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Ecological indicators applied to urban and suburban floras

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Abstract

Among the many approaches to ecological indicators, ecological indicators derived from the floristic composition of a site (i.e. Raunkiaer's forms spectrum or the percentage of different geographical distribution types-chorotypes) are well established in botanical and ecological literature. Nonetheless their relationship with other indicators, such as Ellenberg's ecological indicators, or the Grime model [Grime, J.P., 2002. Plant Strategies, Vegetation Processes and Ecosystem Properties. Wiley, Chichester] and the Hemeroby index [Kowarik, I., 1990. Some responses of flora and vegetation to urbanization in Central Europe. In: Sukopp, H., Hejny, S., Kowarik, I. (Eds.), Urban Ecology. Plants and plant communities in urban environments. SPB Academic Publishing, The Hague] is still poorly explored. We concentrated on an urban ecosystem because such areas, due to their high degree of artificialization, are particularly well suited for studying the interaction of anthropical disturbance with other processes of the ecosystems.

This paper attempts to select a small indicator frameset of many already proposed indicators which best express the variability of the sites studied. A floristic-ecological investigation has been carried out in 10 urban sites, of which 6 were archeological, located in the centre of Rome and 4 suburban, semi-natural, in the NE of the town. Ecological indicators have been calculated on this data set.

The Pearson correlation test was then applied to verify whether the indicators were independent, while stepwise regression analysis was done to evaluate the statistical weight of each ecoindicator.

Disturbance and temperature are the main factors shaping the composition of the sites studied. They are largely interacting and are well expressed with the help of a small subset of the initial set of 19 indicators, namely, by indicators related to life forms and to the geographical distribution of species: Therophytes/Hemicryptophytes, Mediterranean/large distribution, Eurasiatic/large distribution, Mediterranean/Eurasiatic species.

The information provided by Ellenberg's indicators values and Grime's life strategies are largely summarized by these chorological indicators.

Keywords: Disturbance; CSR model; Urban flora; Phytogeographical indicators; Ellenberg's indicator values

1. Introduction

Recent ecological research has developed methods of identifying, monitoring and managing the ecolo-

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gical integrity of environments through the use of *ecoindicators*. Ecological integrity refers to a systemic approach encompassing species, populations and communities, as well the occurence of dynamic processes at appropriate rates and scales (Angermeier and Karr, 1994). Ecological indicators have several purposes (Cairns et al., 1993). They can be used to assess the conditions of the environment, to monitor trends over time or to provide early signal of changes. More generally, they can be used to detect and summarize patterns of the ecosystems, for instance the relationships between plants and habitat factors such as soil, climate, disturbance, etc. A challenge in developing and using ecoindicators is selecting the most effective indicators in characterizing the systems of interest (Dale and Beyeler, 2001).

Ecological indicators can be developed with different approaches. Indicators can be derived from key plant traits (Lavorel and Garnier, 2002), from species richness indices, or from landscape metrics. In the plant ecological and phytogeographical literature a long tradition in using species composition as indicator exists. An example is Raunkiaer's life form concept, which nicely correlates with the climatic condition of the environment (Raunkiaer, 1934). Also the percentage of species with different geographical distributions (chorotypes) is largely exploited in the phytogeographical literature (Celesti Grapow and Blasi, 1998; Nimis and Bolognini, 1990; McCollin et al., 2000; Box, 1981).

Other widely used indicators related to species compositions of plots or sites are Ellenberg's indicator values, the Hemeroby index and Grime's model.

It has since long been recognized that certain species are indicators of the habitat characteristics; some species indicate for instance acid soils. Ellenberg's indicator values (Ellenberg, 1974, 1979), are a generalization of these observations. The indicator values are a set of numbers (light, temperature, continentality, nutrients, moisture, pH and salinity) on a scale from 1 to 10 expressing the species' optima under field conditions with respect to a given factor of the habitat; *Calluna vulgaris*, f.i., an acidophylous species, has pH indicator value 1, whereas *Bromus erectus*, a basophilous species, has pH indicator 8.

The usefulness of Ellenberg's indicators in environmental analyses derives from the simplicity of the model; they achieve the maximum effectiveness in synthetic comparative studies on large temporal and/or spatial scales (Pignatti et al., 2001).

An indicator closely related to Ellenberg's indicator values is the Hemeroby index. Hemeroby expresses the degree of past and present human impacts on ecosystems according to a 10 points scale (Van de Maarel, 1975; Kowarik, 1990; Fanelli and De Lillis, 2004).

Grime's model (2002) focuses on two main categories: *stress*, including the phenomena which restrict photosynthetic production, and *disturbance*, associated with the partial or total destruction of plant biomass. Environments with simultaneously high stress and high disturbance are inaccessible to plants, while the other three combinations generate a suite of adaptations representing the three main life strategies: competitive (C), ruderal (RUD) and stress-tolerant (*S*) species. Intermediate types of life strategies can be defined (CS, CSR, RS, CR). Grime's CSR model attempts to summarise the different ecological factors related to plant life; the different strategies may nonetheless be regarded as another type of ecological indicators. In fact, interspecific variability is larger than intraspecific variability; plant species are, therefore, well suited for serving as useful indicators of environmental parameters (Lavorel and Kramer, 1999).

These species-based indicators are currently used in assessing the properties of environments and in monitoring changes. The question has been rarely addressed if different sets of indicators are correlated and which indicators are most effective at differentiating habitats with different properties. This paper focusses on extracting the indicators that can summarize the maximum of information with best statistical efficiency. We tested a few of the many indicators proposed in the literature along a centre-suburb gradient in the town of Rome. Rome is well suited to such a study; it is in fact, very diverse, with about 1500 spontaneous plant species and 100 plant associations. Interesting patterns in the distribution of species and communitiy-types in the town of Rome have been emphasized in previous research (Celesti Grapow et al., 1995; Fanelli, 2002). Urban flora and vegetation carries a rich information about the properties of urban ecosystems (Stülpnagel et al., 1990; Sukopp and Werner, 1983), but the high fragmentation of ecomosaics often makes the analysis of properties of spontaneous vegetation difficult (McCollin et al., 2000; Erhardt et al., 2002; Franzaring, 1997); the application of ecoindicators can be, therefore, useful and effective.

In this paper, we ask if it is possible to achieve a simplification in the description of these patterns without losing information by selecting only the most significant indicators among the many applied.

2. Study area

The town of Rome rises on a slightly hilly territory with M. Mario as maximum elevation (130 m. a.s.l.). The urban area is cut by the Tevere river; the Aniene, the principal influent of Tevere, and a series of ditches and small rivers complete the hydrographic net.

The oldest lithologies of the Roman area, dating back to the Plio-Pleistocene period, are only sporadically exposed in a few sectors such as Magliana, Monte Mario, Valle dell'Inferno. They are covered by marine-eolian and fluvio-lacustrine sediments related to glacio-eustatic variations of the sea level during the glacial periods. The most widespread lithological units, characterizing the urban area, are of volcanic origin (from 800,000 to 20,000 years ago). They consist of pyroclastic ejecta (tuffs and pozzolanas), ignimbrites and lava flows, among

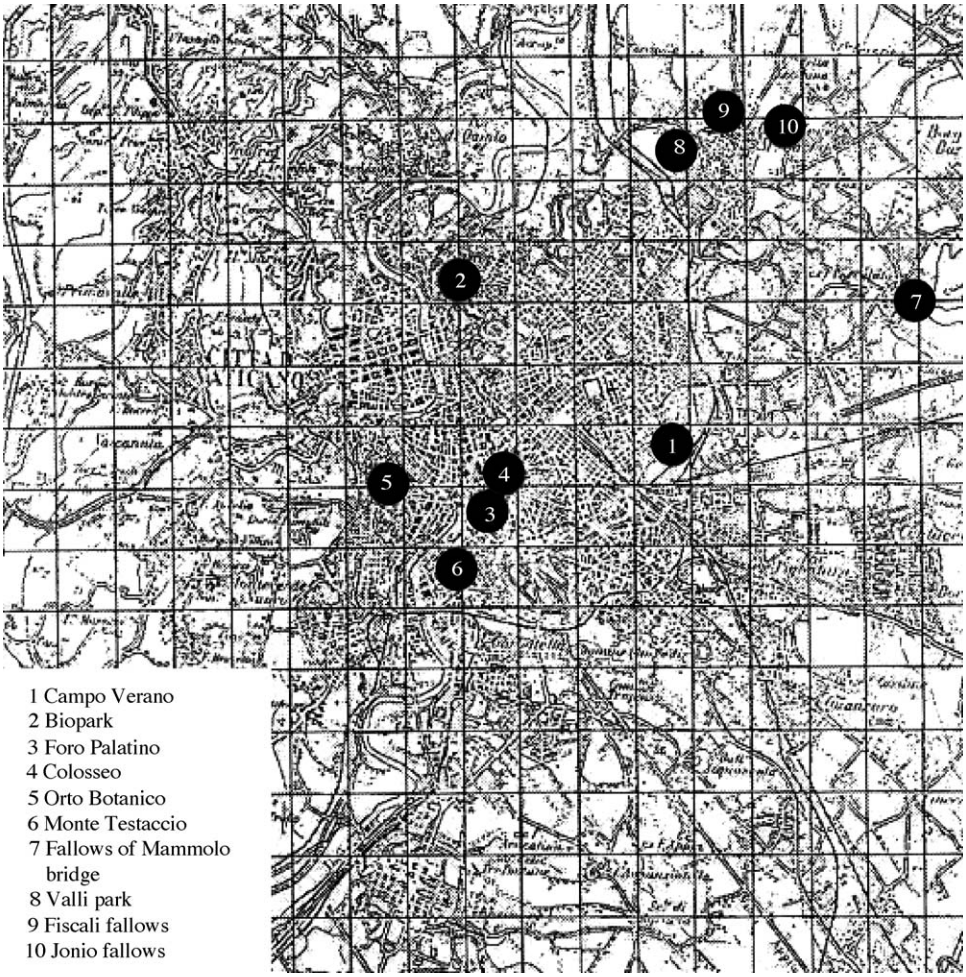

Fig. 1. Location of the study sites.

which the most significant is the "Capo di Bove", over which the ancient Appia road runs. Also recent alluvial deposits are present, related to the existing drainage basin, dating back to the Holocene.

Climatic data referred to the thermopluviometric station of "Monte Mario" present a mean annual temperature of 15.3 °C and yearly rainfall of 889 mm, concentrated in spring and autumn. Summer drought spans over 3 months. This climate is assigned to the Meso-Mediterranean type, upper sub-humid (Blasi, 1994).

Rome counts 2,900,000 inhabitants. A "core town" is easily detected because surrounded by a highway (GRA) which separates the centre and the densely populated first belt of suburbs from the outskirts. A floristic-ecological investigation has been carried out in 10 sites. Six archeological sites in the centre of the town (1 Campo Verano, 2 Biopark, 3 Foro-Palatino, 4 Colosseo, 5 Orto Botanico, 6 Monte Testaccio) and four suburban, more natural sites, in the NE of Rome (7 Mammolo Bridge, 8 Valli Park, 9 Fiscali, 10 Viale Ionio) (Fig. 1).

The central archeological sites are located in parks that break the almost continuous urban tissue of the ancient historical centre. Vegetation is restricted to spaces among the archeological monuments, ranging from small crevices to more open areas a few hundred square metres large (Fig. 2). These are colonized mainly by herbaceous, native species, possibly dispersing from the southern and south-western surrounding areas (Agro Pontino and Campagna Romana), which are connected to the inner town by strips of semi-natural vegetation, in particular along the Appia road and the Tevere river. The strict ruderal component, typical in particular of house gardens, that in Rome are almost not-existent, is not very well represented in these areas.

The NE sub-urban sites are relatively large open areas occupied by fallows and grasslands with pioneer vegetation (belonging to *Brometalia rubenti-tectorum* and *Agropyretalia repentis*), typical of continental climates on loamy soils (Fanelli, 2002); these habitats are heavily fragmented and unconnected and are present in several zones of the town, among heavily

Fig. 2. An example of the central archeological sites (Foro-Palatino). Vegetation is restricted to spaces among the archeological monuments.

build-up areas, settled mainly in the time spanning from 1930 to 1970 (Fig. 3).

An idea of the most frequent species typical of the two areas is given in the Appendix A. The species shown in the table have been selected basing on stocks of common and exclusive species of the centre and the suburbs.

Nomenclature follows Anzalone (1994, 1996).

3. Methods

The floristic analysis was carried out in the years 1998–2000, and extended and completed in 2000–2003. A complete list of the flora of each site was prepared in the suburban sites, Botanical Garden and M. Testaccio. Floristic lists for a few sites (Campo Verano, Biopark, Foro-Palatino, Colosseo) were derived from literature data (Celesti Grapow et al., 2001). We, therefore, obtained a matrix of 641 species and 10 sites.

Several indicators were applied to the floristic matrix. In the literature, there are number of other indicators that we could have applied to the floristic matrix, but they are less frequently used and moreover values for the species in our study sites were not readily available.

- Percentage of Raunkiaer's life forms (*scapose* and *caespitose* phanerophytes, representing a small percentage in all sites, were excluded from the elaborations to be able to compare the study sites). An index based on the ratio between therophytes and hemicryptophytes (*T*/*H*) has been calculated.
- Percentage of main chorotypes (geographical distribution types after Flora d'Italia: Pignatti, 1982). The ratios between Mediterranean or Eurasiatic and large distribution species and between Mediterranean and Eurasiatic species (% Med/% LD; %Euras./% LD; %Med/%Euras.) were calculated.

1. Ellenberg's Ecological Indicators (1979) were applied to the floristic matrix. These indicators refer to climatic variables: light regime (*L*), temperatures (*T*), continentality of climate (*K*)

Fig. 3. An example of the suburban sites (Valli Park). Fallows and grasslands with pioneer vegetation among heavily build-up areas.

and to edaphic conditions: moisture of soil (*F*), soil reaction (*R*) nutrients availability (*N*). The indicators for each species are derived from Ellenberg (1979); Mediterranean species lacking in the original list were scored according to phytosociology (Pignatti, unpublished database); these values are stored in a databank available upon request.

2. Hemeroby index was calculated relying on a databank of about 2000 phytosociological relevés classified into 104 vegetation types (Fanelli, 2002). To each vegetation type a Hemeroby value was given according to the table in Kowarik (1990) and average values for species were derived.
3. Grime's categories (2002) were calibrated from Italian flora by means of weighted averaging (Ter Braak and Barendregt, 1986; Hill et al., 2000) on the above mentioned phytosociological databank. Original categories were derived from Grime et al. (1988).
4. Species richness was expressed as ln of species number (ln *S*) (Margalef, 1972) to normalize the set of data.

In summary, we converted the original floristic matrix into a matrix of 10 sites and 19 ecological indicators. Both the original floristic matrix and the ecoindicators matrix were subjected to principal component analysis (PCA), in order to reduce dimensionality of the matrix. Subsequently, the Pearson correlation test was applied to the ecoindicators matrix, in order to verify whether the indicators were correlated, and stepwise regression was used to evaluate the statistical weight of each ecoindicator in expressing the whole data set.

4. Results

4.1. Pearson bivariate correlation test

The results showed that among the applied indicators several statistically significant (at 0.01 and at 0.05 level two-tailed) correlations exist (Table 1).

In particular, the soil moisture indicator is correlated with species richness and with the strategies expressing competitive ability (*C*) (Fig. 4A). Human impact, expressed by Hemeroby, is correlated with water and temperature (*F* and *T* Ellenberg's indicators) (Fig. 4B). Finally, the chorological indices are correlated with many of the variables in this analysis: Med/Euras. is correlated with ln *S*, *L*, *T*, −*F*, −*N*,

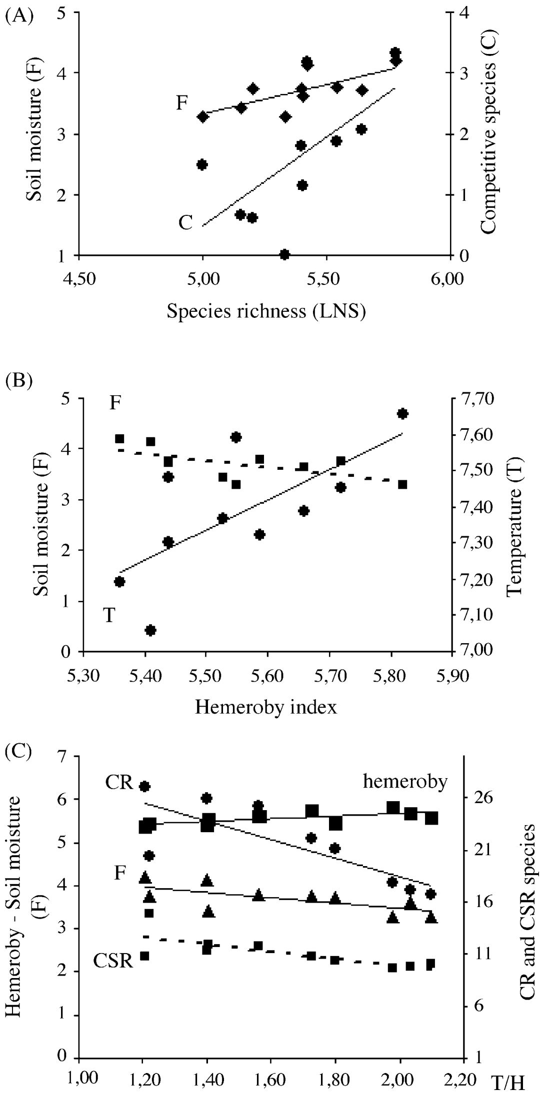

Fig. 4. Synthetical representation of the bivariate correlation output: (A) correlation of species richness (lnS) with soil moisture (*F* indicator) and Competitive strategy of Grime's model; (B) correlation of Hemeroby with soil moisture and temperature (Ellenberg *F* and *T* indicators); (C) correlation of *T*/*H* index with Hemeroby, *F* indicator, CR and CSR strategies.

Table 1
Output of the correlation bivariate test: the statistical significances are reported

	ln *S*	*L*	*T*	*K*	*F*	*R*	*N*	Hemeroby	*C*	*S*	RUD	CR	SR	CSR	CS	*T*/*H*	Med/Euras.	Med/LD
ln *S*	1																	
L	−0.67*	1																
T	−0.67*	0.71*	1															
K	−0.01	0.21	−0.39	1														
F	0.71	−0.77**	−0.86*	0.18	1													
R	0.40	−0.26	−0.68*	0.45	0.49	1												
N	0.57	−0.74*	−0.94**	0.38	0.89*	0.67*	1											
Hemeroby	−0.58	0.35	0.69*	−0.52	−0.64*	−0.38	−0.59	1										
C	0.63*	−0.87**	−0.77**	−0.00	0.84**	0.55	0.85**	−0.36	1									
S	0.18	−0.45	−0.28	−0.43	0.16	0.28	0.20	−0.08	0.24	1								
RUD	0.41	−0.08	0.01	−0.52	0.09	−0.11	−0.13	0.10	−0.12	0.34	1							
CR	0.55	−0.49	−0.81**	0.52	0.79**	0.88**	0.87**	−0.57	0.75*	0.10	−0.18	1						
SR	−0.36	0.72*	0.54	0.15	−0.70*	−0.54	−0.69*	0.13	−0.88**	−0.38	0.13	−0.69*	1					
CSR	−0.16	0.31	−0.13	0.59	0.26	0.14	0.11	−0.45	−0.16	−0.33	−0.21	0.31	0.06	1				
CS	−0.38	−0.18	0.31	−0.39	−0.17	−0.26	−0.10	0.50	0.26	−0.07	−0.54	−0.19	−0.40	−0.39	1			
T/*H*	−0.24	0.25	0.59	−0.62	−0.68*	−0.57	−0.63	0.67*	−0.43	0.00	0.32	−0.80**	0.48	−0.75*	0.24	1		
Med/Euras.	−0.69*	0.65*	0.91**	−0.48	−0.78**	−0.59	−0.80**	0.80**	−0.60	−0.27	0.03	−0.76*	0.38	−0.24	0.44	0.68*	1	
Med/LD	−0.76*	0.91**	0.74*	0.20	−0.91**	−0.35	−0.76*	0.46	−0.89**	−0.37	−0.23	−0.61	0.78*	0.07	−0.02	0.41	0.63*	1
Euras./LD	−0.43	0.62	0.17	0.64*	−0.52	0.11	−0.30	−0.03	−0.62	−0.18	−0.30	−0.12	0.63	0.30	−0.40	−0.06	−0.03	0.75*

* Correlation is significant at the 0.05 level (two-tailed).

** Correlation is significant at the 0.01 level (two-tailed).

Hemeroby, −CR, *T*/*H*, whereas Med/LD is correlated positively with *L*, *T*, SR, Med/Euras. and inversely with species richness, *F*, *N*, *C*; Euras./LD versus *K*, Med/LD; *T*/*H* is inversely correlated with *F* indicator, CR, CSR strategies and positively with Hemeroby (Fig. 4C).

A high degree of covariation is, therefore, present in our matrix; only three variables show no significant correlation with the others: percentage of ruderal, stress-tolerant and competitive-stress-tolerant Grime's strategies. The latter are poorly represented in the dataset.

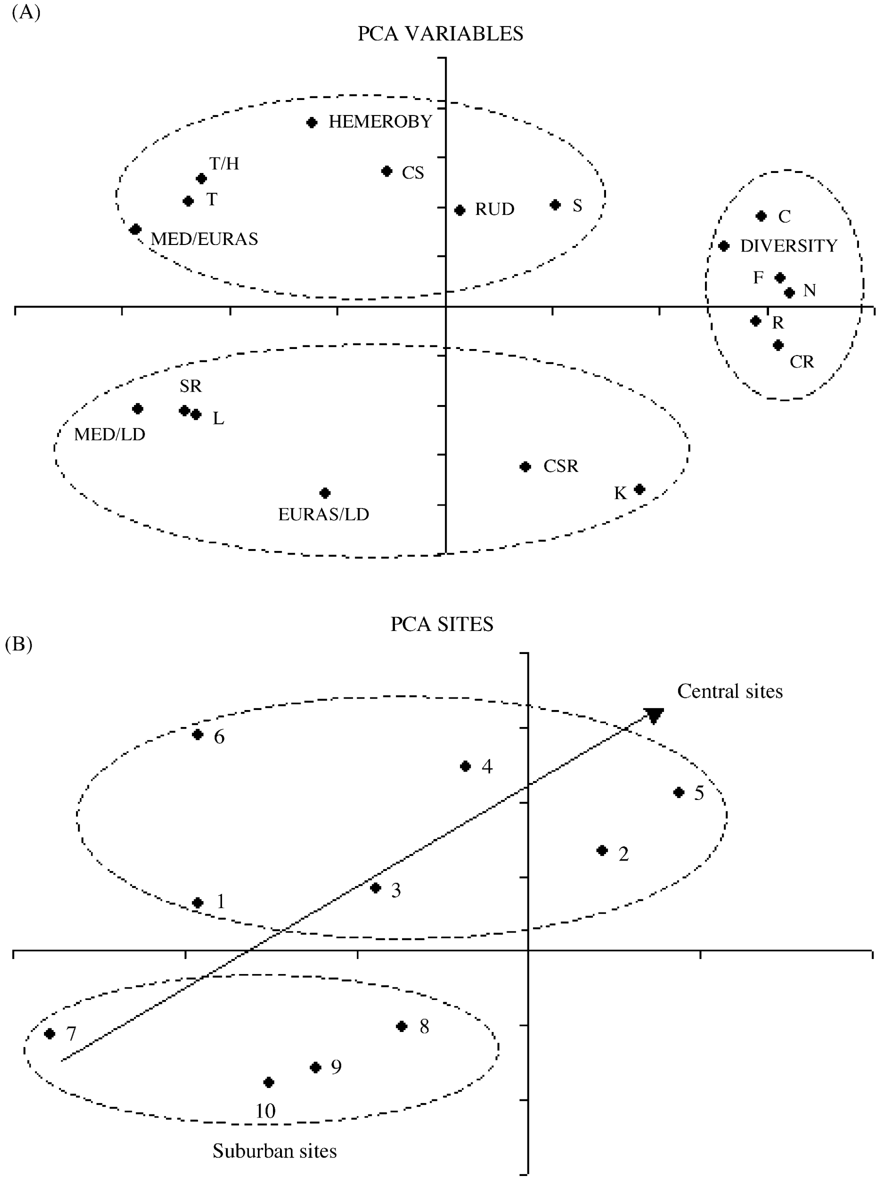

Fig. 5. PCA ordination diagram according to axes 1 and 2 on the ecoindicators matrix. (A) PCA variables. Along the first axis, the climatic Ellenberg's indicators are well separated from the edaphic ones. Three clusters are identified: the first is linked to mediterraneity, the second to continentality, the third to edaphic factors. (B) PCA sites (see Fig. 1 and study sites in the text). Along the second axis, the sites follow the gradient from suburb to centre, reflecting the gradient of the variables.

In summary:

1. Ellenberg's indicators (except for climate continentality) are correlated with Grime's model through C, CR and SR species.
2. Hemeroby is correlated with *T* and *F* Ellenberg's indicators.
3. Chorological indicators are correlated with all other indicators.

4.2. Principal component analysis

Variables are clustered into three groups (Fig. 5A):

(1) *T*/*H* and Med/Euras. chorological indices, Hemeroby, *T* Ellenberg indicator, CS and RUD strategies; these variables are associated with archeological central sites.
(2) Med/LD and Euras./LD chorological indices, *L* and *K* Ellenberg indicators, SR and CSR strategies are associated to suburban sites.
(3) Species richness, *F*, *R*, *N* Ellenberg indicators, *C* and CR strategies; these variables are associated to two central sites: BioPark (2) and Orto Botanico (5).

The first cluster of variables is broadly related to mediterraneity (in fact Med/Euras. expresses the percentage of species adapted to Mediterranean climate); the second to continentality and to anthropical impact (*K*, CS, CSR), and the third to soil moisture (*F*) and species richness. Along the first axis, the climatic Ellenberg indicators are well separated from the edaphic ones; Grime strategies follow a gradient reaching from SR–CS–RUD–S–C to CR species.

Sites are ordered on the second axis of PCA along a gradient reaching from suburban sites toward the centre of Rome (Fig. 5B). Therefore, the two different landscape types are recovered: centre and suburbs. They are distinguished in particular by the two stocks of exclusive species shown in the Appendix A: (1) Mediterranean annual and perennial species belonging to grassland vegetation in open spaces in the suburban landscape; (2) Atlantic and subatlantic species in the central sites.

4.3. Stepwise regression analysis

The indicators linked to life forms, chorology and species richness were selected as dependent variables. Results showed (Table 2) that CR and CSR species have the highest weight on the *T*/*H* index ($R^2 = 0.63$ and 0.92); Ellenberg *L*, *F*, *K*, indicators on the index Med/LD ($R^2 = 0.83$; 0.93; 0.99); Ellenberg *K* and *F* indicators on the Euras./LD index ($R^2 = 0.40$; 0.83); T

Table 2
Regression analysis results: statistical summary and coefficients are reported

Variables entered	Regression summary for dependent variables: model summary and coefficients								
	R	R^2	Adjusted R^2	Standard error of the estimate	Change statistics R^2 change	*F* change	Sig. *F* change	Beta coefficient	Sig.
T/*H*									
CR	0.796	0.633	0.587	0.21313	0.633	13.818	0.006	−0.63	0.001
CSR	0.957	0.916	0.892	0.10883	0.283	23.679	0.002	−0.56	0.002
Med/LD									
L	0.909	0.826	0.804	0.573	0.826	37.958	0	0.25	0.015
F	0.965	0.932	0.912	0.38307	0.106	10.899	0.013	−0.77	0
K	0.995	0.991	0.986	0.15176	0.059	38.6	0.001	0.3	0.001
Euras./LD									
K	0.636	0.404	0.33	0.46198	0.404	5.426	0.048	0.77	0.002
F	0.911	0.83	0.781	0.26387	0.426	17.522	0.004	−0.67	0.004
Med/Euras.									
T	0.906	0.822	0.799	0.18717	0.822	36.855	0	0.91	0
Diversity (ln *S*)									
F	0.655	0.43	0.358	0.07765	0.43	6.025	0.04	0.66	0.04

indicator on the Med/Euras. index. ($R^2 = 0.82$); *F* indicator (excluding chorological indices) on the species richness index ($R^2 = 0.43$).

Largest values of beta coefficients relate to *T* indicator (0.91) versus Med/Euras., *K* indicator (0.77) versus Euras./LD, *F* indicator (−0.77) versus Med/LD indices.

5. Discussion

Grime's CSR model and Ellenberg's set of indicator values are different models of the structure of plant communities (Franzaring et al., 2003). These models are considered to be largely independent, and are based on different assumptions (but see Thompson et al., 1993). The results presented here show that different models give largely overlapping information and (at least in the sites here studied) are complementary. The structure of the matrix of bivariate correlation shows in fact a large amount of covariation among the different variables. Moreover on the first axis of PCA, different Grime's strategies are well separated, with a gradient reaching from SR to CSR and *C* and CR, in the same way as along this axis light and temperature indicators are separated from soil moisture, nutrients and soil reaction. Indicators expressing the same ecological information, for instance CSR and continental and subcontinental species, are correlated. In fact, in suburban sites, CSR species with optimum in continental climates, such as *Elymus repens* and *Dasypyrum villosum* are dominant; whereas in central sites, with more oceanic climate, and where therefore, *K* Ellenberg's indicator is lower, CS species are dominant.

Other indicators have been shown to be also correlated with Ellenberg's indicators and Grime's strategies. In particular, considering the indicators derived from chorological distribution and life forms the following correlations arise:

(1) *T*/*H* indicator is significantly correlated to the fraction of species with CR and CSR strategy in the Grime's model.
(2) The ratio Mediterranean species/largely distibuted species is correlated with three Ellenberg's indicators: light, continentality and soil moisture indicators.
(3) Species richness (ln *S*) is correlated with soil moisture (Ellenberg's indicator *F*).
(4) The ratio of eurasiatic/largely distributed species is correlated with continentality and soil moisture Ellenberg's indicators.
(5) The ratio Mediterranean/Eurasiatic species is correlated with temperature indicator.

Hemeroby surprisingly is not correlated with any of Grime's strategy types, but, instead, with temperature and moisture indicators. Perhaps, these are spurious correlations because we studied parks that are subjected more or less to the same type of human impact (mowing, trampling, etc.). It is nonetheless possible that the ruderality axis of Grime deals with a different ecological factor from the gradient of impact described by Hemeroby. Possibly, ruderality is related to the destruction of biomass per se (Grime, 2002), whereas in the gradient of impact the degree of irregularity of biomass destruction has more importance. The topic needs further research.

Disturbance in our system is apparently well described by the *T*/*H* ratio, that is correlated with CR and CSR species. *T*/*H* ratio was originally proposed to express a climatic gradient, but is also related to disturbance, which enhances annuals or short-lived perennials. In Grime's model, the fraction of annuals is an important determinant of the ruderal and intermediate strategies. CSR species in the study area are limited to suburban disturbed environments, for instance fallows and wastelands. A few of the most widespread species in the suburubs, in particular many annual or perennial grasses, belong to this strategy: *Dasypyrum villosum*, *Bromus hordeaceus*, *Poa trivialis*.

Light (suburb: 7.68; centre: 7.38), temperature (suburb: 7.44; centre: 7.34) and continentality (suburb: 3.33; centre: 3.15) indicators are higher in suburban sites; Ellenberg's moisture indicator (suburb: 3.56; centre: 3.78) is higher in central sites. These differences seem to be most important in structuring the urban ecosystem of Rome, at least when only parks are considered. Probably they are related to the different structures of the landscape of archaeological central sites, with ruins and only small spaces available for plants, and the suburban fallows with large open spaces. In central sites, soils are usually poorly drained, due to extensive pavements. Shady niches related to walls and ruins are present. These microniches can be occupied by species with high *F*, low *L* and low *T* indicator values. These three indicators, therefore, do not represent independent ecological factors, but, at least in our study case, a single ecological factor, water availability. It is not possible to support this conclusion with direct measurements because water availability in these sites is subjected to high variability in space and time from microniche to microniche.

Ellenberg's light, continentality and soil moisture indicators are correlated with three other indicators: the ratio Mediterranean/large distribution species, the ratio Eurasiatic/large distribution species and species richness. It has been shown in previous work (Celesti et al., 1989; Menichetti et al., 1989) that in the urban environment of Rome species richness and large distribution species are correlated.

Ellenberg's temperature indicator and the ratio Mediterranean/Eurasiatic are correlated. This correlation is quite obvious, as long as Eurasiatic species are less thermophilous than mediterranean species; nonetheless, the fact that Med/Euras. is little or not at all correlated with other important parameters shows that the temperature indicator should be considered when trying to describe the environment of the sites.

6. Conclusions

In summary, three main ecological factors shaping the composition of the communities seem to underly the structure of the matrix of the indicators: disturbance, water and temperature. These three main ecological factors are interacting factors, and not independent variables. In our urban ecosystem, these fundamental parameters can be effectively expressed with the help of a small subset of the initial set of 19 indicators, namely, by indicators related to the geographical distribution of species and life-forms: *T*/*H*, Med/LD; Euras./LD; Med/Euras. We suggest these may be particularly useful for summarising environmental patterns because they are simple to use and are available in areas where Ellenberg's and Grime's models are difficult to apply or to extrapolate, for instance in tropical areas. It is nonetheless necessary to test if this set of variables has general value or is limited to urban ecosystems. Testing this approach on a larger or different data set (Knapp et al., 2004) should be rewarding.

Appendix A

Please see Table A.1.

Table A.1
Most frequent species in the study sites: species are clustered in blocks according to distribution types and life forms

	Frequency (%)		
	Suburban sites	Urban sites	
Stellaria media	50	40	Cosmopolitan/subcosmopolitan therophytes in common
Cardamine hirsuta	40	40	
Conyza canadensis	40	30	
Chenopodium album	30	40	
Geranium molle	50	50	
Setaria viridis	30	50	
Veronica polita	40	30	
Solanum nigrum	10	50	Cosmopolitan/subcosmopolitan therophytes discriminant
Digitaria sanguinalis	0	50	
Tribulus terrestris	10	30	
Portulaca oleracea	0	40	
Bromus madritensis	30	50	Mediterranean therophytes *s.l.* in common
Calendula arvensis	40	40	
Gaudinia fragilis	30	20	

Table A.1 (*Continued*)

	Frequency (%)		
	Suburban sites	Urban sites	
Trifolium nigrescens	30	50	
Hypochoeris achyrophorus	40	40	
Lotus ornithopodioides	50	40	
Avena barbata	50	50	
Dasypyrum villosum	50	40	
Knautia integrifolia	40	10	Mediterranean therophytes *s.l.* discriminant
Trifolium stellatum	0	30	
Pallenis spinosa	40	0	
Carthamus lanatus	30	0	
Diplotaxis erucoides	30	0	
Vicia lutea	30	0	
Vulpia ligustica	50	30	
Carlina corymbosa	40	0	Mediterranean hemicryptophytes discriminant
Centaurea bracteata	40	0	
Convolvulus cantabrica	40	0	
Echium italicum	40	0	
Eryngium campestre	40	0	
Chelidonium majus	10	20	Eurasiatic in common
Galium album subsp. *album*	20	30	
Lamium maculatum	10	20	
Ranunculus lanuginosus	10	20	
Alliaria petiolata	10	10	
Linaria vulgare	50	30	
Mycelis muralis	0	20	Eurasiatic discriminant
Rumex conglomeratus	0	20	
Rumex obtusifolius	0	20	
Epilobium tetragonum	0	30	
Eupatorium cannabinum	0	20	
Elymus repens	40	20	Continental species in the suburban sites
Erodium moschatum	30	0	
Lathyrus latifolius	30	0	
Lophochloa cristata	30	0	
Onopordum illyricum	30	0	
Rapistrum rugosum	30	0	
Trifolium fragiferum	30	0	
Vicia lutea	30	0	
Acanthus mollis	0	50	Atlantic and subatlantic species in the urban sites
Smyrnium olusatrum	10	30	
Anthriscus sylvestris	0	30	
Cyperus rotundus	0	50	
Viola odorata	0	50	
Adiantum capillus-veneris	0	40	
Amaranthus deflexus	0	40	
Capparis spinosa	0	40	
Cerastium semidecandrum	0	40	
Erigeron karwinskianus	0	40	
Erophila verna	0	40	

The frequency is the percentage of sites where the species occur.

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