Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology: Official Journal of the Societa Botanica Italiana
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tplb20

The vegetation of the Borgotrebbia landfill (Piacenza, Italy): Phytosociological and ecological characteristics

L. Giupponi[a], C. Corti[a] & P. Manfredi[b]

[a] Istituto di Agronomia, Genetica e Coltivazioni Erbacee, Università Cattolica del Sacro Cuore, Via Emilia Parmense 84, 29122 Piacenza Site, Italy

[b] M.C.M. Ecosistemi s.r.l., Località Faggiola s.n.c., 29027 Gariga di Podenzano (PC), Italy

Accepted author version posted online: 05 Aug 2014.Published online: 08 Aug 2014.

Plant Biosystems, 2014
http://dx.doi.org/10.1080/11263504.2014.945507

ORIGINAL ARTICLE

The vegetation of the Borgotrebbia landfill (Piacenza, Italy): Phytosociological and ecological characteristics

L. GIUPPONI[1,*], C. CORTI[1,**], & P. MANFREDI[2,***]

[1]*Istituto di Agronomia, Genetica e Coltivazioni Erbacee, Università Cattolica del Sacro Cuore, Via Emilia Parmense 84, 29122 Piacenza Site, Italy and* [2]*M.C.M. Ecosistemi s.r.l., Località Faggiola s.n.c., 29027 Gariga di Podenzano (PC), Italy*

Abstract
Our study aimed to analyse the vegetation of the Borgotrebbia landfill in phytosociological and ecological terms, in order to contribute to the current knowledge of the landfill's vegetation, and to better understand the environmental characteristics of the area, with a view to its restoration. Five vegetation types were identified, all classified into the *Stellarietea mediae* class that includes annual ruderal communities. Ellenberg's and Landolt's indices shed light on the ecological characteristics of all the vegetation and five typologies. The vegetation of the study area indicates a moderately basic, semi-dry soil, rich in nutrients, low in humus and badly aerated. The high therophyte percentage indicates a stressed environment, the main cause of this stress being a marked edaphic aridity during the dry summer months. In these conditions, annual plants, which complete their life cycle in a short time after the spring precipitations, are favoured. Finally, the species variety within the various typologies of vegetation increases with a decrease in the percentage of species tolerating salts and heavy metals in the soil. As a consequence, this suggests a possible contamination of the soil in some of the areas.

Keywords: *Cover soil, ecological indices, heavy metals, landfill vegetation, phytosociology*

Nowadays environmental restoration of the landfill top cover is one of the most interesting issues for the landfill managers and the local authorities. Restoration of degraded areas necessitates the gathering of information regarding environmental characteristics, such as climatic conditions, soil properties and any disturbances (biotic and abiotic) affecting them, as these properties can influence the growth and the survival of vegetation. Setting the chemical and physical characteristics of the cover soils of the landfill is a fundamental activity that requires expensive analysis whose results are often unsatisfactory due to the high spatial variability of these properties. For this reason, the study of the vegetation represents a valid alternative method, being quicker, practical and economical.

Each plant has its own ecological requirements that play a crucial role for its survival and spread. Plants with similar requirements are associated in communities which repeat themselves where ecological conditions are the same. As a consequence, plant communities provide useful information about ecological characteristics of a particular habitat. Phytosociology is a discipline that studies plant communities, classifying them into a hierarchical system of units (*syntaxa*) whose ecological meaning become more detailed from the highest rank (the class) to the association level (Braun-Blanquet 1979; Loidi 2004; Biondi 2011; Blasi & Frondoni 2011; Pott 2011; Yilmaz 2011). Assigning a syntaxonomical meaning to a phytocoenosis and performing the phytosociological relevés by the ecological indicator values will give a picture of landfill sites in terms of environmental conditions and substrate characteristics. Until now, these techniques of plant ecology have been little applied to the monitoring and rehabilitation of landfills, although the results of some recently published works (Huber-Humer & Klug-Pümpel 2004; Klug et al. 2008; Tintner et al. 2008; Tintner & Klug 2011) suggest positive prospects for the future.

This study aims to identify the different types of vegetation occurring on the Borgotrebbia landfill (Piacenza, Italy) and to define them in phytosocio-

Correspondence: L. Giupponi, Istituto di Agronomia, Genetica e Coltivazioni Erbacee, Università Cattolica del Sacro Cuore, Via Emilia Parmense 84, 29122 Piacenza Site, Italy, Tel. +347 9069751. Email: luca.giupponi@unicatt.it

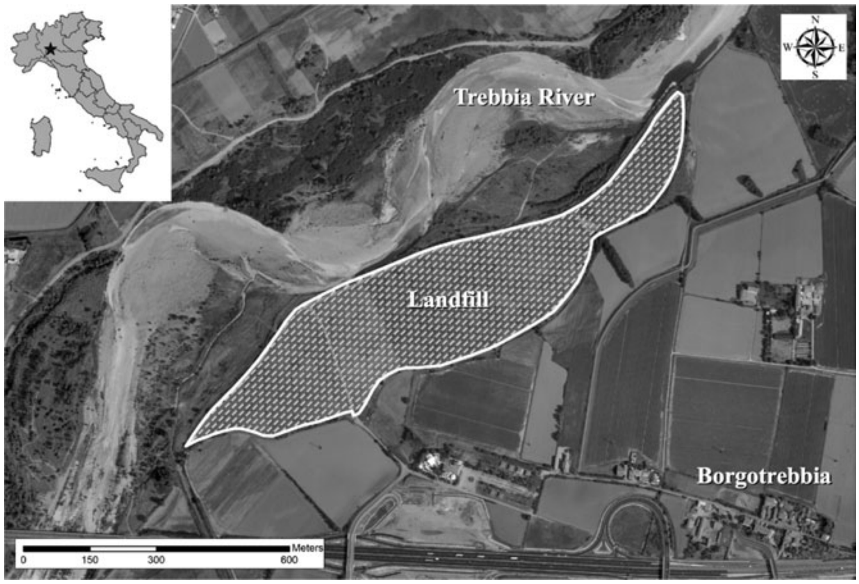

Figure 1. Study area.

logical and ecological terms, in order to obtain information as complete as possible on the environmental conditions of the site in view of a future restoration (Life + 10 ENV/IT/0400 New Life; http://www.lifeplusecosistemi.eu). Ellenberg's (1979) indices, readapted from Pignatti (2005), together with Landolt's (1977) indices updated by Landolt et al. (2010), were used. These indicator values are commonly used to describe environmental conditions (Diekmann 2003; Kollmann & Fischer 2003) even though the mathematical treatment of their ordinal scale reveals some problems. We also intend to contribute to the current knowledge of the vegetation of landfills and for this reason richness in species, biodiversity and evenness were calculated for each type of vegetation identified, as they are considered important parameters that describe the ecological value of a unit of vegetation.

Materials and methods

Study area

The studied closed landfill is made of municipal solid waste and lies within the administration area of Piacenza city (Emilia-Romagna, Italy) at Borgotrebbia (coordinates: 45°03′58′ N, 09°39′06″E; altitude: 60 m; Figure 1). It lies along the hydrographic right bank of the Trebbia River in proximity to its confluence with the Po River and covers an area of about 20 ha. The average annual temperature is 13.3°C, and the average annual precipitation amounts to 778 mm. Most of the rain falls during the spring and autumn, while there is a water deficit during the warmer summer months (Figure 2).

Emilia-Romagna is phytogeographically localized between the Middle-European Region and the Mediterranean Region (Tomaselli 1970; Pignatti 1979); the study area lies at the southern limit of the Middle-European Region in temperate continental bioclimatic zone (Rivas-Martínez 2004). The potential vegetation would be riparian forests of *Populetalia albae* Br.-Bl., 1935 in contact with oak-hornbeam woodlands (Ferrari 1997; Puppi et al. 2010), but the natural vegetation has almost completely disappeared due to the intense anthropic activities.

The landfill was active from 1972 to 1985 and was then covered with a layer of soil of various types, about 50 cm thick. Projects aimed to restore forest vegetation were realized since 2005, but they had little success and involved only a small part of the landfill (localized in the south-western portion). Now most of the area is covered by grassland which is occasionally mown or grazed by sheep.

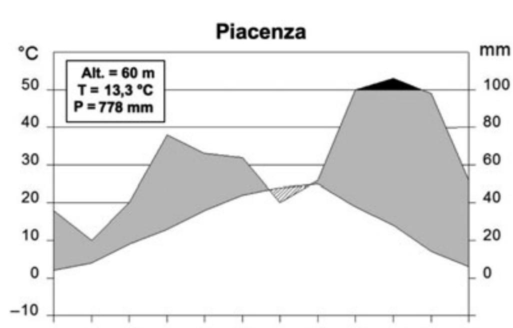

Figure 2. Ombrothermic diagram of Walter and Lieth (1960). Data source: weather station of San Lazzaro Alberoni (Piacenza), 1961–2005.

Vegetation sampling

Fifty-two phytosociological relevés were realized in the study area in accordance with the method of the Zurigo-Montpellier school (Braun-Blanquet 1964). Each relevé was georeferenced. The size of the sampling plots was 16 m^2 (4×4 m). We used the conventional Braun-Blanquet scale.

Species nomenclature follows Conti et al. (2005). Life forms according to Raunkiaer's (1934) categories follow Pignatti (1982), and it was checked on field, chorological types follow Romani and Alessandrini (2001). Biological and chorological spectra of the floristic list were elaborated.

Syntaxa nomenclature follows the main national and European phytosociological literature (Mucina et al. 1993; Oberdorfer 1993a,b; Matuszkiewicz 2001; Rivas-Martínez et al. 2001; Fanelli 2002; Aeschimann et al. 2004; Ubaldi 2008; Landolt et al. 2010; Puppi et al. 2010; Biondi et al. 2013;). In particular, the synoptic scheme of Landolt et al. (2010) is followed.

Data analysis

The vegetation data were organized in a matrix (31 surveys × 90 species) in which the values of the coverage were transformed according to Van der Maaler (1979). The data matrix was analysed using statistical multivariate programs from the Syn-tax 2000 package (Podani 2001). Cluster analysis was performed using the method of group average (Unweighted Pair Group Method with Arithmetic Mean, UPGMA) and chordal distance coefficient. The principal coordinates analysis (PCoA) was carried out.

Ellenberg's (1979) ecological indices, adapted to Italian flora (Pignatti 2005), and Landolt's (1977) ecological indices, updated by Landolt et al. (2010), were used to determine the ecological features of the vegetation relating the environmental factors. More specifically were used: luminous intensity (*L*), temperature (*T*), continentality (*C*), soil moisture (*U*), soil reaction (*R*) and nutrient supply (*N*) indicator values according to Pignatti (2005), and soil humus (*H*), soil aeration (*D*), soil salinity (*S*) and heavy metals (*M*) indicator values according to Landolt et al. (2010).

For each group of vegetation, the following were calculated: the average of the indicator values for each ecological factor weighted on the percentage of species coverage; diversity using the Shannon function (Whittaker 1972); evenness according to Häupler (1982); the mean number of species and therophytes/hemicryptophytes (T/H) ratio. These data were used to carry out the principal component analysis (PCA).

Combining the results of the data analysis and the direct observation, a vegetation map of the study area

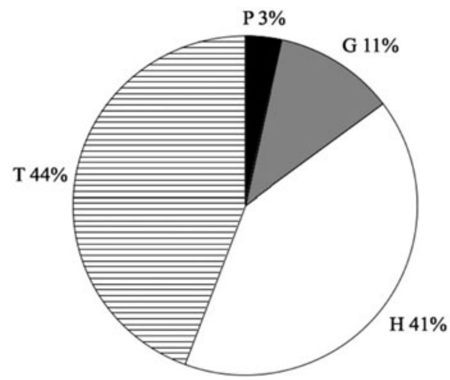

Figure 3. Biological spectrum of flora list (T, therophytes; H, hemicryptophytes; G, geophytes; P, phanerophytes).

was also drawn up using ArcGIS 10 software (®Esri). In order to mark the boundary of the vegetation spots, air photographs were taken from the Emilia-Romagna web site (http://geoportale.regione.emilia-romagna.it/it) and used together with geosupplied polygons on field.

Results

In the study area, 90 species were observed. The average number of species for each relevé was 14. Figures 3 and 4 show, respectively, the biological and chorological spectra of the flora listed. Therophytes and hemicryptophytes make up 44 and 41% of the total species; 11% are geophytes and 3% are phanerophytes. The most common chorological type is the Cosmopolitan (32%) followed by Adventitious (15%) and Paleotemperate (11%). Most of the species (95%) are very widespread in the province of Piacenza, only four (*Alopecurus rendlei*, *Malva alcea*, *Mentha arvensis* and *Onopordum acanthium*) are considered uncommon in this area

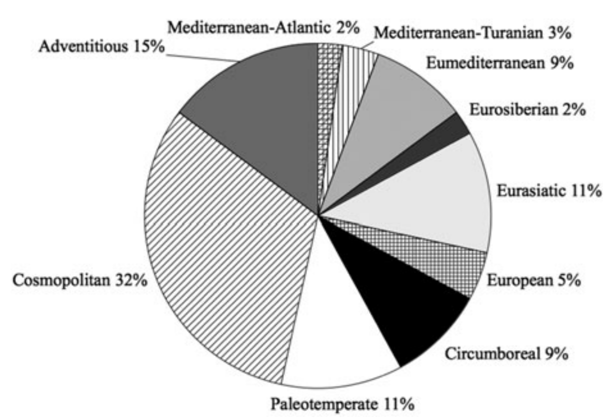

Figure 4. Chorological spectrum of flora list.

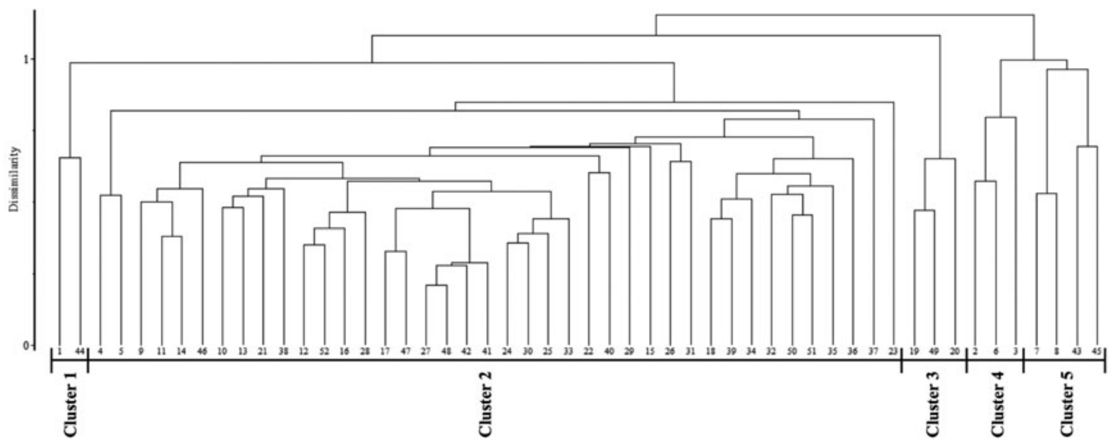

Figure 5. Dendrogram of relevés.

(Romani & Alessandrini 2001; Banfi et al. 2005; Bracchi & Romani 2010; Giupponi et al. 2013).

The dendrogram (Figure 5) resulting from the cluster analysis shows five relevé groups corresponding to five different vegetation types. Table I shows the relevés arranged according to the dendrogram sequence. The five groups show a considerable floristic similarity, but differ physiognomically for the dominance of one or two species. The most frequent species are *Cynodon dactylon*, *Convolvulus arvensis*, *Rumex crispus* and *Elymus repens*. Cluster 1 includes two relevés that are characterized by *Rumex crispus* and *Bromus sterilis* dominance; cluster 2 includes 40 relevés that are dominated by *Elymus repens*. Cluster 3 includes three relevés dominated by *Chenopodium album* and *Amaranthus retroflexus*; this cluster also presents a set of species which are exclusive of this group (*Abutilon teophrasti*, *Echinochloa crus-galli*, *Sonchus asper, Sonchus oleraceus*, *Xanthium orientale* subsp. *italicum*, *Persicaria lapathifolia* and *Solanum nigrum*). Cluster 4 includes three relevés dominated by *Alopecurus rendlei* and *Bromus hordeaceus*; cluster 5 includes five relevés characterized by a high *Hordeum murinum* coverage. Species of Table I are grouped in different phytosociological classes. Species attributed to each class are characteristic/differential of such class or characteristic/differential of syntaxa included in such class. The considered classes are described as follows:

- *Stellarietea mediae* Tüxen, Lohmeyer & Preising ex von Rochow, 1951, which includes nitrophilous annual ruderal vegetation.
- *Artemisietea vulgaris* Lohmeyer, Preising & Tüxen ex von Ronchow, 1951, which includes communities mainly consisting of perennial hemicryptophyte grasses that grow on soils rich in nitrogenous substances in rural, agricultural and urbanized areas.
- *Molinio-Arrhenatheretea* Tüxen, 1937, which includes communities of mesophilous meadows and pastures.
- *Bidentetea tripartitae* Tüxen, Lohmeyer & Preising ex von Rochow, 1951, which includes meso-hydric communities occurring on the polluted river beds and emerging in summer on sludges.

Most of the species of identified vegetation clusters belong to the class *Stellarietea mediae* (Table I). There are few plants belonging to the *Artemisietea vulgaris* and *Bidentetea tripartitae* classes, while several species belong to the *Molinio–Arrhenatheretea* class, although their frequencies and covers vary widely in the different groups. Cluster 2 is rich in species of the *Stellarietea mediae* class. Cluster 3 is the only vegetation type with a good presence of *Bidentetea tripartitae* annual plants. Clusters 1, 4 and 5 share low coverage values of *Elymus repens* and several *Molinio–Arrhenatheretea* species.

The result of the PCoA (Figure 6) confirms the cluster analysis results showing a good separation among the relevé groups that could be due to different ecological factors.

Table II shows the parameters values (mean indicator values of each ecological factor, mean number of species, Shannon index, evenness and T/H ratio) calculated to five clusters. Figure 7 shows the PCA result considering the first component and the second one. Figure 8 shows the PCA result considering the first component and the third one. The first three principal components explain 93.23% of the data variance. In Figure 7, the relevé groups are mainly separated according to the number of species and the presence of species tolerating salts and heavy metals in the soil (*S* and *M* indicator values; axis 1) and according to the prevalence of therophytes (values of T/H ratio) and heliophilus plants (*L* indicator values; axis 2). In Figure 8, the relevé groups are mainly separated according to soil moisture (*U* indicator values; axis 3).

Figure 9 shows the distribution of the five groups of vegetation in the study area. The most extensive vegetation type is that of cluster 2 (which occupies a large part of the landfill), while the areas of the other vegetations are decidedly smaller.

Discussion and conclusion

The results of the analyses conducted on the vegetation of the Borgotrebbia landfill gave interesting information about the environmental characteristics of the site.

The terophyte percentage (44%) of the Borgotrebbia landfill flora is significantly higher than those

Table I. Phytosociological table of relevés arranged according to the sequence of the dendrogram.

sporadic sp.	life form	n. cluster	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	5	5	5	5	1	1	4	4	4	3	3	3	Pres. %
		n. relevé	4	5	9	11	14	46	10	13	21	38	12	52	16	28	17	47	27	48	42	41	24	30	25	33	22	40	29	15	26	31	18	39	34	32	50	51	35	36	37	23	7	8	43	45	1	44	2	6	3	19	49	20	
		n. of species	18	17	20	12	14	18	13	10	11	8	7	8	7	7	6	5	5	3	3	5	6	5	7	7	13	10	15	17	15	10	13	11	14	14	12	12	13	17	19	16	36	37	21	25	24	14	22	19	23	18	17	16	
		***Stellarietea mediae* Tüxen, Lohmeyer & Preising ex von Rochow 1951**																																																					
	G	*Cynodon dactylon* (L.) Pers.	1	2	1	1	+	+	1	+	+	+	1	+	2	1	2	1	+	+	.	+	.	.	.	.	+	+	.	2	+	+	2	1	2	1	1	+	1	1	+	1	+	2	.	1	+	+	1	+	+	+	.	1	85
	T	*Bromus sterilis* L.	2	+	+	+	+	1	+	+	+	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	2	+	.	.	.	2	2	+	.	.	+	1	2	+	.	1	2	1	1	2	2	1	+	+	.	.	.	58
	T	*Chenopodium album* L.	.	.	+	.	.	1	1	.	.	.	2	1	1	+	+	.	.	.	.	.	.	.	.	+	.	.	+	.	.	+	1	1	+	.	+	+	+	+	1	.	.	.	+	1	+	1	.	.	+	4	4	3	52
	T	*Polygonum aviculare* L.	.	.	.	+	+	1	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	1	1	2	+	+	+	+	1	.	.	+	1	1	2	+	+	+	2	+	.	.	.	44
	T	*Hordeum murinum* L.	+	.	+	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.	2	2	1	+	+	+	.	1	.	.	3	3	4	2	1	+	1	.	1	.	.	.	44
	T	*Avena fatua* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	1	1	1	2	+	+	1	.	+	.	+	1	+	.	.	.	+	.	.	.	.	.	27
	T	*Ambrosia artemisiifolia* L.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	1	1	+	1	.	1	1	+	.	3	3	.	.	.	.	.	.	.	+	2	2	29
	T	*Atriplex patula* L.	.	.	.	.	r	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	+	.	1	.	.	.	+	.	.	.	.	.	.	.	1	.	+	19
	T	*Amaranthus retroflexus* L.	.	.	r	.	r	+	r	.	.	.	+	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	+	.	+	.	.	.	r	.	.	r	2	.	.	.	.	r	.	1	.	.	.	3	3	1	35
	H	*Lactuca serriola* L.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	+	.	r	r	+	+	r	.	.	.	.	.	.	.	17
	H	*Verbena officinalis* L.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	r	.	.	.	.	.	+	.	+	2	.	r	.	.	.	.	.	.	r	.	15
	T	*Veronica persica* Poir.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	+	+	.	+	+	+	+	.	.	+	+	+	.	.	.	29
	T	*Vicia sativa* L.	+	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	1	+	.	+	1	.	.	.	.	.	.	.	.	.	.	+	3	1	2	+	.	+	+	+	+	.	.	.	37
	T	*Geranium dissectum* L.	+	2	+	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	2	2	1	1	+	+	+	1	+	.	.	.	33
	T	*Stellaria media* (L.) Vill.	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	1	4	.	+	.	.	+	+	+	+	27
	T	*Alopecurus myosuroides* Huds.	+	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	+	.	+	+	+	+	.	.	.	19
	T	*Lamium purpureum* L.	.	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	13
	H	*Capsella bursa-pastoris* (L.) Medik.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	+	.	.	.	12
	G	*Cirsium arvense* (L.) Scop.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	+	r	1	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	.	.	.	.	.	.	12
	H	*Mentha arvensis* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
	G	*Sorghum halepense* (L.) Pers.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
	T	*Cardamine hirsuta* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	6
	T	*Torilis arvensis* (Huds.) Link	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	4
	T	*Crepis setosa* Haller f.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	r	.	.	+	.	r	+	.	.	.	.	10
	H	*Rumex pulcher* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	+	r	.	.	.	.	.	.	r	.	.	.	+	.	.	.	.	.	.	.	10
	T	*Crepis vesicaria* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	r	.	.	.	.	4
	T	*Matricaria chamomilla* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	4
	G	*Aristolochia clematitis* L.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	4
s	T	*Papaver rhoeas* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	2
	T	*Myosotis arvensis* (L.) Hill	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	r	.	.	.	4
	G	*Lepidium draba* L.	r	.	.	.	.	.	.	.	r	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
	H	*Potentilla reptans* L.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
	T	*Sonchus asper* (L.) Hill	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	+	6
	T	*Sonchus oleraceus* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	2	.	4
	T	*Solanum nigrum* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	4
s	T	*Portulaca oleracea* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	2
		***Artemisietea vulgaris* Lohmeyer, Preising & Tüxen ex von Ronchow 1951**																																																					
	G	*Elymus repens* (L.) Gould	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	4	5	4	3	4	5	5	5	5	4	4	2	+	+	+	1	1	1	+	+	+	+	1	3	100
	G	*Convolvulus arvensis* L.	+	+	2	1	1	1	1	+	+	+	1	+	2	1	1	+	2	2	3	3	+	1	1	1	+	1	1	1	1	2	+	+	+	2	1	1	+	+	2	1	+	+	.	.	1	+	+	+	+	+	+	+	96
	T	*Artemisia vulgaris* L.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	+	.	.	+	.	1	+	1	+	+	.	.	.	.	.	.	.	+	1	+	+	.	.	.	.	.	.	.	.	.	.	25
	T	*Galium aparine* L.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	15
	H	*Ballota nigra* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	8
	H	*Verbascum thapsus* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	r	+	.	r	.	.	.	.	.	.	.	.	.	.	.	8
	T	*Melilotus albus* Medik.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	+	r	.	.	.	.	.	.	.	.	.	.	6
	H	*Onopordum acanthium* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	4
	H	*Tanacetum vulgare* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	4
	H	*Malva alcea* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
	H	*Malva sylvestris* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	4
	H	*Cichorium intybus* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	r	.	.	.	.	.	.	.	.	.	.	4
	T	*Lapsana communis* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	+	.	.	.	.	.	.	.	.	.	4
s	H	*Cirsium vulgare* (Savi) Ten.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	2
s	H	*Dipsacus fullonum* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2

(*Continued*)

Table I – (*continued*)

sporadic sp.	life form	n. cluster	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	5	5	5	5	1	1	4	4	4	3	3	3	Pres. %
		n. relevé	4	5	9	11	14	46	10	13	21	38	12	52	16	28	17	47	27	48	42	41	24	30	25	33	22	40	29	15	26	31	18	39	34	32	50	51	35	36	37	23	7	8	43	45	1	44	2	6	3	19	49	20	
		n. of species	18	17	20	12	14	18	13	10	11	8	7	8	7	7	6	5	5	3	3	5	6	5	7	7	13	10	15	17	15	10	13	11	14	14	12	12	13	17	19	16	36	37	21	25	24	14	22	19	23	18	17	16	
		***Molinio-Arrhenatheretea* Tüxen 1937**																																																					
	H	*Rumex crispus* L.	+	+	1	1	+	1	+	+	.	+	1	+	+	2	.	.	.	.	.	+	+	+	+	+	+	+	2	+	1	+	3	1	+	+	+	1	+	+	1	1	+	+	.	1	3	3	+	1	.	+	1	+	85
	H	*Arrhenatherum elatius* (L.) P. Beauv. ex J. & C. Presl	+	r	.	.	.	+	+	+	.	.	.	.	.	+	.	.	+	.	+	.	.	.	1	.	+	.	1	.	+	.	.	r	.	+	.	.	.	.	.	1	+	+	.	.	r	.	+	1	.	.	.	+	40
	H	*Poa trivialis* L.	.	.	+	+	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	+	.	.	+	r	.	.	27
	T	*Bromus hordeaceus* L.	1	2	+	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	2	+	+	+	.	3	2	+	.	.	.	27
	T	*Alopecurus rendlei* Eig	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	2	3	4	.	.	.	13
	T	*Geranium molle* L.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	+	+	.	.	.	.	17
	H	*Lolium perenne* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	.	.	+	+	.	.	.	.	8
	H	*Plantago lanceolata* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	+	.	.	.	+	+	+	.	.	+	.	+	.	.	.	.	.	15
	H	*Trifolium repens* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	8
	T	*Medicago lupulina* L.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	6
	T	*Erigeron annuus* (L.) Desf.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	4
	H	*Trifolium fragiferum* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	+	.	.	.	.	.	.	.	.	.	.	4
	H	*Dactylis glomerata* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	1	.	r	.	.	.	.	.	.	.	.	.	.	12
	H	*Salvia pratensis* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	r	.	.	.	.	4
s	H	*Poa pratensis* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	2
s	G	*Ornithogalum umbellatum* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	2
	H	*Alopecurus pratensis* L.	.	.	.	.	.	.	+	r	+	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	10
	H	*Taraxacum officinale* Weber	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	+	.	.	.	6
	H	*Trifolium pratense* L.	r	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	6
	H	*Agrimonia eupatoria* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	4
		***Bidentetea tripartitae* Tüxen, Lohmeyer & Preising ex von Rochow 1951**																																																					
	T	*Xanthium orientale* L. subsp. *italicum* (Moretti) Greuter	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	+	1	1	8
	T	*Echinochloa crusgalli* (L.) P. Beauv.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	6
	T	*Abutilon theophrasti* Medik.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	r	6
	T	*Persicaria lapathifolia* (L.) Delarbre	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	4
		other species																																																				
	H	*Ranunculus bulbosus* L.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	r	r	.	.	1	1	+	+	.	.	+	.	+	.	.	.	19
	-	*Cerastium* spp.	+	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	+	.	+	.	.	.	17
	H	*Medicago sativa* L.	r	.	.	.	.	r	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	r	+	.	.	.	.	.	.	.	r	.	.	.	15
	H	*Hypericum perforatum* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	r	.	.	.	.	.	.	.	.	.	.	4
	-	*Valerianella* spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	4
	H	*Galium verum* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	4
	G	*Eleocharis palustris* (L.) Roem. & Schult.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	4
s	H	*Lythrum salicaria* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	2
s	H	*Euphorbia cyparissias* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
s	P	*Robinia pseudoacacia* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
s	-	*Allium* spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
s	P	*Salix alba* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
s	P	*Amorpha fruticosa* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	2
s	T	*Humulus japonicus* Siebold & Zucc.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	2
s	G	*Bolboschoenus maritimus* (L.) Palla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	2

of the Piacenza province flora (28%) (Romani & Alessandrini 2001) and the Emilia-Romagna flora (28%) (Pignatti et al. 2001), but is lower than that of the Mottola landfill flora (Southern Italy) (De Mei & Di Mauro 2006). In Italy, the frequency of therophytes gradually increases from North to South in response to a decrease in precipitation and the establishment of a markedly arid climate (Pignatti 1976, 1994). More generally, the annual species are concentrated in urban areas because they are better adapted to the arid and unstable conditions that are typical of such environments. Indeed, in central Europe, therophytes are mainly used as indicators of the environmental degradation due to an excessive urbanization (Sukopp & Werner 1983). Our study area is characterized by a short period of water deficit (in July) and a low level of human disturbance, in contrast with the therophyte percentage observed. A similar percentage was recorded by Celesti Grapow et al. (1996) and Capotorti et al. (2013) for the Rome urban flora. In our area, the high therophyte level is probably related to the

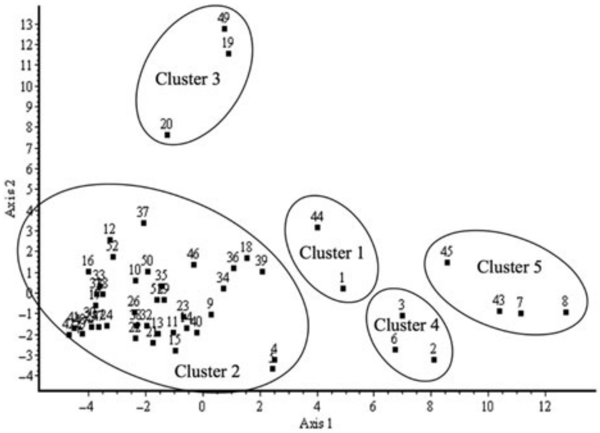

Figure 6. Ordination of relevés (PCoA). The numbers of clusters are the same used for the dendrogram.

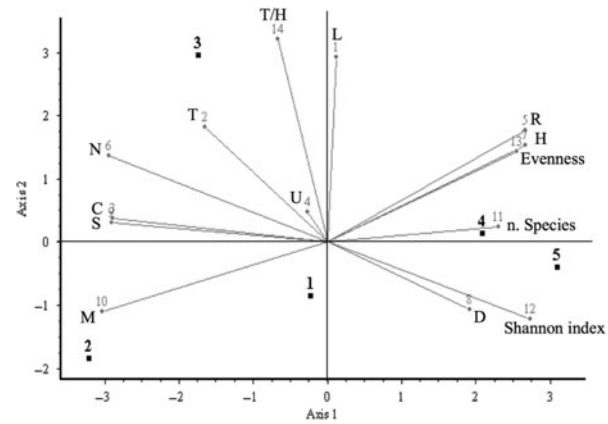

Figure 7. PCA of the vegetation clusters using the ecological variables (*L*, luminous intensity; *T*, temperature; *C*, continentality; *U*, soil moisture, *R*, soil reaction; *N*, nutrient supply, *H*, soil humus; *D*, soil aeration; *S*, soil salinity; *M*, heavy metals; T/H, therophytes/hemicryptophytes ratio). Variance explained of the first and second principal component: axis 1 = 48.79%; axis 2 = 23.21%.

chemical–physical characteristics of the landfill coverage soil. In general, various types of material such as gravel, pebbles, backfill, yard residue, etc. are used for the basic covering of landfill. As well as not being very fertile, these coarse materials have a little capacity to retain rainwater and therefore tend to dry very quickly, becoming inhospitable to plants during periods of less rainfall. In these conditions, annual plants, which complete their life cycle in a short time after the spring precipitations, are favoured. Furthermore, the area is irregularly disturbed by the mowing and the grazing. These disturbances also favour annual plants.

The phytosociological analysis of the five vegetation types did not allow to classify them at the association level, but only at higher syntaxonomical levels. This problem is due to the fact that the nitrophilous vegetations (*Stellarietea mediae* and *Artemisietea vulgaris*) obtain the most sintaxonomical uncertainty because of the frequency of the transgressive species (Ubaldi 2008). All the vegetation types were classified into the *Stellarietea mediae* class. The strong presence of *Elymus repens* in the study area may be due to the fact that this graminaceous plant can achieve competitive advantage over the other grasses in this environment. *Elymus repens* is a very common species in disturbed habitats (Akbar et al. 2009). Centeri et al. (2009) noted a decreasing in the coverage from very disturbed to less disturbed environments.

The identified vegetation clusters seem to describe a single community, defined as *Convolvolus arvensis–Cynodon dactylon* community, in which we recognize two variants and three *facies*. The first variant corresponds to the vegetation of cluster 3, with the presence of several annual species of the class *Bidentetea tripartitae*, while the second one corresponds to cluster 4 with a good presence of *Alopecurus rendlei*. The remaining clusters show different *facies* of the association; more specifically, cluster 1 represents the *Rumex crispus facies*, cluster 2 the *Elymus repens facies* and cluster 5 the *Hordeum murinum facies*. The last plant community has characteristics very similar to the association *Hordeetum murini* Libbert, 1932, described by Pajazitaj (2009) in Kosovo, from which it differs in the absence of many species, particularly the Pontic species.

Table II. Values of ecological parameters of the five types of vegetation (*L*, luminous intensity; *T*, temperature; *C*, continentality; *U*, soil moisture; *R*, soil reaction; *N*, nutrient supply; *H*, soil humus; *D*, soil aeration; *S*, soil salinity; *M*, heavy metals; T/H, therophytes/hemicryptophytes ratio).

	L	*T*	*C*	*U*	*R*	*N*	*H*	*D*	*S* (%)	*M* (%)	Mean no. of species	Shannon index	Evenness	T/H
Cluster 1	7.16	6.75	5.20	4.54	5.83	5.35	2.87	2.31	56.95	63.40	19	3.06	0.92	1.48
Cluster 2	7.22	6.70	5.73	4.57	5.74	5.87	2.46	2.40	62.98	69.96	11	3.02	0.74	1.53
Cluster 3	7.42	6.92	5.62	4.59	6.01	6.18	2.84	2.32	62.33	59.59	17	2.84	0.89	9.00
Cluster 4	7.28	6.51	5.08	4.99	6.10	5.25	2.96	2.38	44.37	49.67	14	3.20	0.92	3.00
Cluster 5	7.30	6.71	5.23	4.22	6.10	4.64	2.91	2.55	51.66	50.99	30	3.63	0.92	2.61
Average	7.28	6.72	5.37	4.58	5.96	5.46	2.81	2.39	55.66	58.72	18	3.15	0.88	3.52
± SD	0.10	0.15	0.28	0.27	0.16	0.59	0.20	0.09	7.80	8.52	7.26	0.30	0.08	3.13

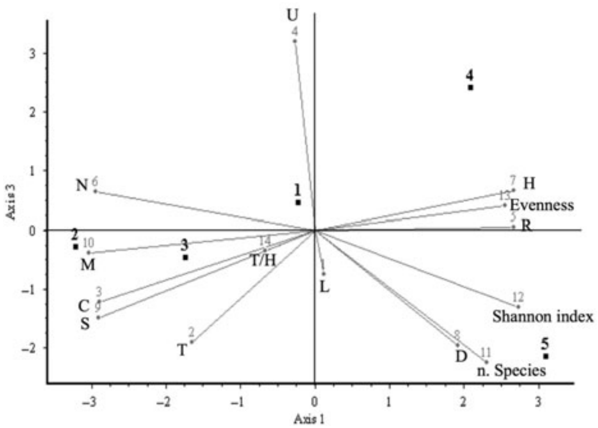

Figure 8. PCA of the vegetation clusters using the ecological variables (*L*, luminous intensity; *T*, temperature; *C*, continentality; *U*, soil moisture; *R*, soil reaction; *N*, nutrient supply; *H*, soil humus; *D*, soil aeration; *S*, soil salinity; *M*, heavy metals; T/H, therophytes/hemicryptophytes ratio). Variance explained of the first and third principal component: axis 1 = 48.79%; axis 3 = 21.23%.

The use of Ellenberg's and Landolt's indices allowed us to reach further understanding of the main ecological characteristics of the vegetation of the landfill. The mean of indicator values of the climate parameters (*L*, *T* and *C*) describes a vegetation of a temperate climate and of stations generally having full light, typical of normal conditions in the area of the Po valley, even though there are some species with the temperature requirements of Mediterranean environments, such as *Abutilon theophrasti*, *Amaranthus retroflexus* and *Crepis setosa*. As regards the characteristics of the substrate of the landfill, the vegetation as a whole indicates a moderately basic, semi-dry soil, rich in nutrients, low in humus and badly aerated. These features are in accordance with those of soil favourable to nitrophilous and ruderal vegetations of *Stellarietea mediae*. The most abundant nitrophilous species are represented by *Amaranthus retroflexus*, *Chenopodium album* and *Elymus repens*, followed by *Rumex pulcher*, *Ballota nigra*, *Onopordum acanthium* and *Echinochloa crusgalli*, which, however, are less and less abundant. *Amaranthus retroflexus* and *Chenopodium album* are typical ruderal weeds (Grime 2001) which tend to become dominant in these environments because of the allelopathic effects exerted on other species (Liu & Ma 2009) and the high seeding, respectively.

The values for the *S* (salt tolerant species) and *M* (heavy metal tolerant species) parameters indicate the presence of a high percentage of species that are able to tolerate soils with accumulation of salts and heavy metals. This finding may indicate a real concentration of salts and heavy metals in the soil (Landolt et al. 2010).

The ecological analysis of vegetation expressed by five clusters also allowed us to gain understanding of

Figure 9. Vegetation map of study area. Legend with the correspondence between the number and the vegetation type which represents using the name of the community and the name of the variant and facies (1, vegetation of cluster 1; 2, vegetation of cluster 2; 3, vegetation of cluster 3; 4, vegetation of cluster 4; 5, vegetation of cluster 5).

the factors which distinguish them. Cluster 3 is characterized by having more heliophilous and thermophilous species than the others, as well as a higher percentage of therophytes than hemicryptophytes (T/H ratio). Vegetations of groupings 4 and 5 show high values in terms of biodiversity and evenness, but differ in the need of soil moisture. Cluster 4 represents a phytocoenosis of a wetter environment as compared with the other groups, in particular with cluster 5 which, on the contrary, has a dry environment coenosis, demanding well-aerated soils. The vegetation of cluster 2 differs from the others especially in the poverty of species and in the high presence of plants that are tolerant of heavy metals and salts in the soil. Similar characteristics were observed by Ali et al. (2004) analysing the herbaceous communities in polluted and unpolluted areas of some industrial areas of the Punjab (Pakistan). The authors found that the vegetation of the contaminated area generally comprised a reduced number of species. Cluster 2, furthermore, assumes the lowest value of evenness due to the high coverage of *Elymus repens*, which is a species that spreads quickly being able to reproduce both by seed and by rhizomes (Szczepaniak 2009). This grass is also allelopathic, producing ethylacetate extracts, cyclic hydroxamic acids and several other chemicals that may be exuded from its shoots and roots and can suppress the growth or the reproductive vigour of competing plants (Whitson et al. 2000). Finally, the vegetation of cluster 1 presents ecological characteristics very similar to those of cluster 2, from which it differs only in a greater number of species.

According to the results obtained, we recommend the people involved in the restoration of the Borgotrebbia landfill to better investigate on the vegetation stresses. In particular, we suggest to analyse the water balance of the soil, in order to find out how much water is available for the plants during the year, and to make chemical analyses in order to understand whether a real soil contamination of heavy metals is present.

Notes

* Current address: Centro Interdipartimentale di Studi Applicati per la Gestione Sostenibile e la Difesa della Montagna – Ge.S.Di.Mont., Università degli Studi di Milano, Via Morino 8, 25048 Edolo (BS), Italy. Email: luca.giupponi@unimi.it

** Email: carla.corti@unicatt.it

*** Email: manfredi@mcmecosistemi.com

References

Aeschimann D, Lauber K, Moser DM, Theurillat JP. 2004. Flora alpina. 3 Bde. Bern-Stuttgart-Wien: Haupt Verlag.

Akbar KF, Hale WHG, Headley ADD. 2009. Floristic composition and environmental determinants of roadside vegetation in north England. Polish J Ecol 57: 73–88.

Ali M, Ahmad T, Rashid A. 2004. Phytosociological synthesis as inferred from soil analysis of some industrial areas of the Punjab. Asian J Sci 3: 320–324.

Banfi E, Bracchi G, Galasso G, Romani E. 2005. Agrostologia Placentina. Memorie della Società Italiana di Scienze Naturali e del Museo Civico di Storia Naturale di Milano XXXIII(II): 1–80.

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

Biondi E, Allegrezza M, Casavecchia S, Galdenzi D, Gigante D, Pesaresi S. 2013. Validation of some *syntaxa* of Italian vegetation. Plant Biosyst 147(1): 186–207.

Blasi C, Frondoni R. 2011. Modern prospective for plant sociology: The case of ecological land classification and the ecoregions of Italy. Plant Biosyst 145(Suppl. 1): 30–37.

Bracchi G, Romani E. 2010. Checklist aggiornata e commentata della flora della Provincia di Piacenza. Piacenza: Museo Civico di Storia Naturale di Piacenza.

Braun-Blanquet J. 1964. Pflanzensoziologie. 3rd ed., Wien: Springer-Ver.

Braun-Blanquet J. 1979. Fitosociologia. Bases para el estudio de las comunidades vegetales. Blume: Ed. Madrid.

Capotorti G, Del Viico E, Lattanzi E, Tilia A, Celesti-Grapow L. 2013. Exploring biodiversity in a metropolitan area in the Mediterranean region: The urban and suburban flora of Rome (Italy). Plant Biosyst 147(1): 174–185.

Celesti Grapow L, Blasi C, Andreis C, Biondi E, Raimondo FM, Mossa L. 1996. Studio comparativo sulla flora urbana in Italia. Giorn Bot Ital 130: 779–793.

Centeri C, Herczeg E, Vona M, Balźs K, Penksza K. 2009. The effects of land-use change on plant-soil-erosion relations, Nyereg Hill, Hungary. J. Plant Nutr Soil Sci 172: 586–592.

Conti F, Abbate G, Alessandrini A, Blasi C, editors. 2005. An annotated checklist of Italian flora. Roma: Palombi & Partner.

De Mei M, Di Mauro M. 2006. Study of some characteristic Mediterranean vegetation species best suited for renaturalization of terminal-phase municipal solid waste (MSW) landfills in Puglia (Southern Italy). Acta Oecol 30: 78–87.

Diekmann M. 2003. Species indicator values as an important tool in applied plant ecology – A review. Basic Appl Ecol 4: 493–506.

Ellenberg H. 1979. Zeigerwerte der Gefässpflanzen Mitteleuropas (indicator values of vascular plants in Central Europe). 2nd ed., Gottingen: Scr Geobot 9.

Fanelli G. 2002. Analisi fitosociologica dell'area Metropolitana di Roma. Braun-Blanquetia 27: 1–269.

Ferrari C. 1997. Le fasce di vegetazione dell'Emilia Romagna. In: Tomaselli M, editor. Guida alla vegetazione dell'Emilia-Romagna. Parma: Collana Annali Facoltà di Scienze Matematiche Fisiche e Naturali dell'Università di Parma. pp. 25–41.

Giupponi L, Corti C, Manfredi P. 2013. *Onopordum acanthium* L. subsp. *acanthium* in una ex-discarica della Pianura Padana (Piacenza, Italy). Inf Bot Ital 45(2): 213–219.

Grime JP. 2001. Plant strategies, vegetation processes and ecosystem properties. Chichester: Wiley.

Häupler H. 1982. Evenness als Ausdruck der Vielfalt in der Vegetation. Vaduz: Cramer.

Huber-Humer M, Klug-Pümpel B. 2004. The vegetation on different top covers of an abandoned solid waste landfill. Die Bodenkultur 55(4): 155–163.

Klug B, Tintner J, Huber-Humer M, Meissl K. 2008. Evaluating and planning waste landfill top covers with the help of vegetation and population ecology. In: De Santis A, Baker R, Klug B, Vanicek P, Homem LJ, Foyo A, Ercanoglu M, Dordevic D, editors. Proceedings of the 1st WSEAS International Conference on Environmental and Geological Science and Engineering (EG'08); 2008 September 11–13; Malta. WSEAS Press. pp. 76–84. www.wseas.org

Kollmann J, Fischer A. 2003. Vegetation as indicator for habitat quality. Basic Appl Ecol 4: 489–491.

Landolt E. 1977. Ökologische Zeigerwerte zur Schweizer Flora. Zurich: Geobotanisch Institut ETH.

Landolt E, Bäumler B, Erhardt A, Hegg O, Klötzli F, Lämmle RW, et al. 2010. Flora indicativa. Ökologische Zeigerwerte und biologische Kennzeichen zur Flora der Schweiz und der Alpen. [Ecological indicator values and biological attributes of the Flora of Switzerland and the Alps]. Bern-Stuttgart-Wien: Haupt Verlag.

Liu S, Ma DW. 2009. The allelopathy of different development stages of *Amaranthus retroflexus* L. on root border cells of cucumber. Shengtai Xuebao/Acta Ecol Sinica 29: 4392–4396.

Loidi J. 2004. Phytosociology and Biodiversity: an undissociable relationship. Fitosociologia 41(1 Suppl. 1): 3–13.

Matuszkiewicz W. 2001. Guidebook to the plant communities of Poland. Vademecum geobotanicum. Warszawa: PWN.

Mucina L, Grabherr G, Ellmauer T. 1993. Die Pflanzengesellschaften Österreichs. Band 1 – Anthropogene Vegetation. Jena: G Fischer.

Oberdorfer E. 1993a. Süddeutsche Pflanzengesellschaften. Vol 1. Stuttgart: Gustav Fischer Verlag.

Oberdorfer E. 1993b. Süddeutsche Pflanzengesellschaften. Vol 3. Stuttgart: Gustav Fischer Verlag.

Pajazitaj Q. 2009. *Hordeetum murini* Libbert, 1932 – A ruderal association in Kosovo. Acta Agricolturae Slovenica 93(3): 337–343.

Pignatti S. 1976. Geobotanica. In: Cappelletti C, editor. Trattato di Botanica. Vol 2. Torino: UTET. pp. 801–977.

Pignatti S. 1979. I piani di vegetazione in Italia. Giorn Bot Ital 113: 411–428.

Pignatti S. 1982. Flora d'Italia. Vol. 3. Bologna: Edagricole.

Pignatti S. 1994. Ecologia del Paesaggio. Torino: UTET.

Pignatti S. 2005. Valori di bioindicazione delle piante vascolari della Flora d'Italia [Bioindicator values of vascular plants of the Flora of Italy]. Braun-Blanquetia 39: 3–97.

Pignatti S, Bianco PM, Fanelli G, Paglia S, Pietrosanti S, Tescarollo P. 2001. Le piante come indicatori ambientali, manuale tecnico-scientifico. Roma: Agenzia Nazionale Protezione Ambiente.

Podani J. 2001. Syn-tax 2000. Computer program for data analysis in ecology and systematics – User's manual. Budapest: Scientia Publishing.

Pott R. 2011. Phytosociology: A modern geobotanical method. Plant Biosyst 145(Suppl. 1): 19–29.

Puppi G, Speranza M, Ubaldi D, Zanotti AL. 2010. Le serie di vegetazione della regione Emilia-Romagna. In: Blasi C, editor. La Vegetazione d'Italia. Roma: Palombi & Partner. pp. 181–203.

Raunkiaer C. 1934. The life forms of plants and statistical plant geography. Oxford: The Clarendon Press.

Rivas-Martínez S. 2004. Global bioclimatics. Clasificación Bioclimática de la Tierra. Madrid; 1996–2009 [cited 2004 Aug 2004]. Centro de Investigaciones Fitosociológicas. Available from: http://pendientedemigracion.ucm.es/info/cif/book/bioc/global_bioclimatics_0.htm

Rivas-Martínez S, Fernandez-Gonzalez F, Loidi J, Lousa M, Penas A. 2001. Syntaxonomical checklist of vascular plant communities of Spain and Portugal to association level. Itinera Geobotanica 14: 5–341.

Romani E, Alessandrini A. 2001. Flora Piacentina. Piacenza: Museo Civico di Storia Naturale di Piacenza.

Sukopp H, Werner P. 1983. Urban environments and vegetation. In: Holzner W, Werger MJA, Ikusima I, editors. Man's impact on vegetation. The Hague: Junk. pp. 247–260.

Szczepaniak M. 2009. Biosystematic studies of *Elymus repens* (L.) Gould (Poaceae): Patterns of phenotypic variation. Acta Soc Botan Polon 78: 51–61.

Tintner J, Klug B. 2011. Can vegetation indicate landfill cover features? Flora 206: 559–566.

Tintner J, Meissl K, Klug B. 2008. Possible succession on landfill top cover in the Pannonia area – An example from eastern Austria. In: De Santis A, Baker R, Klug B, Vanicek P, Homem LJ, Foyo A, Ercanoglu M, Dordevic D, editors. Proceedings of the 1st WSEAS International Conference on Environmental and Geological Science and Engineering (EG'08); 2008 September 11–13; Malta. WSEAS Press. pp. 103–111. www.wseas.org

Tomaselli R. 1970. Note illustrative della carta della vegetazione naturale potenziale d'Italia. Collana Verde 27. Roma: Ministero Agricoltura e Foreste.

Ubaldi D. 2008. Le vegetazioni erbacee e gli arbusteti Italiani, tipologie fitosociologiche ed ecologia. Roma: Aracne editrice.

Van der Maaler E. 1979. Transformation of cover-abundance values in phytosociology and its effects on community similarity. Vegetatio 39: 97–114.

Walter H, Lieth H. 1960. Klimadiagramm-Weltatlas. Jena: G Fischer Verlag.

Whitson TD, Burrill LC, Dewey SA, Cudney DW, Nelson BE, Lee RD, Parker R. 2000. Weeds of the West. Laramie: University of Wyoming.

Whittaker RH. 1972. Evolution and measurement of species diversity. Taxon 21: 213–251.

Yilmaz KT. 2011. Incorporating vegetation analysis into ecological characterization of landscapes: The Turkish case. Fitosociologia 48(2 Suppl. 1): 83–92.