti (1982), measure the coverage percentages of the annual therophytic species (T), and perennial species, subdivided into hemicryptophytic (H) and perennial non-hemicryptophyte species, these including phanerophytes (P), nano-phanerophytes (NP), geophytes (G), camaephytes (CH). The indices are calculated according to the following formulas:

$$IT = \frac{\sum_{i=1}^{n} [c_{(t)}]_i}{C_{(tot)}} \times 100 \qquad IP = IH + IF$$

with

$$IH = \frac{\sum_{i=1}^{n} [c_{(h)}]_i}{C_{(tot)}} \times 100 \qquad IF = \frac{\sum_{i=1}^{n} [c_{(f)}]_i}{C_{(tot)}} \times 100$$

where:

IT= Index of the therophytic component

IP= Index of the perennail component

IH= Index of the hemicryptophytic component

IF= Index of the periennal non-hemicryptophytic component

$[c_{(t)}]_i$; $[c_{(h)}]_i$; $[c_{(f)}]_i$ = coverage values of each therophyte species (t), and perennial hemicryptophyte (h) or non-hemicryptophyte (f) species, given as the absolute value relative to a single sampling, or as a mean value of samplings from a table;

$C_{(tot)}$ = total coverage value, obtained by summing the values of *c* for all of the species present, according to the formula [$C_{(tot)} = \Sigma c_i$]

These indices provide indications regarding the trend towards structuration of vegetal coenoses in relation to the level of disturbance. In particular, high IT values express the pioneering tendency of the herbaceous therophyte communities characterised by high human disturbance (e.g. tillage, weeding), while the abundance of perennial species, resulting in high values of IP, is determined by the different co-participation of IH and IF. The presence of herbaceous perennial vegetation (high IH values) indicates moderate disturbance (e.g. cutting, pasturing), while the abundance of non-hemicryptophyte perennial species (high IF values) is

determined by the evolution of the vegetation towards stable coenoses with low disturbance levels.

PHYTOGEOGRAPHIC INDICES

The phytogeographic indices relative to the chorological types are normally used for floristic studies, although in this case they are useful to provide information regarding the presence and the grade of coverage of endemism, of cosmopolitan species, and of exotic flora. The calculation of these phytogeographic indices is based on the coverage values (as percentages) of all of the species that have the same distribution areas (chorological type of Pignatti, 1982) or the same local behaviour (invasive status according to Viegi *et al.*, 2003; Camarda *et al.*, 2005), grouped according to the categories indicated in Tab. 4.

and artificiality of the vegetal coenoses in relation to the human pressure in the territory. The presence of endemism (or the relative rarity) can indeed be useful for qualitatively individuating and evaluating the agricultural areas that are valuable from a floristic point of view. The index of the exotic component provides a significant measure of the degree of artificiality of the territory, and it can be useful for environments with strong human determinism, both within agricultural areas and in the urban and peri-urban belts, where the presence of hemi-hemerophyte indigenous species (coming from nearby territories) or of cultivated / wild exotic species (like, for example, plantations of ornamental trees and *Robinia pseudoacacia* or *Ailanthus altissima* communities) can inhibit the evolutive dynamics of the spontaneous vegetation.

Tab. 4 - Synthesis of the phytogeographic categories per group of species

GROUPS OF SPECIES	PHYTOGEOGRAPHIC CATEGORIES	REFERENCES
Endemic (l)	Endemic, sub-endemic	Pignatti 1982; Tutin *et al.*, 1964-1980; Tutin *et al.*, 1993; Conti *et al.*, 2005
Groups with a wide distribution (d)	Cosmopolitan, sub-cosmopolitan, sub-tropical	Pignatti 1982; Tutin *et al.*, 1964-1980; Tutin *et al.*, 1993
Exotic and cultivated (e)	Cultivated, casual adventitious, naturalised adventitious, doubtful exotic, hemi-hemerophyte	Viegi *et al.*, 2003; Camarda *et al.*, 2005; Poldini *et al.*, 2001

The indices are calculated individually as follows:

$$IL = \frac{\sum_{i=1}^{n}[c_{(l)}]_i}{C_{(tot)}} \times 100$$

$$ID = \frac{\sum_{i=1}^{n}[c_{(d)}]_i}{C_{(tot)}} \times 100$$

$$IE = \frac{\sum_{i=1}^{n}[c_{(e)}]_i}{C_{(tot)}} \times 100$$

where:

IL = Index of the endemic component
ID = Index of the components with a wide distribution
IE = Index of the exotic components
$[c_{(l)}]_i$; $[c_{(d)}]_i$; $[c_{(e)}]_i$ = coverage value of each endemic (*l*), widely distributed (*d*) and exotic (*e*) species, given as the absolute value relative to a single relevé, or as a mean value of relevés from a table;
$C_{(tot)}$ = total coverage value, obtained by summing the values of *c* of all of the species present, according to the formula $[C_{(tot)} = \Sigma \, c_i]$

The phytogeographic indices provide measures of the degree of simplification, exotic contamination

INDEX OF FLORISTIC BIODIVERSITY

The Index of Floristic Biodiversity (*IFB*) represents the only value calculated on the basis of the number of species present independent of their degree of coverage, and it is obtained by dividing the number of species found in a given coenosis (*sp*) by the area of the relevé expressed in square metres (*sm*), according to the formula:

$$IFB = sp \, / \, sm$$

The *IFB* expresses the relative abundance (over the area) of the species within the various vegetal coenoses. These indications are useful to compare analogous vegetation typologies in different territories, or at different stages of the same series.

Results

PRACTICAL EXAMPLES

The application of the bioindicator system was based on data derived from specific studies carried out in sample areas. The results of the application of the system are reported below for two study areas in the hilly agricultural territory of the Marche Region,

corresponding to two tributary basins of the Misa River, in the agricultural area of Serra de' Conti (AN). These two river basins are representative of the internal Marche hills characterised by relatively extensive agricultural practices.

Indeed, these are territories traditionally used for agriculture, and they show different levels of land parcelling, with consequent influences on the non-productive sections. In these areas, cereals and sunflower rotations are dominating, and to a lesser extent, alpha-alpha; for the arboreal cultivation, this is mainly vineyards. In this context, the semi-natural spontaneous vegetation is very fragmented and limited, mixing in a mosaic with cultivated fields.

The two river basins in the sampling area, known as Spescia and Bottiglie (Fig. 1), have areas of 80.83 hectares and 60.33 hectares, respectively, with the presence of non-cultivated areas (hedges, ditches, access roads, etc.) that represent 13% and 19%, respectively, of the total area.

The management of the land used for agriculture (the "Superficie Agricola Utilizzata"; SAU) in the two river basins is markedly different: the Spescia basin has a more simplified cropping system, with some years seeing a single crop, while the Bottiglie basin has a higher level of land parcelling because of the fragmentation of the land ownership and the adoption of measures of land use according to organic agricultural techniques (about 50% of the SAU), with the consequent increased differentiation of the cultivation and increased frequency of the margin areas.

From the bioclimatic point of view, the analysis of the thermo-pluviometric data (from the Pergola and Jesi stations, in the Ancona Province) has allowed the inclusion of the study areas in the oceanic temperate bioclimate, of the Submediterranean variant, with Submediterranean thermotype and low humid ombrotype.

The phytosociological study of the vegetation, together with the climatic, geological and morphological correlations, has allowed the identification of four different vegetation series and one riparian succession (Rismondo & Taffetani 2005; Taffetani *et al.*, 2006). The description of the series follows the indications and nomenclature adopted for the synphytosociological maps of the Natura 2000 sites included in the "Project of the Ecological Network of Marche Region" (Biondi *et al.*, 2007).

EDAPHOXEROPHILOUS, NEUTRO-BASIPHILOUS SERIES OF THE DOWNY OAK: *ROSO SEMPERVIRENTIS-QUERCO PUBESCENTIS*

QUERCO PUBESCENTIS SIGMETUM (FIG. 2).

The most mature vegetation in this unit is located in the summit sectors of the two catchment basins and it is represented by the forest coenosis of the association *Roso sempervirentis-Quercetum pubescentis quercetosum pubescentis* found in a nearby zone outside the study territory. Linked to this series, there is the shrub layer of the association *Spartio juncei-Cytisetum sessilifolii* (class *Rahmo-Prunetea*). The herbaceous vegetation is represented by *Bromus erectus* and *Osyris alba* communities containing grassland species of the class *Festuco-Brometea*, together with edge species of the class *Trifolio-Geranietea*. For the commensal vegetation of crop fields, the associations identified are: *Biforo testiculate-Adoninetum cupanianae* for the commensal species of durum wheat; and *Linario spuriae-Stachyetum annuae* for the weed vegetation in the sunflower and sugar-beet cultivation.

Fig. 2 - Vegetation transect
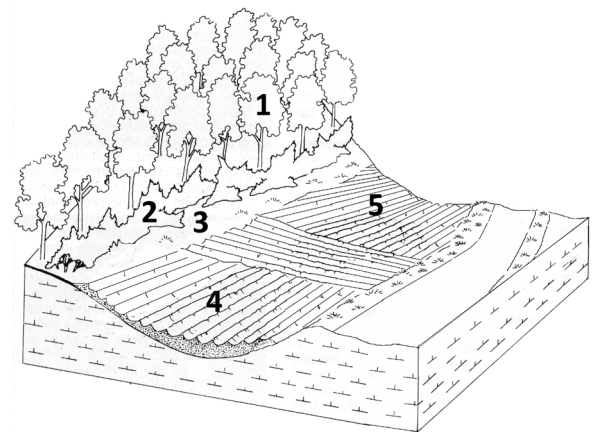
EDAPHOXEROPHILOUS SERIES OF THE DOWNY OAK
1. Wood: *Roso sempervirentis-Quercetum pubescentis quercetosum pubescentis*
2. Shrub layer: *Spartio juncei-Cytisetum sessilifolii*
3. Herbaceous margins: *Bromus erectus* and *Osyris alba* communities
4. Cereal commensals: *Biforo testiculatae-Adonidetum cupanianae*
5. Sunflower and sugar-beet commensals: *Linario spuriae-Stachyetum annuae*

CLIMATOPHILOUS, NEUTROPHILOUS SERIES OF TURKEY OAK: *LONICERO XYLOSTEI-QUERCO CERRIDIS LONICERO XYLOSTEI* SIGMETUM (FIG. 3).

For this series, which is only found in the Bottigle basin, the most mature stage is represented by the association *Lonicero xylostei-Quercetum cerridis loniceretosum xylostei*, seen for a nearby area. The shrub layer is from the association *Rubo ulmifolii-*

Fig. 3 - Vegetation transect
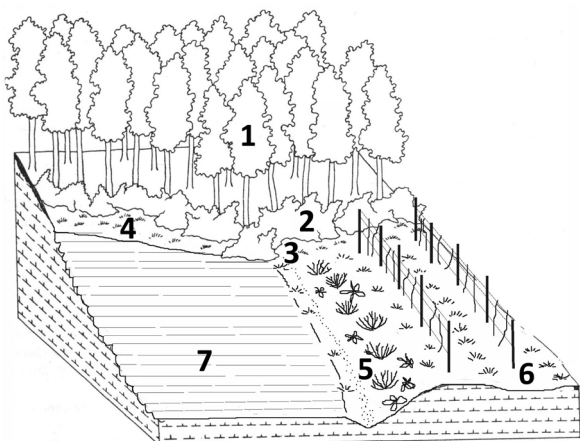
CLIMATOFILOUS SERIES OF THE TURKEY OAK
1. Wood: *Lonicero xylostei-Quercetum cerridis loniceretosum xylostei*
2. Shrub layer: *Rubo ulmifolii-Ligustretum vulgaris*
3. Edges: *Centaureo neapolitanae-Galietumum albi*
4. Tall herbs: *Centaureo bracteatae-Brometum erecti*
5. Tall herbs: *Pulicaria dysenterica* communities
6. Vineyard commensals: *Cynodon dactylon* and *Convolvulus arvensis* communities
7. Cereal commensals: *Biforo-testiculatae-Adonidetum cupanianae*; Sunflower and sugar-beet commensals: *Linario spuriae-Stachyetum annuae*

Ligustretum vulgaris, while the edge vegetation is represented by the association *Centaureo neapolitanae-Galietum albi*. The associations of the stable grasslands along field margins can be referred to *Centaureo bracteatae-Brometum erecti* of the class *Festuco-Brometea*. Along the edges of the roads there are communities of nitrophilous tall herbs dominated by *Pulicaria dysenterica*. The associations identified for the agricultural cultivations are: groupings of *Cynodon dactylon* and *Convolvulus arvensis* for the herbaceous vegetation within the vineyards, *Biforo-testiculatae-Adonidetum cupanianae* for the cereal commensals, and *Linario spuriae-Stachyetum annuae* for the sunflower and sugar-beet commensals.

CLIMATOPHILOUS, NEUTRO-BASIPHILOUS, SERIES OF THE HOP HORNBEAM: *ASPARAGO ACUTIFOLII-OSTRYO CARPINIFOLIAE ASPARAGO ACUTIFOLII* SIGMETUM (FIG. 4A)

This series characterises the central parts of the Spescia basin and a portion of the Bottiglie basin. The most mature vegetation is represented by a woody strip of the association *Asparago acutifolii-Ostryetum carpinifoliae* that is only present within the Spescia basin, which is accompanied by a shrub layer of the association *Clematido-Rubetum Ulmifolii*.

The field margins are covered with stable grasses of the association *Centaureo bracteatae-Brometum erecti*, while the ruderal and nitrophilous herbaceous formations are represented by the grasses of the association *Agropyro repentis-Dactyletum glomeratae* and by a *Ballota nigra* community, both from the class *Artemisietea*. The commensal coenoses are described as *Cynodon dactylon* and *Convolvulus arvensis* communities for the herbaceous vegetation within the vineyards, and with the association *Biforo testiculatae-Adoninetum cupanianae* (variant with *Matricaria inodora*) for the durum wheat, while for the sunflower and sugar-beet commensals, the association *Linario spuriae-Stachyetum annuae* has been noted.

Fig. 4 - Vegetation transect
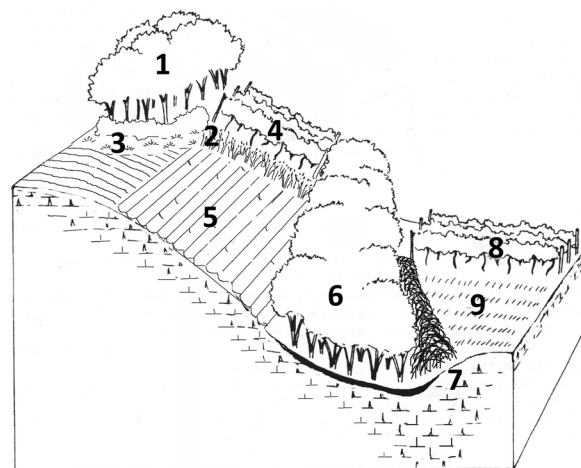
A: CLIMATOPHILOUS SERIES OF HOP HORNBEAM
1. Wood: *Asparago acutifolii-Ostryetum carpinifoliae*
2. Margin vegetation: *Agropyro repentis-Dactyletum glomeratae*
3. Margin vegetation: *Ballota nigra* communities
4. Vineyard commensal: *Cynodon dactylon* and *Convolvulus arvensis* communities
5. Cereals commensals: *Biforo-testiculatae-Adonidetum cupanianae*; Sunflower and sugar-beet commensals: *Linario spuriae-Stachyetum annuae*

B: EDAPHOHYGROFILOUS SERIES OF THE ELM
6. Wood: *Symphyto bolbosi-Ulmetum minoris*
7. Shrub layer: *Rubo ulmifolii-Ligustretum vulgaris; Clematido-Rubetum ulmifolii*
8. Vineyard commensals: *Cynodon dactylon* and *Convolvulus arvensis* communities
9. Cereal commensals: *Biforo-testiculatae-Adonidetum cupanianae*; Sunflower and sugar-beet commensals: *Linario spuriae-Stachyetum annuae*

EDAPHOHYGROPHILOUS, NEUTROPHILUS BASIPHILOUS SERIES OF THE ELM: *SYMPHITO BULBOSI-ULMO MINORIS* SIGMETUM (FIG. 4B)

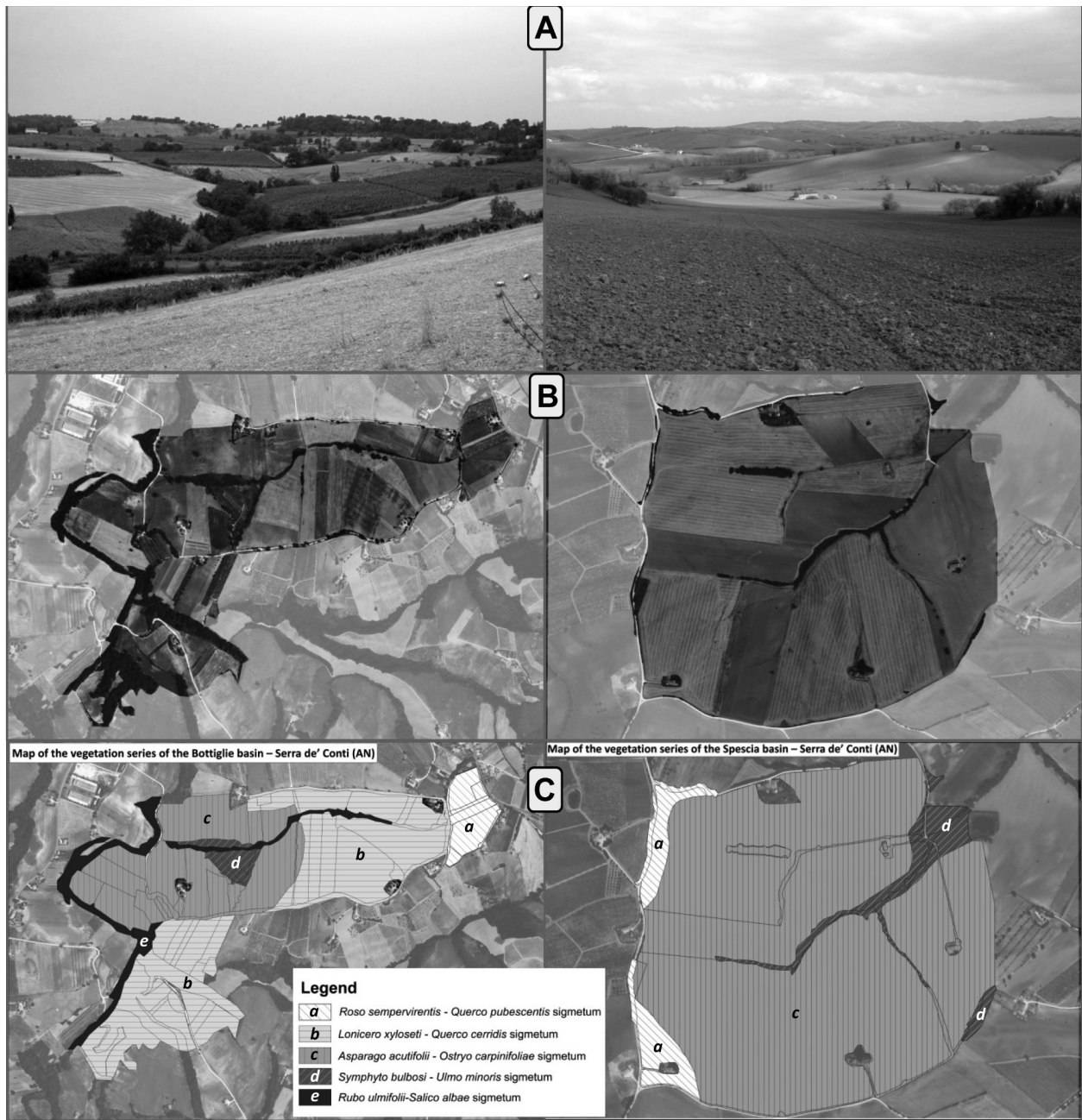This series is characterised by soils that are more

Fig. 1 - Panoramic photographs (A), aerial photographs (B) and maps of the vegetation series (C) of the two river basins of Bottiglie (left) and Spescia (right).

humid and have a greater clay content, and it is found in both of the river basins in contact with the systems of the main water courses. The most mature vegetation comprises wood nuclei of *Ulmus minor* of the association *Symphito bulbosi-Ulmetum minoris* (class *Querco-Fagetea*). Linked to these there is a shrub layer of the association *Rubo ulmifolii-Ligustretum vulgaris*, alternating with a less evolved shrub formation from the association *Clematido-Rubetum ulmifolii*. The associations identified for the agricultural cultivations

are: *Cynodon dactylon* and *Convolvulus arvensis* communities for the herbaceous vegetation within the vineyards, *Biforo-testiculatae-Adonidetum cupanianae* for the cereal commensals, and *Linario spuriae-Stachyetum annuae* for the sunflower and sugar-beet commensals.

EDAPHOHYGROPHILUS, NEUTROPHILOUS SERIES OF THE WHITE WILLOW: *RUBO ULMIFOLII-SALICO ALBAE* SIGMETUM

These are linear formations of willow and

poplar attributed to the association *Rubo ulmifolii-Salicetum albae* described for the mesomediterranean (Mediterranean macrobioclimate) and submediterranean (Temperate macrobioclimate) sectors of central Italy (Allegrezza *et al*., 2006). These phytocoenoses are characterised by the presence of *Salix alba*, *Rubus ulmifolius* and *Clematis vitalba*, together with other Mediterranean species such as *Hedera helix* and *Arum italicum*. This structure follows the banks of the main water course from midway along the Bottiglie basin.

APPLICATION OF THE BIONDICATOR SYSTEM

The bioindicator system can be applied at various scales: from the single point sampling to the farm level, and from the vegetation units to the landscape systems. Below we provide the values of all the indices of the system (Tab. 5) and the graphs relating to the values of the *IM*, the *IFB*, the Life-Form Indices (IT, IH, IP), and the Phytogeographic Indices (IL, ID, IE) (Fig. 5) applied to the vegetation series *Lonicero xylostei-Querco cerridis lonicero xylostei* sigmetum, which is considered to be the main representative for the hilly agricultural areas of the central sectors of the Italian Adriatic side.

IM and IFB of the vegetal communities present in a specific territory can therefore allow a precise evaluation of the degree of conservation and the level of disturbance of the agro-ecosystem in relation to the farming practices.

Of particular note here is the significance of the graph that shows the indices of the life-forms (IT, IH, IF; Fig. 5C). This reveals the presence of annual, perennial and hemicryptophyte (herbaceous perennial) species in the various coenoses, indicating which of these has a more stable structure in relation to the degree of disturbance. Specifically, it is possible to show progressive growth in the levels of the presence and coverage of perennial species in the progressively less disturbed situations. This is shown by the differences between the percentages of the cereal commensals and the vineyard commensals, where a lower presence of annual species in favour of hemicryptophytes shows a greater structuration of the herbaceous coverage due to the management of the vineyard, which is subjected to infrequent attention. From the phytogeographic point of view, the increases in the IL, ID and IE indices (Fig. 5D) demonstrate the greater presence of cosmopolitan species in the less mature communities because of the human disturbance, from the herbaceous margins

Tab. 5 - Values of the indices relative to the vegetation series *Lonicero xylostei-Querco cerridis lonicero xylostei sigmetum*

Vegetation typology	IM	IX	IW	IA	IT	IP	[IH - IF]	IL	ID	IE	IFB
		(0-9)				(0%-100%)			(0%-100%)		(sp/sm)
Lonicero xylostei-Quercetum cerridis	8.7	0.0	0.0	0.0	0.1	99.9	[0.9 - 99.0]	1.6	0.0	0.0	0.5
Rubo ulmifolii-Ligustretum vulgaris	8.0	0.0	0.0	0.0	0.0	100.0	[4.1 - 95.9]	0.0	1.8	0.0	1.0
Centaureo neapolitanae-Galietum albi	6.7	0.0	0.0	0.0	1.0	99.0	[71.1 - 27.9]	0.3	14.6	0.0	1.1
Centaureo bracteatae-Brometum erecti	4.5	0.1	0.0	0.0	23.0	77.0	[54.0 - 23.0]	0.0	0.2	8.4	4.2
Pulicaria dysenterica communities	3.5	0.0	0.0	0.0	2.9	97.1	[77.3 - 19.8]	0.0	9.0	3.7	2.4
Cynodon d. and *Convolvulus a.* communities	1.4	0.0	0.0	0.0	59.5	40.5	[20.8 - 19.7]	0.0	15.2	1.1	2.1
Biforo testiculatae-Adonidetum cupanianae	1.5	0.0	0.0	0.0	91.1	8.9	[1.5 - 7.4]	0.0	13.1	11.9	1.5
Linario spuriae-Stachyetum annuae	1.3	0.0	0.0	0.0	94.2	5.8	[4.8 - 1.0]	0.0	12.9	4.0	0.9

The graphs relative to the IM and the IFB for the transect of the vegetation series *Lonicero xylostei-Querco cerridis lonicero xylostei* sigmetum (Fig. 5A) show different behaviours according to the vegetation typologies to which they refer (Fig. 5B). In particular, while the maturity values decrease from the wood to the commensal coenoses, the biodiversity instead has the highest values corresponding to the herbaceous coenoses of the fields margins. The measures of the

to the cultivated fields, although to a maximum of not more than 15.2%. The presence of exotic species within the commensal coenoses (of the cereals, sunflowers and sugar-beet) and of the herbaceous margins demonstrate finally the greater exposure to allochthonous contamination derived from tillage and weeding practices.

Moving the analysis scale to the territory level, it is possible to compare different areas like the two river
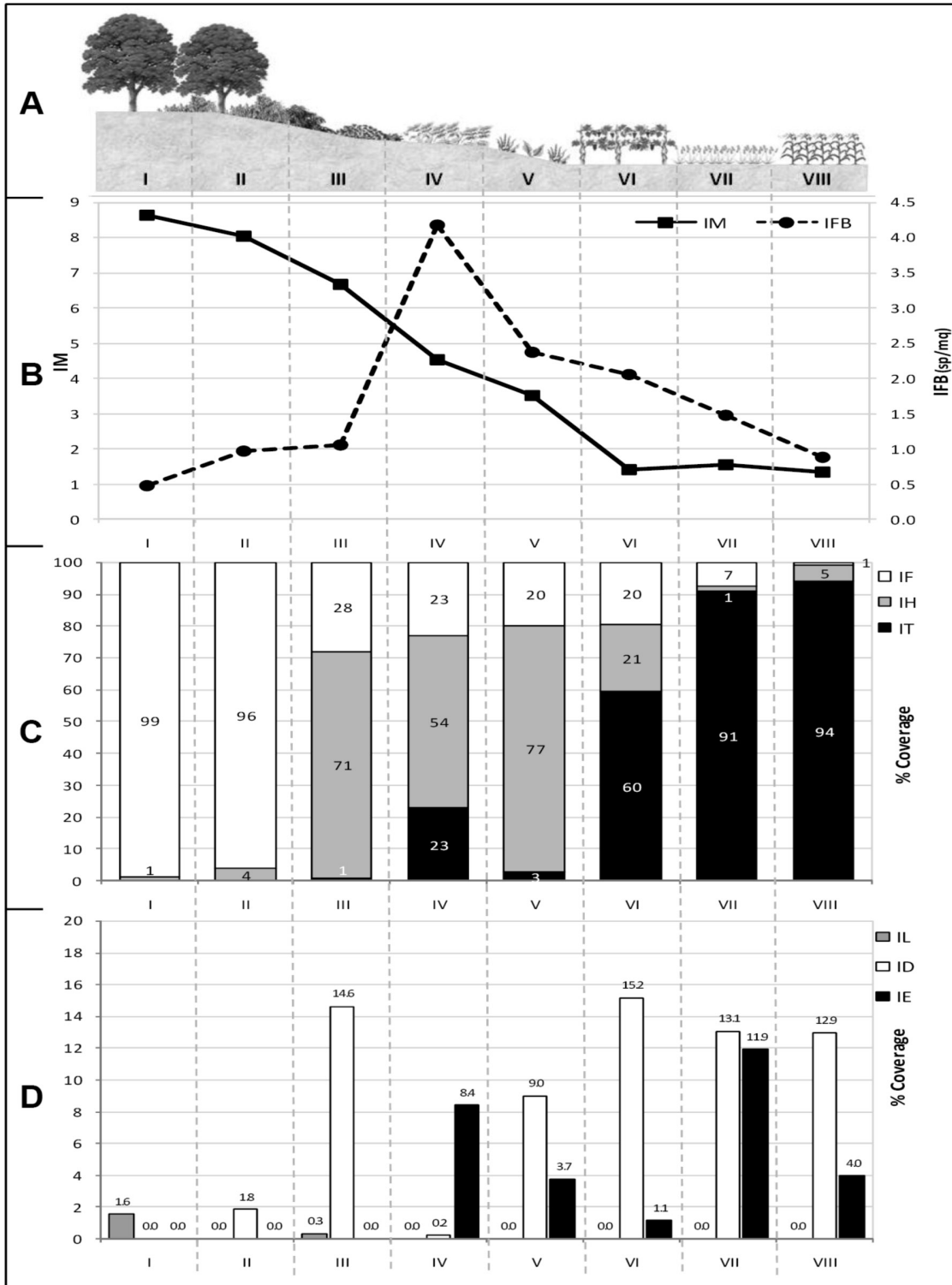
Fig. 5 - (A) Transect of the vegetation series of the Turkey oak *Lonicero xylostei-Querco cerridis lonicero xylostei* sigmetum

I. Wood: *Lonicero xylostei-Quercetum cerridis*
II. Shrub layer: *Rubo ulmifolii-Ligustretum vulgaris*
III. Edges: *Centaureo neapolitanae-Galietumum albi*
IV. Grassland: *Centaureo bracteatae-Brometum erecti*
V. Tall herbs: *Pulicaria dysenterica* communities
VI. Vineyard commensals: *Cynodon dactylon* and

Convolvulus arvensis communities
VII. Cereal commensals: *Biforo-testiculatae-Adonidetum cupanianae*
VIII. Sunflower and sugar-beet commensals: *Linario spuriae-Stachyetum annuae*

(B) Graph of *IM* and *IFB* Indices; (C) Histogram of *IT, IH, IF* Indices; (D) Histogram of *IL, ID, IE* Indices

basins studied, using the proposed indices, so as to reveal the effects of different cropping systems on the components of the agro-ecosystem. Through the use of the GIS software, it has been possible to calculate the areas of all the vegetation typologies that have been described and mapped. From the comparisons of the two river basins for the areas occupied by all the vegetation typologies divided according to the IM (Fig. 6), it is possible to see how the greater subdivision into land parcels and the cultivation diversification of the Bottiglie basin has resulted in a wider distribution of the maturity values in the various IM classes. This difference can be interpreted as a consequence of the

The data relating to the land use, as expressed through the pie charts of the Incidence of Unproductive Areas IUA) (Fig. 8), confirm the positive effects of crop diversification on the presence of semi-natural areas and, as a consequence, on the overall level of maturity expressed by the system. The importance of this factor has also been demonstrated by agronomic studies carried out within these two areas (Roggero & Toderi 2002a; b; Orsini *et al.*, 2008), where the use of monitoring systems for the runoff and quality of downstream water has allowed the evaluation of the effects of different farming practices on the loss of nutrients, water pollution, and soil erosion. These
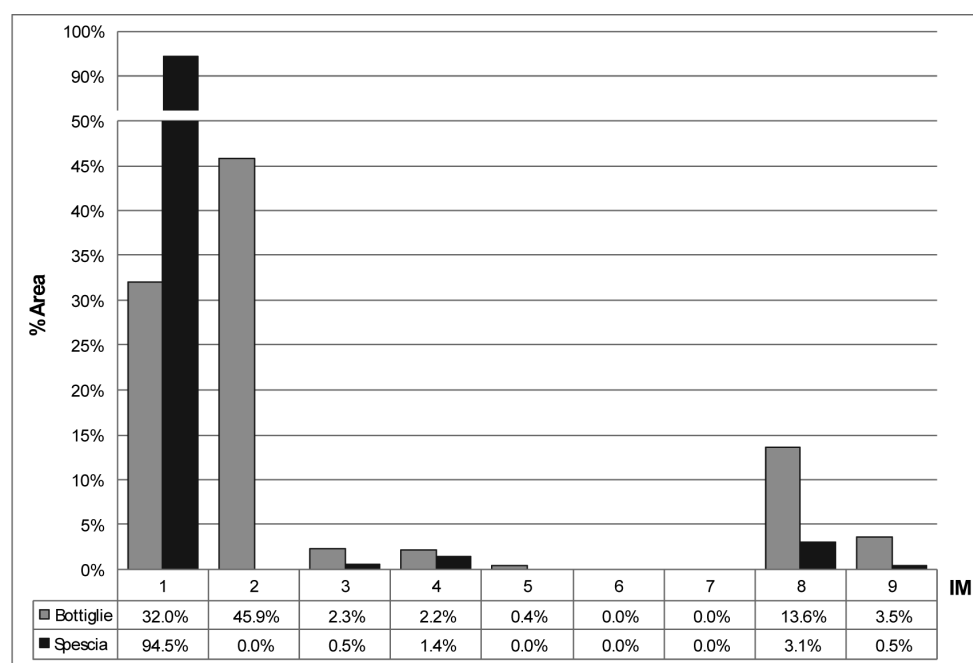

Fig. 6 - Histogram and data relative to the areas (%) occupied by the vegetation typologies subdivided according to the Maturity Index within the river basins of Bottiglie and Spescia.

IM	1	2	3	4	5	6	7	8	9
Bottiglie	32.0%	45.9%	2.3%	2.2%	0.4%	0.0%	0.0%	13.6%	3.5%
Spescia	94.5%	0.0%	0.5%	1.4%	0.0%	0.0%	0.0%	3.1%	0.5%

adoption of low-impact farming practices in terms of chemical weeding and phytosanitary treatments, with respect to the Spescia basin, where chemical weeding is also carried out for crop margins and unproductive aeras. These differences are also evident in a comparison of the maps relating to the IM distribution (Fig. 7), through which it is possible to see the various chromatic gradients that are indicative of the maturity values of all of the vegetation typologies identified in both of the river basins.

Moreover, based on the data relating to the areas occupied by all of the mapped vegetation typologies, the Index of Synthetic Maturity (ISM) can be obtained for the two river basins studied. The values (Bottiglie ISM = 2.72; Spescia ISM = 1.75) show the difference that arises from the cropping systems adopted in these two areas, confirming what has already been seen from the maps of the IM (Fig. 7).

data have confirmed the importance of farmland fragmentation and crop diversification operated in the Bottiglie basin, and the consequent greater contribution of the semi-natural vegetation, towards the reduction of nitrate pollution and soil erosion following rainy events.

Conclusions

Advantages and limits of the methods described

The study of the vegetation from the geobotanical and phytosociological points of view represents an effective, detailed, flexible and precise evaluation method for the landscape dynamics. The system of bioindicators for the evaluation of the environmental quality of agro-ecosystems proposed in this study does not substitute for the phytosociological analysis. Its objective is
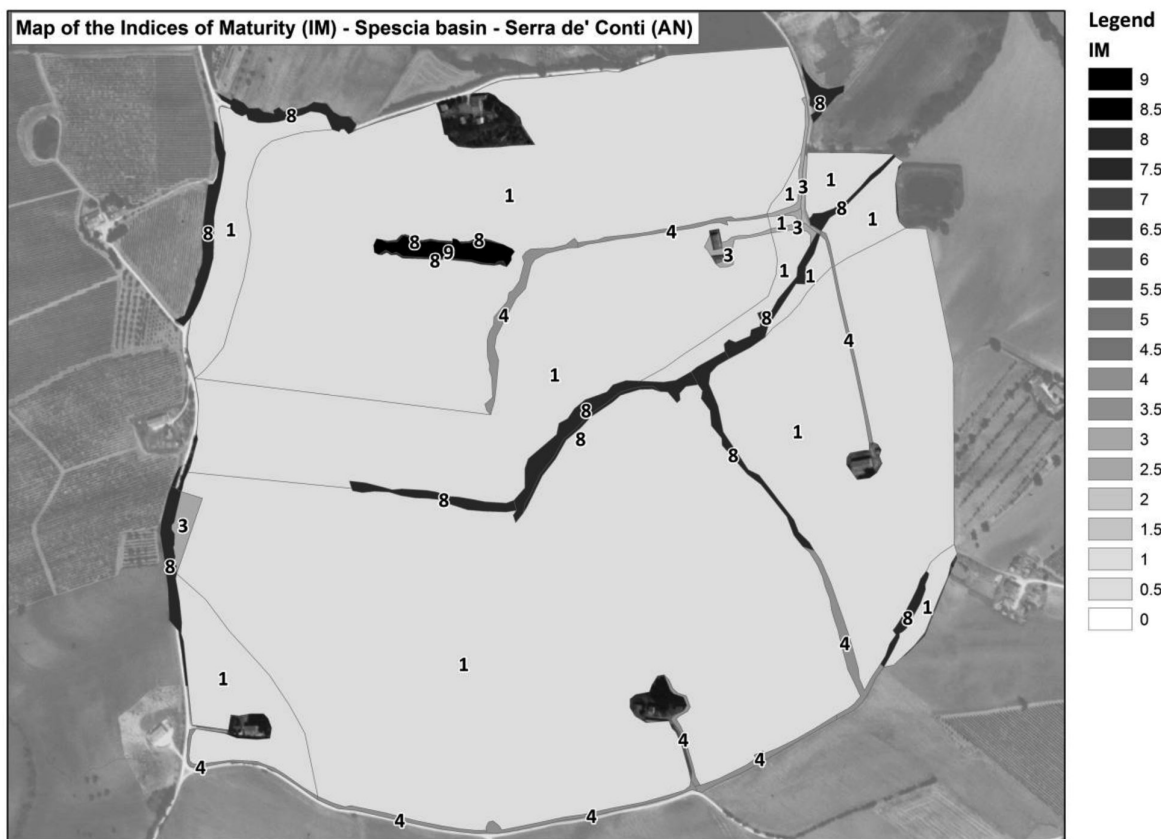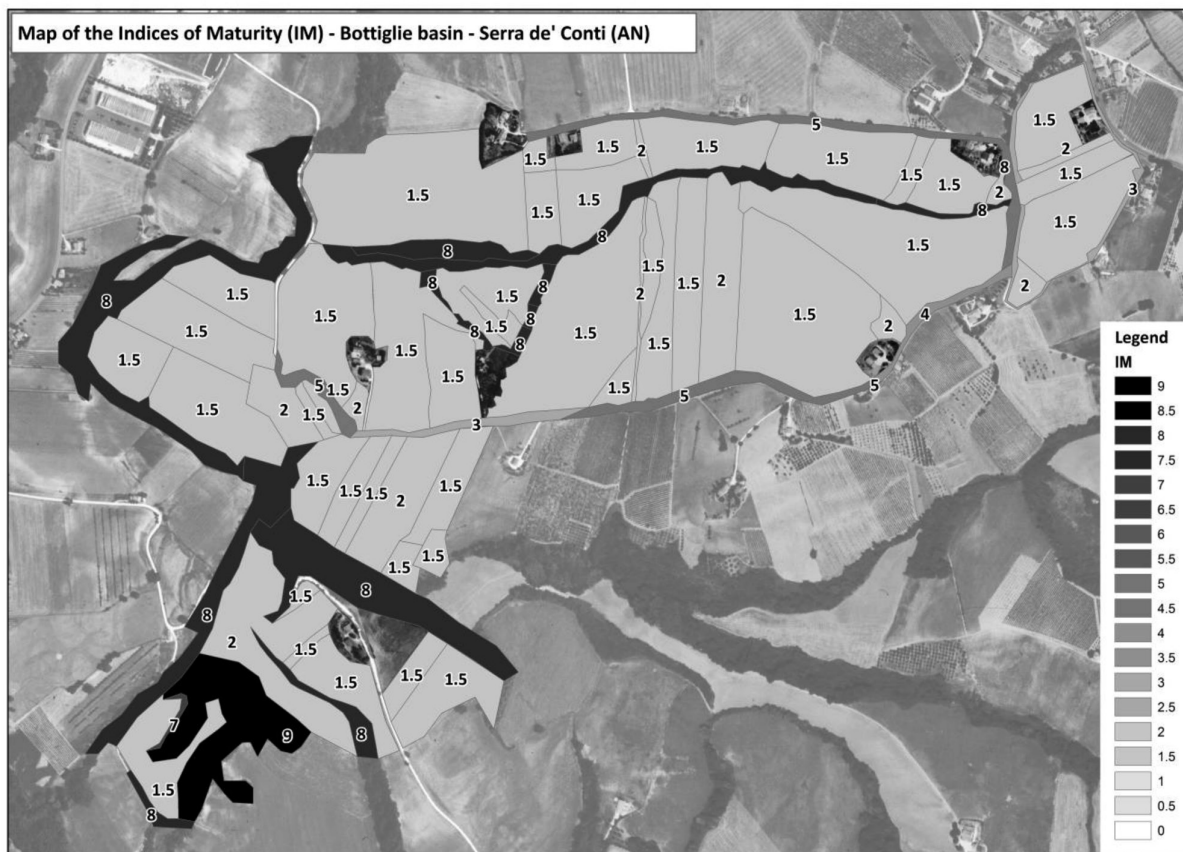
Fig. 7 - Distribution of the Indices of Maturity relative to all of the vegetation typologies identified
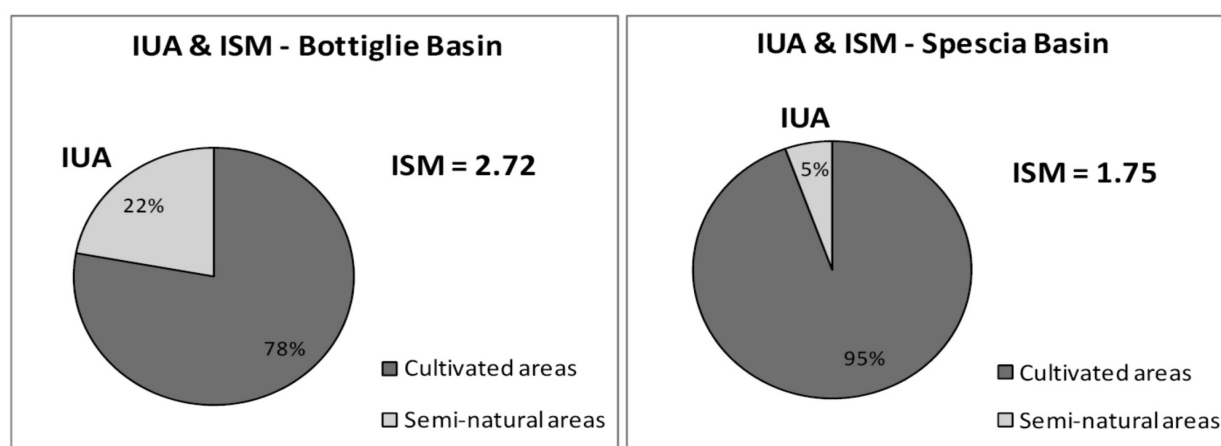
Fig. 8 - Incidence of Non-productive Area (IUA) and Index of Synthetic Maturity (ISM) relating to the two river basins studied

instead to integrate with the phytosociological analysis to provide a qualitative-quantitative evaluation method of the vegetal landscape that can be used under conditions where because of a high degree of artificiality and with the need for comparisons over short periods, the phytosociological analysis cannot be applied, or where it cannot provide significant evaluation elements. The applicative potential of the system arises from the possibility of using qualitative information provided by the vegetational analyses concerning the reconstruction of the phytocoenotic mosaic through the phytosociological relevé and the description of the landscape units; this provides an analytical basis that is extraordinarily rich in qualitative and generalisable information. This method can therefore provide depth for interpretative aspects concerning the maturity levels and floristic richness of the vegetal coenoses and their dynamic tendencies towards a specific degree of maturation (increase of structural complexity) or towards the regression to pioneering or less-evolved stages (with increased floristic and structural simplicity). Furthermore, it is possible to reveal the presence in the territory of limiting factors (hygrophilia, xerophilia, alophilia) and to transfer the information to a mapping system (via the GIS software). This is useful for the spatial representation of the synthetic indices, which can be integrated with studies from other sectors at different levels of interpretation (e.g. fauna, agronomic management, agricultural economics, etc.). The use of this method shows its greatest efficiency with regards to the agro-ecosystem, such that it is specifically studied and calibrated to provide answers that are both specific and suited to the context of application. In particular, the IM has been structured such as to

be specifically sensitive to the evolutive dynamics of the pioneering and herbaceous stages (commensal vegetation, nitrophilous margins, grasslands and edges) that are in continuous and rapid modification in contexts that are more or less strongly artificial within the agro-ecosystems.

The limits to the use of the proposed system, with regard to it being a method dedicated to areas strongly affected by human factors, therefore arise from a reduced sensitivity of the indices within environmental contexts of high naturalness and maturity, such as for areas with extensive forest coverage, cliffs and rocky environments, dune systems, humid environments, and dwarf shrubs and grasslands of the Subalpine and Alpine belts.

In contrast, the use of this instrument is particularly significant in situations of high artificiality seen in the agro-ecosystem and other environments subjected to strong human determinism (such as urban and peri-urban areas). In these areas, where the herbaceous vegetation is reduced to very small and discontinuous non-cultivated strips, it is often difficult to obtain the minimum areas for the relevé and even when this is possible, the attribution to a reference vegetation typology is often problematic. In limiting cases, the method proposed allows identification of vegetation mosaics that are difficult to separate, and use of the indicators to obtain both an overall evaluation of maturity, and an analysis of all the floristic, vegetational and ecological components of an area.

This kind of reading and interpretation of the agro-ecosystem is relevant to the application of present-day agricultural and environmental politics (Common Agricultural Policy, Rural Development Programme, Habitat Directive). Within these, the primary objective

of biodiversity conservation (Countdown 2010) requires a solid evaluation of the results of these choices, and a criterion for the identification of areas exposed to simplification or, in contrast, with an high naturalistic value. All of this is also important for the choices to be made for the management of the ecosystems not only in a natural context within protected areas, but also where human disturbance has affected environments within which there are important reservoirs of biodiversity and residual habitats that need to be preserved.

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List of syntaxa quoted in the text

CLASSES

Adiantetea Br.-Bl. in Br.-Bl., Roussine & Nègre 1952

Alnetea glutinosae Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946

Anomodonto-Polypodietea Rivas-Martínez 1975

Artemisietea vulgaris Lohmeyer, Preising & Tüxen ex von Rochow 1951

Asplenietea trichomanis (Br.-Bl. in Meier & Br.-Bl. 1934) Oberdorfer 1977

Bidentetea tripartitae Tüxen, Lohmeyer & Preising ex von Rochow 1951

Cakiletea maritimae Tüxen & Preising ex Br.-Bl. & Tüxen 1952

Calluno-Ulicetea Br.-Bl. & Tüxen ex Klika & Hadač 1944

Cardamino hirsutae-Geranietea purpurei (Rivas-Martínez, Fernández-González & Loidi 1999) Rivas-Martínez, Fernández-González & Loidi 2002

Charetea fragilis Fukarek ex Krausch 1964

Cisto-Lavanduletea Br.-Bl. in Br.-Bl., Molinier & Wagner 1940

Cisto-Micromerietea Oberdorfer 1954

Cytisetea scopario-striati Rivas-Martínez 1975

Crithmo-Limonietea Br.-Bl. in Br.-Bl., Roussine & Nègre 1952

Epilobietea angustifolii Tüxen & Preising ex von Rochow 1951

Erico-Pinetea Horvat 1959

Festuco-Brometea Br.-Bl. & Tüxen ex Br.-Bl. 1949

Festuco-Seslerietea Barbéro & Bonin 1969

Galio-Urticetea Passarge ex Kopecký 1969

Isoeto-Littorelletea Br.-Bl. & Vlieger in Vlieger 1937

Isoeto-Nanojuncetea Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946

Juncetea maritimi Br.-Bl. in Br.-Bl., Roussine & Nègre 1952

Koelerio-Corynephoretea Klika in Klika & Novák 1941

Lemnetea Tüxen ex O. Bolòs & Masclans 1955

Lygeo-Stipetea Rivas-Martínez 1978

Molinio-Arrhenatheretea Tüxen 1937

Montio-Cardaminetea Br.-Bl. & Tüxen ex Br.-Bl. 1948

Mulgedio-Aconitetea Hadač & Klika in Klika 1948

Nardetea strictae Rivas Goday in Rivas Goday & Rivas-Martínez 1963

Nerio-Tamaricetea Br.-Bl. & O. Bolòs 1958

Oryzetea sativae Miyawaki 1960

Oxycocco-Sphagnetea Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946

Parietarietea Rivas-Martínez in Rivas Goday 1964

Pegano-Salsoletea Br.-Bl. & O. Bolòs 1958

Phragmito-Magnocaricetea Klika in Klika & Novák 1941

Pino-Juniperetea Rivas-Martínez 1965

Poetea bulbosae Rivas Goday & Rivas-Martínez in Rivas-Martínez 1978

Polygono-Poetea annuae Rivas-Martínez 1975

Potametea Klika in Klika & Novák 1941

Quercetea ilicis Br.-Bl. ex A. & O. Bolòs 1950

Querco-Fagetea Br.-Bl. & Vlieger in Vlieger 1937

Rhamno-Prunetea Rivas Goday & Borja ex Tüxen 1962

Rosmarinetea officinalis Rivas-Martínez, T.E. Díaz, F. Prieto, Loidi & Penas 2002

Saginetea maritimae Westhoff, Van Leeuwen & Adriani 1962

Salicetea purpureae Moor 1958

Sarcocornietea fruticosae Br.-Bl. & Tüxen ex A. & O. Bolòs 1950

Scheuchzerio palustris-Caricetea nigrae Tüxen 1937

Sedo-Scleranthetea Br.-Bl. 1955

Spartinetea maritimae Tüxen in Beeftink & Géhu 1973

Stellarietea mediae Tüxen, Lohmeyer & Preising ex von Rochow 1951

Thero-Salicornietea Tüxen in Tüxen & Oberdorfer ex Géhu & Géhu-Franck 1984

Thlaspietea rotundifolii Br.-Bl. 1948

Trifolio-Geranietea Müller 1962

Tuberarietea guttatae (Br.-Bl. in Br.-Bl., Roussine & Nègre 1952) Rivas Goday & Rivas-Martínez 1963

Utricularietea intermedio-minoris Pietsch 1965

Vaccinio-Piceetea Br.-Bl. in Br.-Bl., Sissingh & Vlieger 1939