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Application of the floristic-vegetational indexes system for the evaluation of the environmental quality of a semi-natural area of the Po Valley (Piacenza, Italy).

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Abstract

The floristic-vegetational indexes proposed by Taffetani & Rismondo (2009) and updated by Rismondo *et al*. (2011) were used to assess the environmental quality of a semi-natural area located on the outskirts of Piacenza (Emilia-Romagna, Italy), the site of a closed landfill of Municipal Solid Waste (MSW). This method was created and perfected to analyze the ecological functionality of agro-ecosystems and permits simple and rapid measurement of the ecological characteristics and grade of dynamic evolution of the phytocoenoses. These indexes were applied to the vegetation of the different sectors that make up the study area and from the results obtained it was possible to identify those with the worst environmental quality and to formulate some proposals for action aimed at improving them environmentally. In particular an interruption in the evolution of the landfill vegetation was found, due to the chemical-physical characteristics of the cover soil which is compact and of limited depth. The application of the Taffetani & Rismondo (2009) indexes to a real case has also allowed evaluation of their practicality and the information content obtained.

Key words: agro-ecosystems, floristic-vegetational indexes, landfill, maturity, phytosociology, Po valley, restoration.

Introduction

The floristic-vegetational indexes system proposed by Taffetani & Rismondo (2009) is a useful and practical tool for assessing the environmental quality of ecosystems modified by human activities (agro-ecosystems). It is based on the phytosociological study of vegetation, a modern scientific approach (Braun-Blanquet, 1964; Westhoff & Van der Maarel, 1978; Braun-Blanquet, 1979; Gehu & Rivaz-Martínez, 1981; Biondi, 1994; Biondi, 1996; Loidi, 2004; Biondi, 2011; Blasi & Frondoni, 2011; Blasi *et al*., 2011; Pott, 2011) used worldwide and adopted by Directive 92/43/EEC, which is the most important european normative for conservation (Biondi, 2007; Biondi *et al*., 2013). This system of bio-indicators measures the environmental quality of ecosystems on the basis of the characteristics of plant communities and therefore does not depend only on the information returned by individual species. The information content of each plant community is derived from the attribution of a numerical value for each syntaxonomic class and by assigning each species to a syntaxonomic class on the basis of its ecological characteristics. The application of this method permits the conversion of qualitative information related to vegetation into quantitative data able to summarise ecological information and allow easy evaluation and comparison of the quality of agro-ecosystems. The recent formulation and integration of these indexes (Rismondo *et al*., 2011), together with a lack of interest in the study of the ecology of agricultural and urbanized areas, has meant that they have been until now little used (Taffetani *et al*., 2011a; Taffetani *et al*., 2011b; Lancioni & Taffetani, 2012), although increasing emphasis on the protection of agro-ecosystems due to the recognition of the importance of interaction between natural and artificial systems (Baudry *et al*., 2000; Brouwer *et al*., 2001; Le Coeur *et al*., 2002; Marshall & Moonen, 2002; Taffetani *et al*., 2003; Hietala-Koivu *et al*., 2004; Müller *et al*., 2004; Roschewitz *et al*., 2005; Jackson *et al*., 2007; Moonen & Bàrberi, 2008; Pastor & Hernandez, 2009; Lomba *et al*., 2013), could implement their use in future Landscape Ecology studies (Forman & Gordon, 1986; Forman, 1995; Blasi *et al*., 2000; Ingegnoli, 2002; Blasi, 2007; Biondi *et al*., 2011; Biondi *et al*., 2012).

The present work is an integral part of the preliminary investigation of the characterization of a closed landfill involved in a restoration project co-funded by the European Union (LIFE+, LIFE 10 ENV/IT/0400 NewLife; http://www.lifeplusecosistemi.eu) and has as its aim the evaluation of the environmental quality of the landfill and its neighboring areas. In particular, using the Taffetani & Rismondo (2009) indexes, we aim to discover where and how it would be appropriate to intervene in order to implement ecological improvement of the area.

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Materials and Methods

Study area

The study area is located in the administrative area of Piacenza (Emilia-Romagna, Italy), along the eastern bank of the River Trebbia (coordinates: 45°04'13" N, 9°39'33" E) and comprises the Borgotrebbia closed landfill of municipal solid waste and areas adjacent to it (Fig. 1). The area lies within the Site of Community Importance "Basso Trebbia" (SCI IT4010016) and is included in the area of the Trebbia River Park, where the potential vegetation consists of riparian woodland of *Populetalia albae* Br.-Bl. 1935 (Ferrari, 1997; Piccoli, 1997; Puppi *et al*., 2010). The landfill was in use from 1972 to 1985, after which it was covered with a layer of soil, the chemical-physical characteristics of which are known (Tab. 1), and was freely colonized by wild plants. The soil of the landfill is of a loamy texture, neutral-alkaline pH, offering good availability of nutrients, and forms a thin layer of compact structure.

The study area lies in temperate continental bioclimatic zone (Rivaz-Martínez, 2004). Tab. 2 shows the climate data from the San Lazzaro Alberoni (Piacenza) weather station, which is located in the same area and environmental context as the study area; potential evapotranspiration (PE) was calculated according to Thornthwaite & Mather (1955, 1957). The average annual temperature is equal to 13.3 ° C with a range of 22.4 ° C, and annual precipitation amounts to 778.7 mm mainly concentrated in spring and autumn; there is a water deficit during the warmer summer months (P - PE < 0 from May to August).

Sampling of vegetation and analysis of data

Twenty-one phytosociological relevés were conducted within the five different areas outlined in the vegetation transect in Fig. 2. In detail, three relevés were conducted in area A, five in area B, six in C, five in D and two in E. The relevés were conducted in accordance with the method of the Zurich-Montpellier Sigmatist School (Braun-Blanquet, 1964) and periodically monitored from April to September 2013. The indexes of cover-abundance were assigned using the scale modified by Pignatti (1982). The vegetation data, organized in a matrix (species x relevés), were statistically processed after conversion of the cover-abundance indexes into ordinal values (Taffetani & Rismondo, 2009). Cluster analysis was carried out (UPGAMA method; chordal distance coefficient) using Syn-tax 2000 software (Podani, 2001) in order to highlight the floristic-physiognomic similarities of the relevés.

To evaluate the quality and the environmental characteristics of the area, the following floristic-vegetational indexes (Taffetani & Rismondo, 2009; Rismondo *et al*., 2011) were used: index of maturity (IM), index of floristic biodiversity (IFB) , indexes of the life forms (IT = index of the therophytic component, IH = index of the hemicryptophytic component, IF = index of the perennial non-hemicryptophyte component), phytogeographic indexes (IL = index of endemic component,

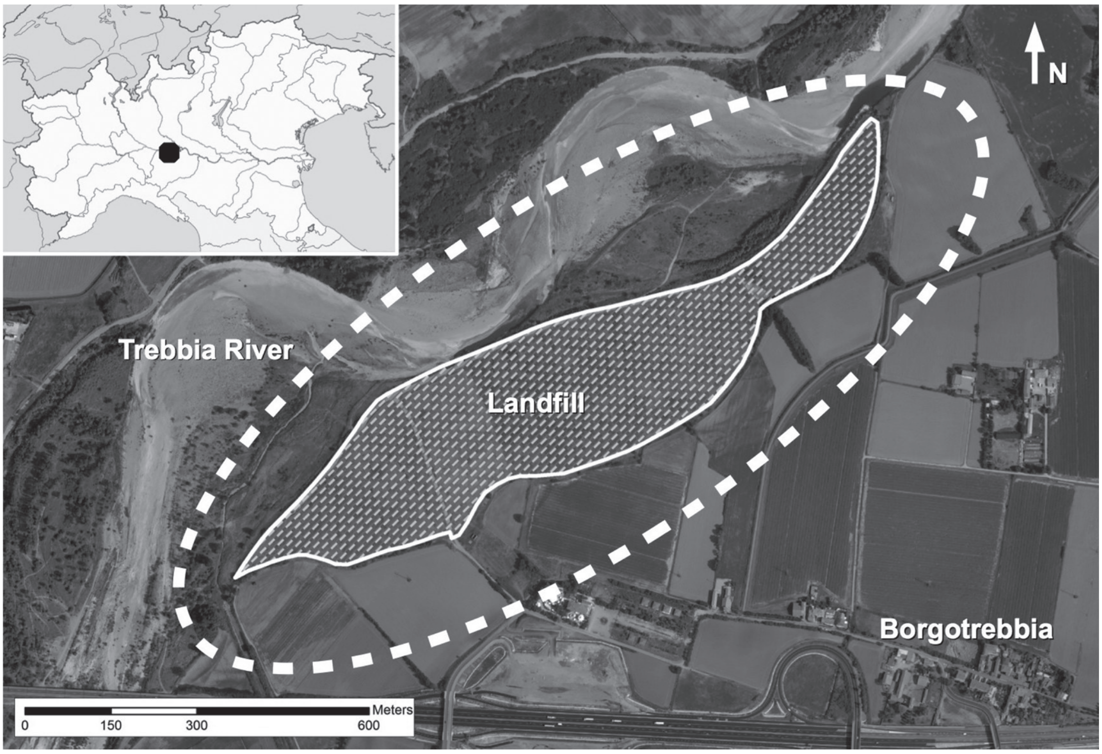

Fig. 1 - Study area. The broken line indicates the area where the phytosociological relevés were conducted.

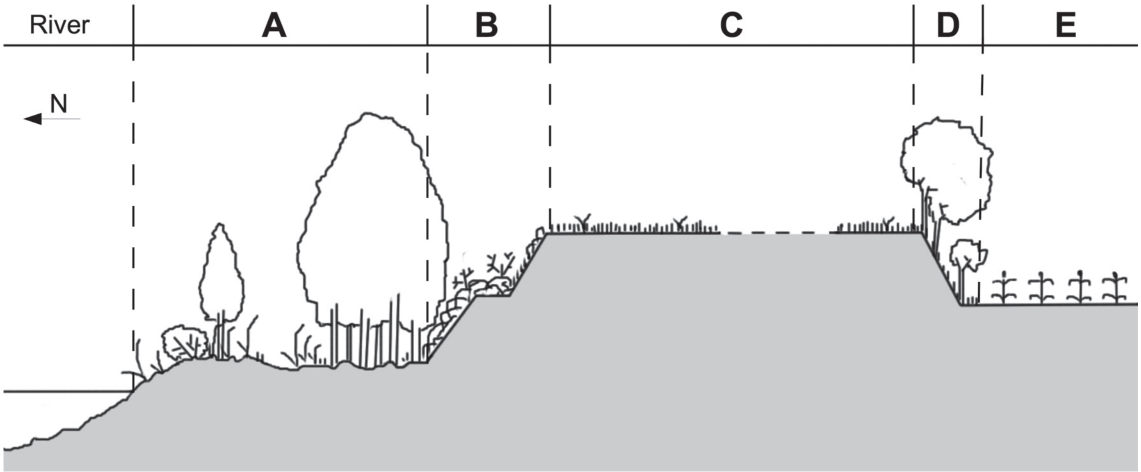

Fig. 2 - North-south vegetation transect of the study area. The letters indicate the different areas where phytosociological relevés were conducted: A = riverside area; B = northern edge of the landfill; C = landfill, D = southern edge of the landfill, E = cultivated fields.

ID = index of the components with a wide distribution, IE = index of the exotic component) and edaphic indexes (IX = index of xerophilia; IW = index of hygrophilia, IA = index of alophilia). The value of each index was calculated for the vegetation of each of the five areas of the transect. The data related to life form and chorological type were taken respectively from Pignatti (1982) and Romani & Alessandrini (2001), while for the attribution of phytosociological class to each species various manuals in the literature (Oberdorfer, 1992; Mucina *et al*., 1993; Rivas-Martínez *et al*., 2002; Ubaldi, 2008; Ubaldi, 2008a; Landolt *et al*., 2010) were consulted. The taxonomic nomenclature follows Conti *et al*., 2005 and later amendments (Conti *et al*., 2007) while the syntaxonomic nomenclature is in accordance with Rivas-Martínez *et al*. (2002).

Results

In the study area 141 species were observed, some of which are infrequent in the province of Piacenza, e.g. *Hordeum marinum* subsp. *marinum, Alopecurus rendlei, Vulpia myuros* and *Onopordum acanthium* subsp. *acanthium* (Romani & Alessandrini, 2001; Banfi *et al*., 2005; Bracchi & Romani, 2010; Giupponi *et al*., 2013a). Fig. 3 shows the dendrogram returned by cluster analysis. From the graph it can be observed that the relevés are separated into four groups, three of which (clusters 1, 2 and 4) coincide with the areas A, B and E of the transect, while cluster 3 combines the relevés of areas C and D which have similar floristic-physiognomic features. Table 3 shows the species grouped in the different phytosociological classes and relevés ranked according to the area in which they were performed. Species attributed to each class are charcteristic/differential of such class or characteristic/differential of syntaxa included in such class. *Hordeum marinum* subsp. *marinum* is included in the *Saginetea maritimae* class in accordance with Brullo & Giusso del Galdo (2003), while *Prunus cerasifera* var. *pissardii* is included in the class *Rhamno-Prunetea* as it is a spontaneous ornamental species that grows along rivers and in disturbed areas of Piacenza (Romani & Alessandrini, 2001; Bracchi & Romani, 2010).

Tab. 1 - Physical-chemical properties of four samples of landfill cover soil. Data source: m.c.m. Ecosistemi s.r.l, 2012.

Soil sample	1	2	3	4
Depth (cm)	45	47	55	30
Sand (%)	33,3	25,0	21,9	11,5
Silt (%)	54,2	62,7	65,8	73,8
Clay (%)	12,5	12,3	12,3	14,7
pH	8,4	8,0	7,9	8,0
C tot. (g/Kg)	38,3	37,8	33,6	22,8
C org. (g/Kg)	19,2	23,5	19,4	16,7
N tot. (g/Kg)	1,7	2,6	2,3	2,1
CSC (meq/100ml)	22,6	32,2	17,0	20,9

Area A has vegetation characterized in the tree and shrub layer by species of *Salici purpureae-Populetea nigrae*, while in the herbaceous layer there are several hygrophilic species from the *Galio-Urticetea* and *Bidentetea tripartitae* classes. The vegetation of the northern edge of the landfill (area B) has some similarities with area A, the same tree species being present although with reduced cover-abundance values, but differs as regards the herbaceous layer which is characterized by a group of *Molinio-Arrhenatheretea* species and *Sambucus ebulus* which is present exclusively in this sector of the study area. The landfill (area C) has a high number of annual nitrophilous-ruderal species of *Stellarietea mediae* with some of *Artemisietea vulga-*

Tab. 2 - Temperature (T), precipitation (P) and potential evapotranspiration (PE), monthly averages. Data source: San Lazzaro Alberoni (PC) weather station, 1961-2005.

Month	G	F	M	A	M	J	J	A	S	O	N	D
T (°C)	2,2	4,0	9,0	12,5	18,0	21,8	24,1	24,6	19,2	13,7	7,5	3,2
P (mm)	35,7	19,7	39,3	76,0	66,0	65,0	41,4	51,9	102,0	131,0	98,4	52,3
PE (mm)	3,0	7,1	29,1	51,3	98,0	131,6	153,6	146,9	88,3	48,9	17,6	5,0
P-PE (mm)	32,7	12,6	10,2	24,7	-32,0	-66,6	-112,2	-95,0	13,7	82,1	80,8	47,3

ris (*Elymus repens* and *Convolvulus arvensis*). R*obinia pseudoacacia* characterizes the vegetation of area D, which in the herbaceous layer has various species of *Artemisietea vulgaris* including *Elymus repens*. To conclude, area E comprises fields of corn (*Zea mays*) in which there are some typical weeds including *Sorghum halepense*.

The graph of Fig. 4 presents the values returned by calculations of the maturity index (IM) and the index of floristic biodiversity (IFB) for the vegetation of each area of the transect. The riverside vegetation (area A) has the highest absolute value of both IM and IFB. The vegetation on the two edges of the landfill (areas B and D) have similar IM values, but that of the northern edge (area B) includes a considerably greater number of species many of which indicate wetland. The lowest values of IM and IFB are found for the cultivated field (area E) while the landfill vegetation, although it includes a good number of species, has low IM compared even to the vegetation at the edges.

Fig. 5 shows the results of the life form indexes (IT, IH, IF). Area A has the highest overall cover of perennial non-hemicryptophyte species (IF) and the lowest value of therophytes (IT). The southern edge (area D), compared with the northern edge (area B), has a greater perennial species cover (particularly of non-hemicryptophytes) and therefore a lower percentage of therophytes. In area C (landfill) there is a high proportion of therophytes although the highest absolute IT value is that for the corn field.

Analysis of the phytogeographical indexes chart (Fig. 6) reveals that there are no endemic species and

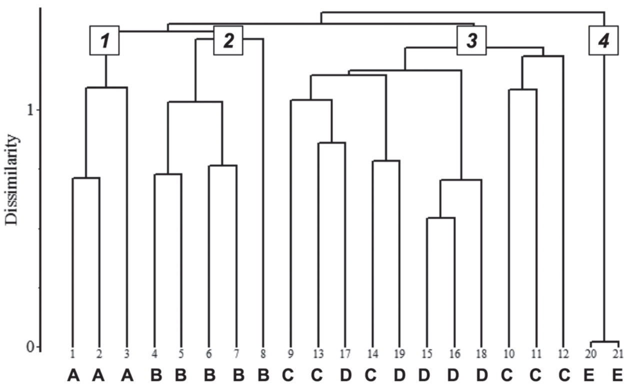

Fig. 3 – Dendrogram of relevés. The numbers in the boxes indicate the clusters while the letters indicate the transect areas where the relevés were performed.

that there is a widespread presence of exotic species, especially in the E area (high cover of *Zea mays*). Area C (landfill) is the only one in which the value of ID exceeds that of IE.

Fig. 7 shows the graph of the edaphic indexes (IX, IW, IA). In the study area there are no species of the xerophile community, while there is only one species belonging to the halophilic community (*Hordeum marinum* subsp. *marinum*) in area C. The values of the hygrophilic index (IW) gradually decrease as the distance of the sampling areas from the river increases.

Discussion

Application of floristic-vegetational index system has permitted identification of the main ecological and functional features that characterize the study area, as well as testing of their validity. Evidence supporting the validity of the indexes can be derived from comparison of the values returned by the vegetation of the area less disturbed by human activities (area A) with those related to the cultivated field (area E). As expected, the vegetation in area A was found to have the highest maturity value (IM = 6) and lowest therophytic component (IT = 14,42%) while vegetation in E was found to be disturbed (consisting almost entirely of therophytes) and little evolved, being constantly subject to different kinds of agronomic intervention (sowing, harvesting, fertilization, weed control, etc.). From a comparison of the indexes relating to the landfill edges (areas B and D) it is shown that, IFB being equal, the vegetation of area B presents a high value of IM due to the presence of species of community *Salici purpureae-Populetea nigrae*, which go up the slope being closed to the area A. This last observation can explain also the high value of index of hygrophilia (IW) of area B as compared with the value of IW in the area D. Considering the long period of time after the closure of the landfill, we would have expected a value of IM much higher in areas B, C and D; this may be due to maintenance interventions (for example the grass mowing) probably realized in the past and to the sheeps, that sometimes stop in this area before grazing in the mountains. Moreover, considering the plate surface of the landfill which should have guaranteed a better conservation of the water and soil, the value of IM should have been higher in area C rather than in areas B and D (steep areas). The graphic in Fig.

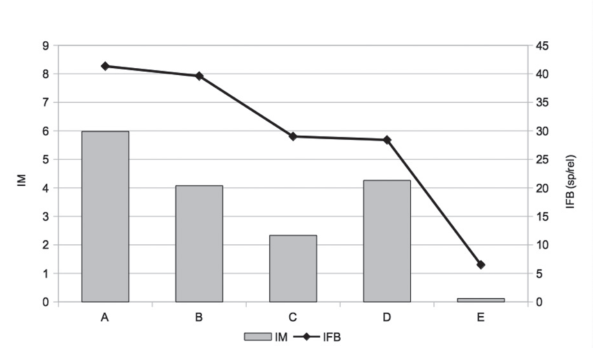

Fig. 4 - Graph of IM and IFB indexes. The letters refer to the transect areas.

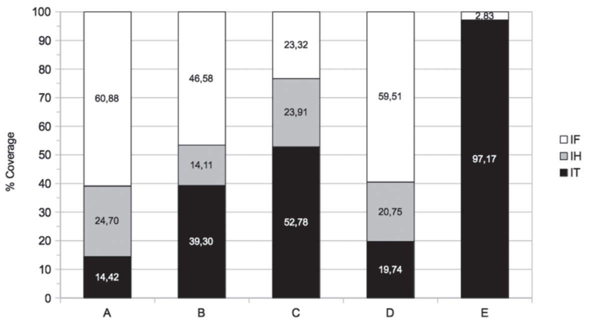

Fig. 5 - Histogram of IT, IH and IF indexes. The letters refer to the transect areas.

5 shows why there is a great difference between the results obtained and the results expected; although the area C has a level of biodiversity comparable with that one in area D, the percentage of therophytes is much higher in area C (IT =52,78%).

On the basis of the results obtained, it seems clear that to improve the environmental quality of the entire area, action should first be taken on the areas found to be qualitatively worse, i.e. the landfill (area C) and the corn field (area E). Given that area E is private and farmed for production purposes and is not involved in restoration projects, we shall not dwell on giving guidance on how to intervene in order to improve its environmental quality. The analyses conducted on this area serve mainly to achieve an idea of the values the indexes can reach in intensively-cultivated areas. With reference to the landfill, the analysis shows that its vegetation is constituted only by herbaceous species with a wide geographical distribution, mainly therophytes of *Stellarietea mediae* class as found by Giupponi *et al.* (2013). This characteristic is the one which has most affected the result returned by the index of maturity which for this vegetation has a particularly low value. Indeed, it is just above 2, the threshold that separates cultivated/disturbed areas (IM < 2) from unproductive areas with semi-natural or natural vegetation (IM > 2) (Taffetani & Rismondo, 2009; Rismondo *et al.*, 2011). Given that IM provides the measurement of the current stage of maturity of a plant community and that area C has been left undisturbed for many years, we can deduce that there is a block in the vegetation dynamic, presumably due to the chemical-physical properties of the soil used for landfill cover. In particular, its shallow depth (average 45 cm) and compact structure would make it unsuitable for the rooting of plants with deep roots such as those of trees and shrubs. These properties also influence the water balance of the soil; indeed, as demonstrated by Giupponi *et al.* (2013a), this area suffers an edaphic water deficit occurring in correspondence with the less rainy summer months (May to September). The block in the vegetation dynamic can be due also to the gas emission caused by chemical-physical transformations of waste material. The different gasses of the landfill (in particular methane and carbon dioxide) (Huber-Humer *et al.*, 2011) produced by the decomposing micro-organisms can be harmful for the plants, because some of them seem to be toxic for the roots and some others would be able to change the chemical features of the soil (Geisler, 1963; Leone *et al.*, 1977, 1979, 1980; Flower *et al.*, 1981; Holmes, 1991; Reichenauer *et al.*, 2011; Xiaoli *et al.*, 2011). In general the gas emissions of the landfills are most produced during the first ten years of the storage of the waste, then they tend to stop completely; in some cases gas emission was observed also over fifty years after the waste disposal (Rovers *et al.*, 1977). In order to evaluate if the a.m. hypothesis could be of interest to

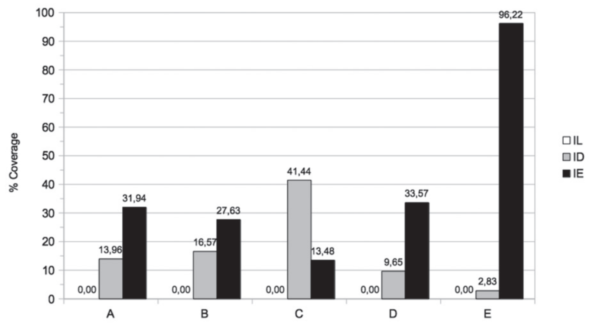

Fig. 6 - Histogram of IL, ID and IE indexes. The letters refer to the transect areas.

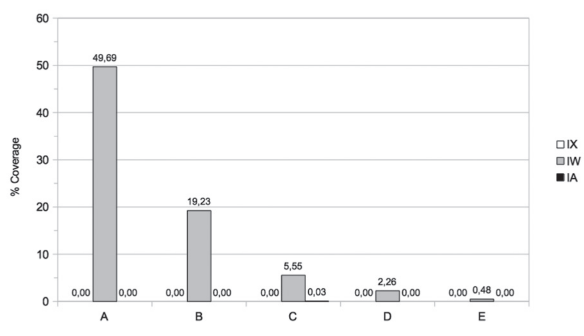

Fig. 7 - Histogram of IX, IW and IA indexes. The letters refer to the transect areas.

Tab. 3 - Phytosociological table of relevés. Syntaxonomic classes are ordered according to increasing maturity coefficient (m) (Taffetani & Rismondo, 2009). The groups of species that characterize the vegetation of each of the five areas are highlighted.

	Relevé number	1A	2A	3A	4B	5B	6B	7B	8B	9C	10C	11C	12C	13C	14C	15D	16D	17D	18D	19D	20E	21E	Presence		m
	Inclination (°)	0	0	0	20	30	30	30	30	0	0	0	0	0	2	35	35	35	35	30	0	0			
	Exposure (°)	-	-	-	300	345	355	345	315	-	-	-	-	-	110	170	165	160	130	110	-	-			
	Surface (m²)	100	100	100	25	25	25	25	25	16	16	16	16	16	16	25	25	25	25	25	100	100			
	Total cover (%)	70	100	95	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100			
Chorotype	N. of species	43	22	59	38	39	41	42	38	29	33	40	21	25	26	29	30	26	23	34	8	5	n.	%	
	Salici purpureae-Populetea nigrae Rivas-Martínez & Cantó ex Rivas-Martínez, Báscones, T.E. Díaz, Fernández-González & Loidi 1991																								9
Avv	Amorpha fruticosa L.	2	1	+	1	1	2	3	+	.	.	.	.	.	.	.	.	.	.	1	.	.	9	43	
PalTem	Populus alba L.	+	+	+	+	+	.	+	+	.	.	.	.	.	.	.	.	.	.	+	.	.	8	38	
PalTem	Populus nigra L.	1	1	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	8	38	
PalTem	Salix alba L.	3	5	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	8	38	
Avv	Acer negundo L.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	3	14	
Orof	Salix eleagnos Scop. subsp. eleagnos	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	10	
	Querco-Fagetea Br.-Bl. & Vlieger in Vlieger 1937																								9
Eur	Ulmus minor Mill.	.	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	14	
EuMed	Celtis australis L. subsp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	2	10	
Eur	Acer campestre L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	1	5	
PalTem	Campanula trachelium L.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
EurAs	Cornus sanguinea L. subsp. sanguinea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	1	5	
Avv	Juglans regia L.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
	Rhamno-Prunetea Rivas Goday & Borja ex Tüxen 1962																								8
Avv	Robinia pseudoacacia L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	4	+	4	1	+	.	6	29	
EuMed	Rubus ulmifolius Schott	.	+	.	+	+	1	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	6	29	
Eur	Clematis vitalba L.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	+	.	.	.	.	.	.	4	19	
EurAs	Salix caprea L.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	1	.	.	+	.	.	3	14	
Avv	Prunus cerasifera Ehrh. var. pissardii	.	.	.	.	+	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	2	10	
PalTem	Rosa canina L.	.	.	.	+	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	10	
Eur	Sambucus nigra L.	.	+	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	10	
Avv	Ailanthus altissima (Mill.)	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
Avv	Ficus carica L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	1	5	
	Trifolio-Geranietea Müller 1962																								7
PalTem	Hypericum perforatum L.	+	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	14	
CirBor	Securigera varia (L.) Lassen	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
	Phragmito-Magnocaricetea Klika in Klika & V. Novák 1941																								6
Cosm	Lythrum salicaria L.	+	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	14	
Cosm	Bolboschoenus maritimus	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	1	5	
Cosm	Eleocharis palustris (L.)	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	1	5	
Cosm	Phragmites australis (Cav.)	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
	Galio-Urticetea Passarge ex Kopecký 1969																								6
Avv	Humulus japonicus Siebold	+	+	+	+	+	1	+	+	.	.	.	.	.	.	.	.	.	.	+	.	.	9	43	
Avv	Helianthus tuberosus L.	3	1	4	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	24	
	Festuco-Brometea Br.-Bl. & Tüxen ex Br.-Bl. 1949																								5
EurAs	Ranunculus bulbosus L.	.	.	.	.	+	.	.	.	.	+	1	.	.	+	.	+	.	.	.	.	.	5	24	
Cosm	Sanguisorba minor Scop.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	14	
Eur	Euphorbia cyparissias L.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	2	10	
PalTem	Poa bulbosa L.	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	2	10	
EurAs	Galium verum L.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
EuMed	Salvia pratensis L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	1	5	
	Koelerio-Corynephoretea Klika in Klika & V. Novák 1941																								5
Cosm	Vulpia myuros (L.)	.	.	.	+	.	.	.	+	.	.	+	.	.	.	+	.	.	.	.	.	.	4	19	
	Lygeo-Stipetea Rivas-Martínez 1978 nom. conserv. propos.																								5
Pont	Althaea cannabina L.	+	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	4	19	
	Bidentetea tripartitae Tüxen, Lohmeyer & Preising ex von Rochow 1951																								4
EuMed	Xanthium orientale L. subsp.	+	+	1	+	+	+	+	+	.	+	+	2	.	.	.	.	+	+	+	.	.	14	67	
EurAs	Bidens tripartita L. subsp.	1	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	14	
Avv	Abutilon theophrasti Medik.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	+	2	10	
Cosm	Persicaria lapathifolia (L.)	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	1	5	
PalTem	Pulicaria vulgaris Gaertn.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
	Molino-Arrhenatheretea Tüxen 1937																								4
Cosm	Rumex crispus L.	+	+	+	+	+	+	+	+	3	1	.	1	+	1	+	+	+	+	+	.	.	18	86	
EurAs	Poa trivialis L.	.	.	+	+	+	+	+	+	.	+	1	.	+	.	+	+	.	.	.	.	.	11	52	
PalTem	Dactylis glomerata L.	+	.	+	+	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	9	43	
Cosm	Bromus hordeaceus L.	.	.	.	+	1	+	+	+	+	3	2	.	.	.	.	.	.	.	.	.	.	8	38	
PalTem	Arrhenatherum elatius (L.) P. Beauv. ex J. & C. Presl	.	.	.	+	+	+	+	+	.	.	.	.	+	.	.	+	.	.	.	.	.	7	33	
CirBor	Taraxacum officinale Weber	.	+	.	.	+	+	.	.	+	+	+	.	.	.	.	.	.	+	.	.	.	7	33	
Cosm	Plantago lanceolata L.	+	.	+	+	.	.	.	.	1	1	+	.	.	.	.	.	.	.	.	.	.	6	29	
EuMed	Alopecurus rendlei Eig	.	.	+	.	.	.	.	.	+	3	1	.	.	.	.	.	.	.	.	.	.	4	19	
CirBor	Agrostis stolonifera L.	1	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	14	
CirBor	Lolium perenne L.	.	.	+	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	2	10	
EurSib	Achillea millefolium L.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
Cosm	Agrimonia eupatoria L.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
PalTem	Medicago lupulina L.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	5	
EuMed	Ornithogalum umbellatum L.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	1	5	
Cosm	Plantago major (L.) Huds.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
CirBor	Prunella vulgaris L.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
PalTem	Silene vulgaris (Moench)	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
PalTem	Trifolium fragiferum L.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	1	5	
Cosm	Trifolium pratense L.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	1	5	

		Artemisietea vulgaris Lohmeyer, Preising & Tüxen ex von Rochow 1951																								3
G	PalTem	Convolvulus arvensis L.	+	.	+	+	+	+	+	+	2	1	1	+	2	+	+	+	+	+	+	+	+	20	95	
G	CirBor	Elymus repens (L.) Gould	+	.	+	+	+	+	+	+	1	2	1	2	5	1	4	3	3	1	2	.	.	18	86	
T	EurAs	Galium aparine L.	.	.	.	+	+	+	+	+	.	.	.	.	1	+	1	2	+	+	+	.	.	12	57	
T	CirBor	Artemisia vulgaris L.	+	.	+	+	+	+	+	+	.	.	+	.	.	+	.	.	.	.	+	.	.	10	48	
H	Cosm	Malva sylvestris L.	+	.	+	.	.	.	.	.	1	1	.	.	.	1	+	+	1	+	1	.	.	10	48	
H	EurSib	Lactuca serriola L.	+	.	+	.	.	.	.	.	.	.	.	.	+	.	+	+	+	+	+	.	.	8	38	
H	MedTur	Carduus pycnocephalus L.	.	.	+	.	.	.	+	+	.	.	.	.	.	+	.	1	1	.	1	.	.	7	33	
H	Cosm	Verbena officinalis L.	+	.	+	.	.	+	.	.	+	.	+	.	.	+	.	.	.	.	+	.	.	7	33	
H	Cosm	Daucus carota L. subsp.	+	.	1	.	1	.	.	+	.	.	+	.	+	.	.	.	.	.	.	.	.	6	29	
H	MedTur	Onopordum acanthium L.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	+	+	1	+	2	.	.	6	29	
H	Eur	Verbascum thapsus L.	+	.	+	+	.	.	.	.	.	.	.	.	.	+	+	.	.	.	+	.	.	6	29	
H	MedAtl	Ballota nigra L.	.	.	.	.	.	+	+	.	.	.	.	.	.	1	.	.	.	1	1	.	.	5	24	
H	Cosm	Cichorium intybus L.	+	.	+	+	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	5	24	
G	EuMed	Sambucus ebulus L.	.	.	.	1	1	3	2	+	.	.	.	.	.	.	.	.	.	.	.	.	.	5	24	
H	Eur	Echium vulgare L. subsp.	+	.	+	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	4	19	
T	Avv	Erigeron annuus (L.) Desf.	+	.	+	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	4	19	
H	Eur	Reseda lutea L. subsp. lutea	+	.	+	.	.	.	.	+	.	.	.	.	.	+	.	.	.	.	.	.	.	4	19	
H	EuMed	Rumex pulcher L.	+	2	+	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	4	19	
H	EurSib	Saponaria officinalis L.	+	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	4	19	
H	Cosm	Urtica dioica L.	.	+	.	.	.	1	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	4	19	
H	EuMed	Bryonia dioica Jacq.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	3	14	
H	PalTem	Cirsium vulgare (Savi) Ten.	.	.	.	.	.	.	+	+	.	.	.	.	.	+	.	.	.	.	.	.	.	3	14	
T	PalTem	Lapsana communis L.	.	.	.	.	+	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	3	14	
H	Avv	Medicago sativa L.	.	.	.	.	.	.	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	3	14	
G	Avv	Phytolacca americana L.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	3	14	
T	Cosm	Melilotus albus Medik.	.	.	.	.	.	.	.	.	.	.	1	.	.	+	.	.	.	.	.	.	.	2	10	
H	PalTem	Silene latifolia Poir. subsp.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	10	
H	Cosm	Verbascum blattaria L.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	2	10	
H	EurAs	Linaria vulgaris Mill. subsp.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
H	EurAs	Tanacetum vulgare L.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	1	5	
		Saginetea maritimae Westhoff, Van Leeuwen & Adriani 1962																								2
T	EuMed	Hordeum marinum Huds.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	1	5	
		Stellarietea mediae Tüxen, Lohmeyer & Preising ex von Rochow 1951																								1
T	MedTur	Bromus sterilis L.	+	.	+	2	1	+	+	+	4	+	2	.	.	+	+	+	2	+	+	.	.	16	76	
G	Cosm	Sorghum halepense (L.) Pers.	+	.	1	+	+	+	+	+	+	.	.	.	.	.	+	+	1	+	+	+	+	15	71	
T	EurAs	Avena fatua L.	.	.	+	1	+	+	+	2	2	+	.	.	.	+	+	+	1	+	1	.	.	14	67	
T	Avv	Erigeron canadensis L.	+	.	+	.	+	+	.	.	+	+	.	.	1	+	+	+	+	.	+	+	.	13	62	
G	MedTur	Lepidium draba L.	.	.	+	+	+	+	+	+	.	+	.	.	+	.	+	+	+	+	+	.	.	13	62	
G	Cosm	Cynodon dactylon (L.) Pers.	+	.	.	.	+	+	.	+	1	4	2	1	1	.	+	.	+	.	.	+	.	12	57	
T	Cosm	Chenopodium album L.	.	.	.	.	.	+	+	.	1	1	.	2	2	.	+	+	1	+	+	.	.	11	52	
T	Avv	Ambrosia artemisiifolia L.	+	.	1	1	1	+	+	+	.	.	4	1	.	+	.	.	.	.	.	.	.	10	48	
T	Cosm	Geranium dissectum L.	.	.	.	.	+	+	+	.	1	+	3	.	+	1	+	.	.	.	+	.	.	10	48	
T	Cosm	Stellaria media (L.) Vill.	.	+	.	.	.	+	.	+	+	+	+	+	+	+	.	.	.	+	.	.	.	10	48	
T	Cosm	Polygonum aviculare L.	+	.	.	.	.	.	.	.	4	+	+	.	2	.	+	+	.	.	.	+	+	9	43	
T	Avv	Amaranthus retroflexus L.	.	.	.	.	.	.	.	.	1	1	.	2	1	.	+	.	1	+	+	.	.	8	38	
T	CirBor	Hordeum murinum L.	.	.	+	.	+	.	.	.	+	+	2	.	.	.	.	+	+	+	.	.	.	8	38	
T	Avv	Papaver rhoeas L.	.	.	+	.	.	+	.	.	.	.	.	.	+	.	+	+	+	+	+	.	.	8	38	
T	EurAs	Sonchus asper (L.) Hill	.	.	.	.	+	+	.	+	.	.	.	.	+	+	.	+	.	.	+	.	.	7	33	
T	Cosm	Vicia sativa L.	.	.	.	+	+	.	.	.	.	+	2	.	+	+	.	+	.	.	.	.	.	7	33	
T	PalTem	Alopecurus myosuroides	.	.	.	.	+	.	.	+	.	.	+	.	.	+	+	.	.	.	+	.	.	6	29	
T	EurAs	Lamium purpureum L.	.	.	.	+	+	.	.	.	.	.	+	+	+	.	+	.	.	.	.	.	.	6	29	
T	Cosm	Torilis arvensis (Huds.) Link	.	.	+	.	.	.	+	.	.	.	.	+	+	.	.	+	.	+	.	.	.	6	29	
T	CirBor	Atriplex patula L.	.	.	+	.	.	.	.	.	+	.	+	+	1	.	.	.	.	.	.	.	.	5	24	
H	Cosm	Capsella bursa-pastoris (L.)	+	.	.	.	.	.	.	.	+	+	+	.	+	.	.	.	.	.	.	.	.	5	24	
T	Avv	Veronica persica Poir.	.	.	.	.	.	+	+	.	+	+	1	.	.	.	.	.	.	.	.	.	.	5	24	
G	EuMed	Aristolochia clematitis L.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	4	19	
T	EuMed	Crepis setosa Haller f.	+	.	+	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	4	19	
H	MedAtl	Diplotaxis tenuifolia (L.)	+	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	19	
T	Cosm	Lysimachia arvensis (L.) U. Manns & Anderb. subsp. arvensis	+	.	.	.	.	.	.	.	1	+	.	.	.	.	.	.	.	.	.	+	.	4	19	
T	Cosm	Erodium cicutarium (L.)	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	+	.	.	3	14	
T	Cosm	Persicaria maculosa (L.)	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	14	
T	Cosm	Portulaca oleracea L.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	+	.	.	.	.	3	14	
T	Cosm	Cardamine hirsuta L.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	2	10	
T	Avv	Cuscuta campestris Yunck.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	2	10	
T	Cosm	Euphorbia helioscopia L.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	2	10	
T	Avv	Amaranthus powellii S.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	1	5	
G	EurAs	Cirsium arvense (L.) Scop.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
T	MedAtl	Crepis vesicaria L.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	1	5	
T	Avv	Echinochloa crusgalli (L.) P.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	1	5	
T	MedTur	Euphorbia falcata L. subsp.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
H	EuMed	Foeniculum vulgare Mill.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
T	Cosm	Fumaria officinalis L. subsp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	1	5	
T	EuMed	Helminthotheca echioides	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
H	PalTem	Lathyrus tuberosus L.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
T	Avv	Matricaria chamomilla L.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	1	5	
T	Eur	Myosotis arvensis (L.) Hill	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
T	Cosm	Poa annua L.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	1	5	
H	Cosm	Potentilla reptans L.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
T	Cosm	Setaria verticillata (L.) P.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	
T	Cosm	Solanum nigrum L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	1	5	
T	Cosm	Veronica arvensis L.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	1	5	
		Cultivated species																								0
T	Avv	Zea mays L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	5	2	10	

the study area, a detailed investigation should be carried out about the interstitial gasses of the soil, which cover the landfill. As shown by the halophile index (IA) the landfill is the only area with a species, even if it is sporadic, of the halophilic communities of *Saginetea maritimae*. In fact various other tolerant halophilic species are present including, *Amaranthus retroflexus*, *Amaranthus powellii* and *Cynodon dactylon* (Pignatti, 2005; Landolt *et al.*, 2010) but they are not assigned to classes of halophilic vegetation since they are optional alofite. Indeed the presence of species such as *Bolboschoenus maritimus, Eleocharis palustris* and in particular *Persicaria lapathifolia* suggests in this case a wet micro-environment (hollows in which the water ceases to flow in particular during the rainy season) rather than a salty soil.

To ensure correct environmental restoration of this area it would be appropriate to initiate pedologic, agronomic or naturalistic actions which can improve the physical-chemical characteristics of the soil. It would also be appropriate to add further good soil to the landfill in order to increase the depth (at least one meter) in order to guarantee the minimum requirements which would permit normal root development and the stability of the most common trees and shrubs of temperate zone (Gilman, 1990; Canadell *et al*., 1996; Schenk & Jackson, 2002; Crow, 2005; Landolt *et al*., 2010). To facilitate development of vegetation some planting of native species, appropriate to the type of environment, would be advisable taking into account the concept of dynamic of vegetation and so the vegetation series of the study area (Ferrari, 1997; Puppi *et al*., 2010). It would also be appropriate to implement a plan for the eradication of alien species present in the whole area, as these could inhibit the dynamic evolution of vegetation and change the ecology and function of ecosystems. Indeed, the vegetation of area A (natural riparian wood) contains several exotic species common in the province of Piacenza and in Italy in general (*Amorpha fruticosa, Humulus japonicus, Ambrosia artemisiifolia, Helianthus tuberosus* and *Phytolacca americana*) (Romani & Alessandrini, 2001; Celesti-Grapow *et al*., 2009; Bracchi & Romani, 2010) and, although it proved to be that with the best ecological characteristics, it has an IM value which is well below that expected of fully-mature woodland. If chemical analyses certified the presence of gas emission from the landfill, it would be appropriate to intervene isolating the surface of the landfill and creating a system of gas outflow.

All the ideas of intervention proposed, together with many others, could contribute to environmental improvement of the area, though to quantify the real improvement, the indexes should be checked on completion of the interventions or applied to models that are able to predict post-intervention vegetation. To conclude, the floristic-vegetational indexes system proposed by Taffetani & Rismondo (2009) has proved to be particularly useful and effective for the purposes of this work and, for this reason, we wish to advise its use for the analysis and monitoring of the environmental characteristics of areas disturbed by human activities in future studies on conservation or environmental restoration.

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