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Temporal analysis of the Brussels flora as indicator for changing environmental quality

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Abstract

With their species diversity, their population abundance and their integrator characters, higher plants represent useful tools to solve problems concerning the environment analysis and management. As they are good bioindicators, plants integrate many environmental parameters and can help to reveal the misworking of the ecosystems. Within this framework, a recent and complete survey of the phanerogamic flora of the Brussels area was carried out by the method of the floristic grid-map based on 1 km — squares. A comparison with earlier data has allowed us to appreciate the consequences of half a century of human activities on plant diversity in the urban ecosystem. The basic aim is to present a method of diagnosis and mapping that has been used, so as to turn the descriptive information about the biological environment of the area into a series of guidelines for land-use regulation and management within the city.

Ellenberg's indicator values were used to express the relationship of flora to soil nitrogen, moisture content, reaction, light and temperature. Considering the biological characteristics of new floristic components and plants which have become rare or disappeared, it was possible to draw conclusions about the alterations in environmental conditions in Brussels. Our results show that the number of species did not differ significantly from 1940 until now. However, considerable changes have appeared during this period: there is a clear increase in the number of alien species; the flora of the Brussels area is becoming more nitrophilous and tolerant to shade, while it does not differ with respect to soil moisture, reaction and temperature.

Human activities have disturbed the distribution and abundance of many species, inducing a decline or disappearance of some of them, principally those which are associated with cropland, with marshland and woodland. On the other hand, numerous species have recently appeared in the city, many of which are aliens. The comparison between indigenous and alien species has revealed that their occurrence depends upon their ecological requirements: alien species are more tolerant of nitrogen, light, drought, heat and alkaline soils.

The response of the flora to human impact is clearly demonstrated. Such sensitivity has obvious implications for both conservation and management. Circumstances, where Brussels plant monitoring is carried out permitting the avoidance of potential disaster and the saving of valuable biological resources, are developed. Arguments for the conservation of wild plants in cities also lead to some remarks concerning nature conservation practices in Brussels.

Keywords: Urban biodiversity; Environmental quality indicator; Alien species; Human impact; Brussels

1. Introduction

Within Central Europe, the flora of the urban environment has been extensively studied for the last two

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decades (Sukopp et al., 1979; Sukopp and Werner, 1983; Brande et al., 1990; Kubikova, 1990; Pysek and Pysek, 1990, 1991; Mandak et al., 1993). In Western Europe, however, only a few studies exist and the data available appear to be rather heterogeneous in comparison with the extent of the area considered, often limited to the boundaries of the city concerned, or by non-exhaustive species lists (Klotz, 1990). Moreover, sampling methods often differ between studies, which makes comparison between urban floras difficult. Generally, the number of species lists available for such comparative studies is relatively small.

While urban land in Belgium consists of 14.6% of the Belgian territory — which is extremely high (Hauser, 1982, in Kivell, 1993), the biodiversity of urban zones has seldom been studied. Some papers have nevertheless been published concerning the flora of some big Belgian cities like Brussels (Tanghe, 1975; Vanden Berghen, 1978; Tanghe, 1986), Liège (Maréchal, 1938; Lambinon, 1989), Ghent (Robbrecht and Jongepier, 1989) or Antwerp (Lambinon, 1991; Slembrouck, 1992).

The impact of human activities on the composition of the flora and vegetation has been recognised as the most important factor during the last 5000 years (Kowarik, 1990). In the Brussels area, this impact has exponentially increased from 1860 until now with the building of new dwellings towards the suburbs and with the construction of city infrastructure (transportation, communications, public utilities, sanitation and sewerage, etc.). This impact has resulted in:

- as regards humid zones, the drainage of marshes, the suppression of brooks or their utilisation to evacuate wastewater, the vaulting and canalisation of many streams, the lowering of aquifers caused by the abstraction of water for public water supply and industrial use (Godart, 1991), the drying up of springs, and the stabilisation of river banks;
- as regards forest zones, monocultural production management, coupled with intensive use for recreational purposes, has led to a regression and, locally, a disappearance of the herbaceous stratum;
- as regards cultivated zones, modernisation of agricultural practices, as well as utilisation of herbicides, has led to the eradication of adventitious species from the most sensitive cultures;
- as regards urban zones, radical changes in mentalities and in the life-style of inhabitants have equally contributed to modifying the composition of the flora. Among them, we should mention the development of transportation which is responsible for the movement of seeds over long distances, the utilisation of herbicides, and the feeding of wild and domestic birds with exotic seeds which are becoming established as adventitious or naturalised species.

What are the impacts of this urban growth on biodiversity and how can it be studied? This paper aims to bring some answers to these questions and represents a contribution to the evaluation of temporal changes in the quality of urban environment. It also aims at the promotion of environmental planning and management that preserves special features, while permitting appropriate uses.

2. Study area

The Brussels-Capital Region is situated in the "Hesbigno-Brabançon" ecological sector, integrated to the Atlantic domain and to the Euro-siberian region, as defined by Delvaux and Galoux (1962).

The city of Brussels, which covers an approximate area of 16 000 ha, has expanded in the humid, marshy, alluvial plain of the Senne river. The sector is characterised by a mild climate with a mean temperature of 9.9°C and mean annual rainfalls of 835 mm. The altitude ranges between 15 and 130 m and the vegetation period (temperature > 10°C) rises to 172 days (Gallez-Richel, 1990).

The geological substrate is essentially formed by clays under Ypresian clayey sands, Bruxellian sands, Ledian sands with calcareous sandstone and Quaternary loamy deposits. Soil distribution varies from very rich (eutrophic) soils in the bottom of valleys, acid and oligotrophic soils on some ridges, damp soils in marshy areas, and dry soils on stony or sandy slopes.

The original vegetation cover was essentially represented by the *Endymio-Carpinetum*, *Primulo-Carpinetum lamietosum* and *asperetosum*, *Fago-Quercetum convallarietosum* and *molinietosum* forests, but also by the *Carici remotae-Fraxinetum* and *Carici elongatae-Alnetum* alluvial forests. After the clearance of the early forest, open semi-natural biotopes like heathland, humid mowed meadows, sedge- and reed-beds, became established.

Spontaneous flora and vegetation are now essentially present in semi-natural sites, but are also developing in more artificial habitats such as parks (Godefroid, 1997), graveyards, residential squares with enclosed gardens, avenue verges, ponds and rivers (Godefroid and Saintenoy-Simon, 1997), backyards, railway embankments (Tanghe, 1997), crops, kitchen gardens (Godefroid and Saintenoy-Simon, 1999) and private gardens.

There are approximately 1 million inhabitants in Brussels and the city appears, from a structural point of view, as a succession of four concentric zones, from its business centre to the outlying suburbs (De Bruyn and Lannoy, 1991 in IBGE, 1995):

- the core is dominated by commercial and administrative activities with a very limited habitat function;
- the districts, constructed in the last century, are densely built;
- the periphery, less densely built;
- the last zone constitutes the suburbs which can be considered as the maximum (or peak) demographic growth zone. This part of the city still keeps a relatively rural aspect.

3. Methods

In order to give a general view of spontaneously growing species in a big city such as Brussels, 388 floristical relevés by the author and 192 relevés by voluntary botanists were compiled and compared with earlier data (archives IFBL/AEF).

From April to November, floristic relevés were carried out following the IFBL (Belgian and Luxembourg Floristical Institute) grid. Brussels covers entirely or partially 187 squares ($1\,\mathrm{km} \times 1\,\mathrm{km}$). During this period of 7 months, numerous inventories were carried out for each of the squares. From 1991 to 1994, the city of Brussels was surveyed intensively for its flora (wasteland, groves, but also foot-paths, walls, railways, etc.). Floristic data accumulated during these 4 years represent 580 field relevés. Earlier data have permitted an extremely instructive comparison of the present situation with regard to previous ones. One hundred and ten relevés exist for the period 1943–1971 and 97 for the period 1972–1990; they have all been used in our analysis. A total of 787 field forms were thus filled in for the Brussels-Capital Region, representing more than 80 000 rough data (one data represents one species found by one observer in a given place and time).

Ellenberg's indicator values (Ellenberg et al., 1991) were used to express the relationship of flora to soil nitrogen, moisture, reaction, light and temperature.

In order to determine the biological potential of one of the widely distributed vegetation type in the city, we carried out 20 phytosociological relevés in lawns scattered in eight parks, following the Braun-Blanquet method.

4. Results

A species level approach was used in our study not only for conservation purposes, but also for administrative purposes because the government requested a list of endangered and ecologically important species. The Brussels Capital administrative region had been created in 1989 and had to adapt itself to other European regions. Among more than 100 European Union Directives concerning environmental topics, many deal with nature. One may add international conventions and treaties, without omitting federal liabilities from the Rio and Kyoto protocols. All these legal constraints have to be applied to a region whose particularity is to be small and extremely urbanised. Nevertheless, the region cannot escape its legal obligations among which one may note at least four domains (Lebrun, 1998): (1) the state of the environment (order of 4 June 1992); (2) Environmental Impact Assessments (EEC 85/337 Directive; order of 23 July 1992); (3) habitat protection (EEC 92/43 Directive) and (4) wildlife conservation (CEE 79/409 Directive and diverse international conventions such as Paris, Ramsar and Bern).

Within this framework, our data base was designed to include considerations for environmental assessments as well as for research: indeed, the elementary sampling unit is not the $1\,\mathrm{km} \times 1\,\mathrm{km}$ quadrant itself, but the different sites (waste lands, parks, cemeteries, railway infrastructures) within this quadrant, in order to have precise information about the localisation of the taxa. This data base is linked to a geographical information system (GIS) in order to represent the spatial patterns of the different ecological attributes of the flora. Species mapping has proved to be a suitable and necessary method to develop protection, conservation and development measures (Schaepe, 1990; Lajeunesse et al., 1995).

The comparison of the two floristical lists indicates that the number of neophytes has increased (Fig. 1): their proportion raised from 12% in 1940–1971 to 20% now. This comparison also indicates that only 579 species are common to the two lists, which give us a Sorensen coefficient of 79.48%, testifying to a great number of fluctuations in the urban flora.

Ecological spectra obtained on the basis of our data compared to the IFBL archives, show a shifting of soil nitrogen spectrum to higher values (Fig. 2). Humidity spectrum indicates a decline of species of very humid to swamped soils (classes 9–12) to the benefit of more mesophile taxa (classes 5 and 6). Light spectrum shows a decline of light plants (classes 8 and 9), while there are no significant changes for reaction and temperature spectra. A comparison between species that have disappeared and those that have appeared indicates significant differences only for nitrogen and light factors (Table 1).

These considerations underline the negative influence of urban management carried out in the second half of this century. An increasing human impact will in fact disturb plant distribution and abundance, inducing the regression and disappearance of some of them, but also producing new communities composed of alien species.

Our recent floristical data have made evident the disappearance of many species, such as *Scandix pecten-veneris*, *Agrostemma githago*, *Vaccinium vitis-idaea*, *Corynephorus canescens*, *Aira praecox*, *Carex rostrata*, etc. (Appendix A).

An important regression of some other taxa has been shown in spite of more intensive prospecting (Figs. 3–5). Among crop plants, *Matricaria recutita* has disappeared from 24 grids, *Anagallis arvensis* subsp. *arvensis* has lost 18 grids, *Chenopodium polyspermum* is regressing in 17 grid, etc. (Fig. 3).

In the group of aquatic and hygrophile plants, it appears that the genus *Potamogeton* is endangered: *P. crispus* was formerly still present in six grid against only one now, while *P. natans* was formerly still present in three grid against only one now.

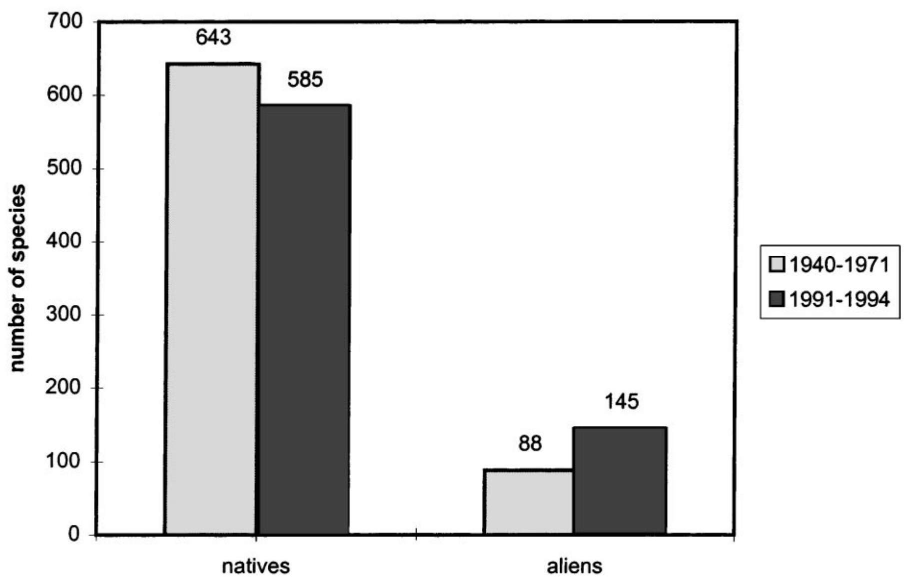

Fig. 1. Differences in number of native and alien species in Brussels between two periods.

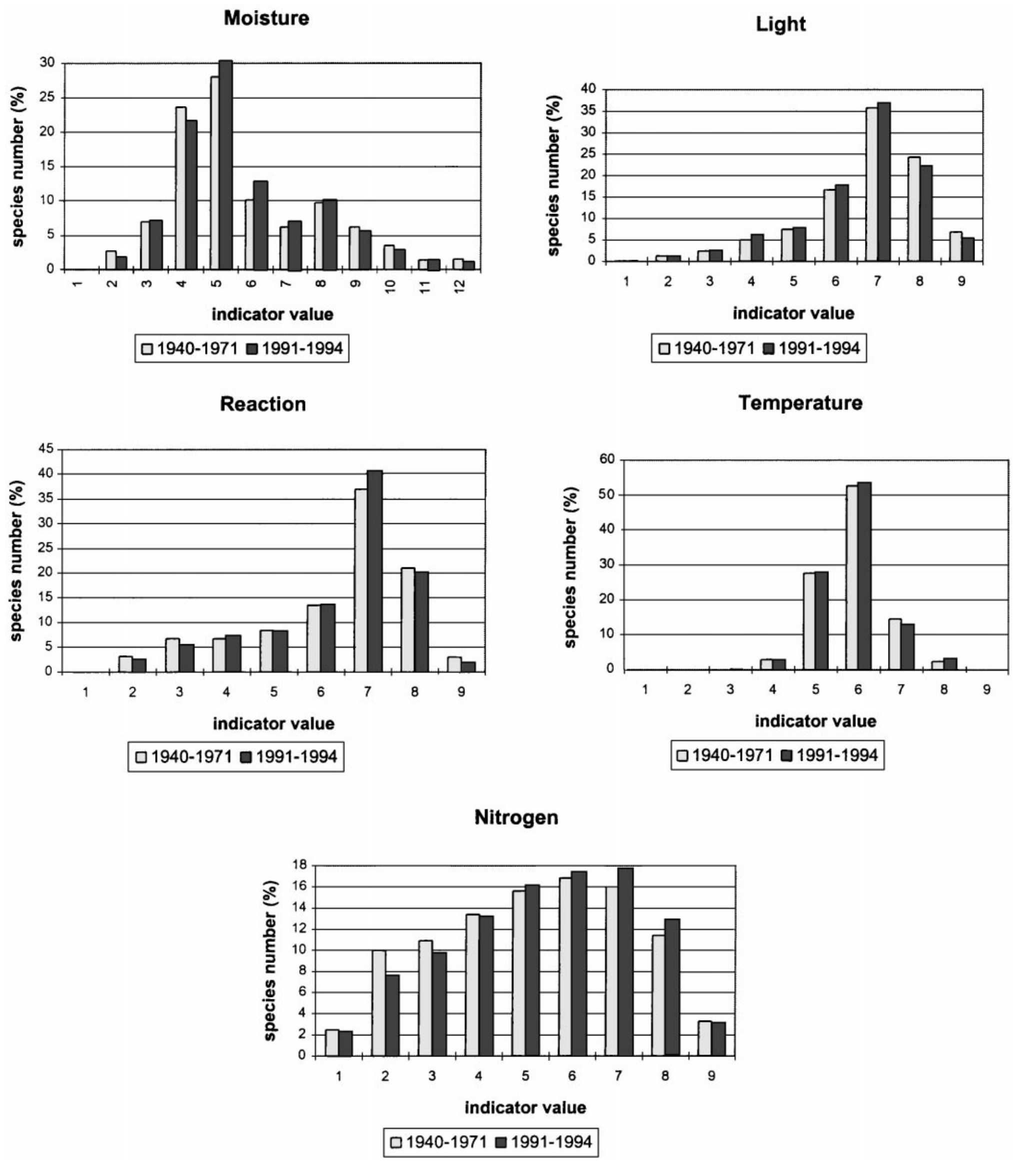

Fig. 2. Frequency distribution of indicator values of the Brussels flora compared for two periods.

We also note an important reduction of *Lythrum salicaria*, *Angelica sylvestris*, *Epilobium parviflorum*, *Carex acutiformis*, *Scrophularia auriculata*, etc. (Fig. 4).

Finally, the data analysis has shown an obvious decline of the herbaceous stratum in forested habitat. Among concerned species, we may note that *Phyteuma spicatum* which loses two thirds of its population. Common taxa like *Ranunculus ficaria*, *Arum maculatum*, *Veronica hederifolia* or *Anemone nemorosa* are also concerned (Fig. 5).

Our recent inventories also emphasised the new advent of some neophytes in Brussels, such as *Ailanthus altissima*, *Elodaea nuttallii*, *Azolla filiculoides*, *Sisymbrium orientale*, *Telekia speciosa*, *Aster* div. sp., etc. (Appendix B).

Table 1
Ecological requirements of flora compared between the two periods[a]

Factor	1940–1971	1991–1994	*t*-value	d.f.	*p*
Light	7.20 ± 1.30	6.77 ± 1.28	−2.5675	244	0.0108
Moisture	5.17 ± 2.69	5.35 ± 2.11	0.5542	231	0.5799
Nitrogen	4.48 ± 2.28	5.35 ± 2.27	2.8600	227	0.0046
Reaction	6.45 ± 1.94	6.85 ± 1.32	1.6466	206	0.1012
Temperature	6.10 ± 0.85	6.19 ± 0.99	0.7126	207	0.4769

[a] Mean indicator value (Ellenberg) ± S.D. are given. Values were calculated for species that have disappeared from the flora of Brussels (those occurring only in the first period) and for those that have appeared (present only in the second period).

Despite an overlap in indicator value between alien and native species, compared ecological spectra of these two sets of species emphasise obvious differences for the five parameters we examined in this study (Fig. 6). These results are statistically confirmed in Table 2 where the average values are considered. Alien species tend to occur in well-lit, dry, nitrogen rich, alkaline and warm places. Temperature appears to be the best discriminating ecological factor.

Our phytosociological relevés, carried out in lawns from eight urban parks located in the Brussels area (Table 3), have shown that the sample plot species composition is influenced by past management practices (regular mowing, trampling, sowing with lawn seeds). Hence, we often found a high representation of eutrophic fertilised meadows, such as *Lolium perenne*, *Ranunculus repens* and *Trifolium repens*. Nevertheless, an interesting vegetation is present with those dominant species: in mesophile to sub-xeric edaphic conditions, we found species from the *Arrhenatherion*-meadows, while on damp soils, we encountered typical *Agrostietea stoloniferae*, *Molinietalia* and *Phragmitetalia* groups.

5. Discussion

5.1. Floristic data as a tool for environmental quality indexing

Ten percent of the Belgian population lives in Brussels. This proportion of the population in urban settlements has great implication on land-use planning and environmental quality. This is one of the reasons why it is desirable to examine bioindicators in the city as they can give us an insight into the degree of land-use co-ordination in different parts of the city.

Detailed floristic inventories were produced two and three centuries ago in Paris, London and other major European urban and peri-urban settings (Celecia, 1997). This important scientific heritage is in need of compilation, analysis and synthesis, as well as comparisons on a regional basis, which would then provide the basis for examining changes in the occurrence and distribution of plant species, populations and communities through time and in relation with urban expansion, land-use and occupation, the introduction of exotic species, ecological invasions, etc. (Barker et al., 1994 in Celecia, 1997).

Table 2
Ecological requirements of flora compared between native and alien species[a]

Factor	Aliens	Natives	*t*-value	d.f.	*p*
Light	7.08 ± 1.24	6.53 ± 1.48	3.6630	666	0.0003
Moisture	5.13 ± 1.73	5.75 ± 2.04	−3.0037	622	0.0028
Nitrogen	5.82 ± 1.99	5.31 ± 1.98	2.4135	606	0.0161
Reaction	6.78 ± 1.16	6.27 ± 1.68	2.8149	499	0.0051
Temperature	6.41 ± 0.87	5.71 ± 0.72	8.5779	520	0.0000

[a] Mean indicator value (Ellenberg) ± S.D. are given. Values were calculated for species found during the period 1991–1994.

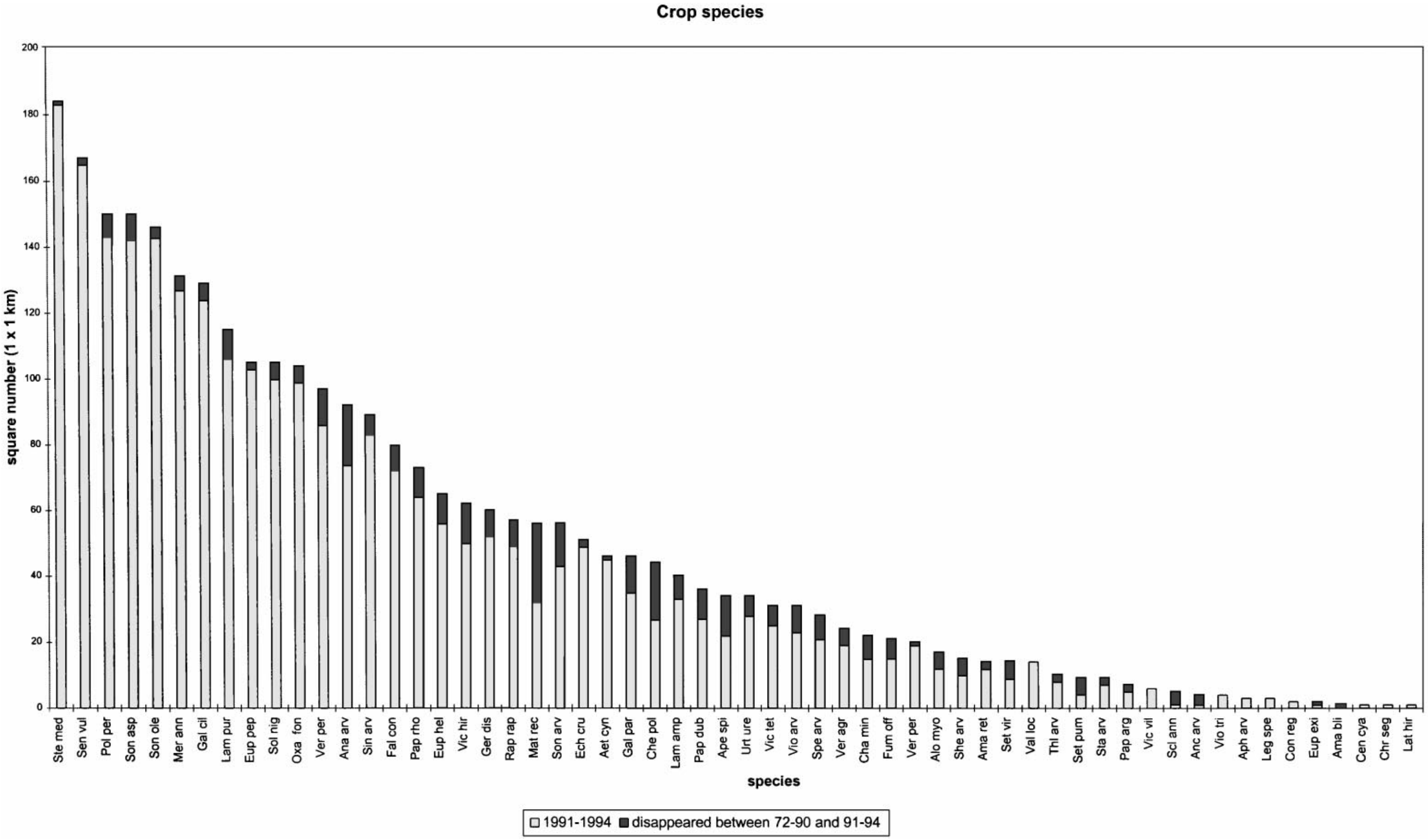

Fig. 3. Importance of the regression of crop species in Brussels between 1972–1990 and 1991–1994. Each taxa is represented by the first three letters of the genera and the species, excepted when confusion is possible.

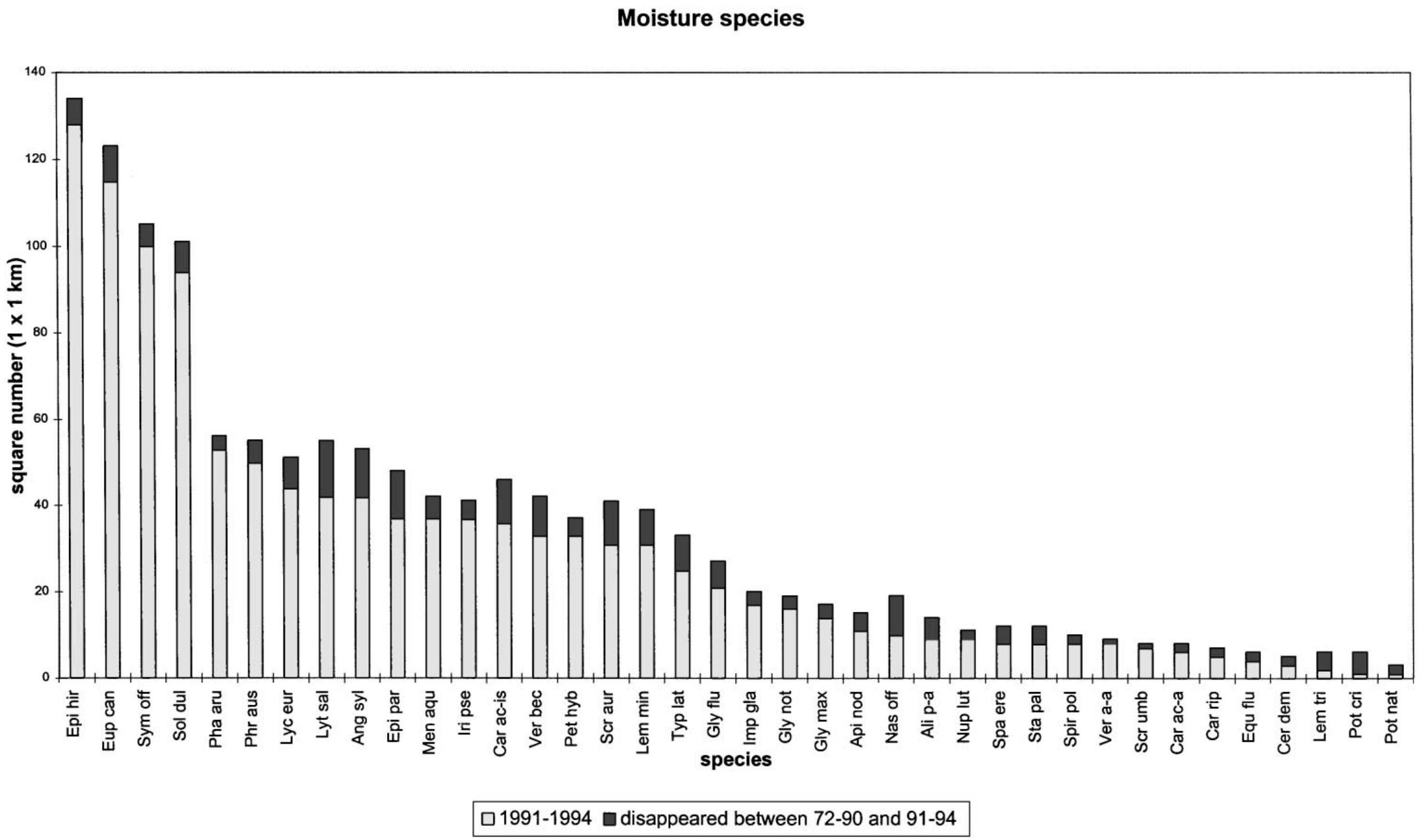

Fig. 4. Importance of the regression of moisture species in Brussels between 1972–1990 and 1991–1994. Each taxa is represented by the first three letters of the genera and the species, excepted when confusion is possible.

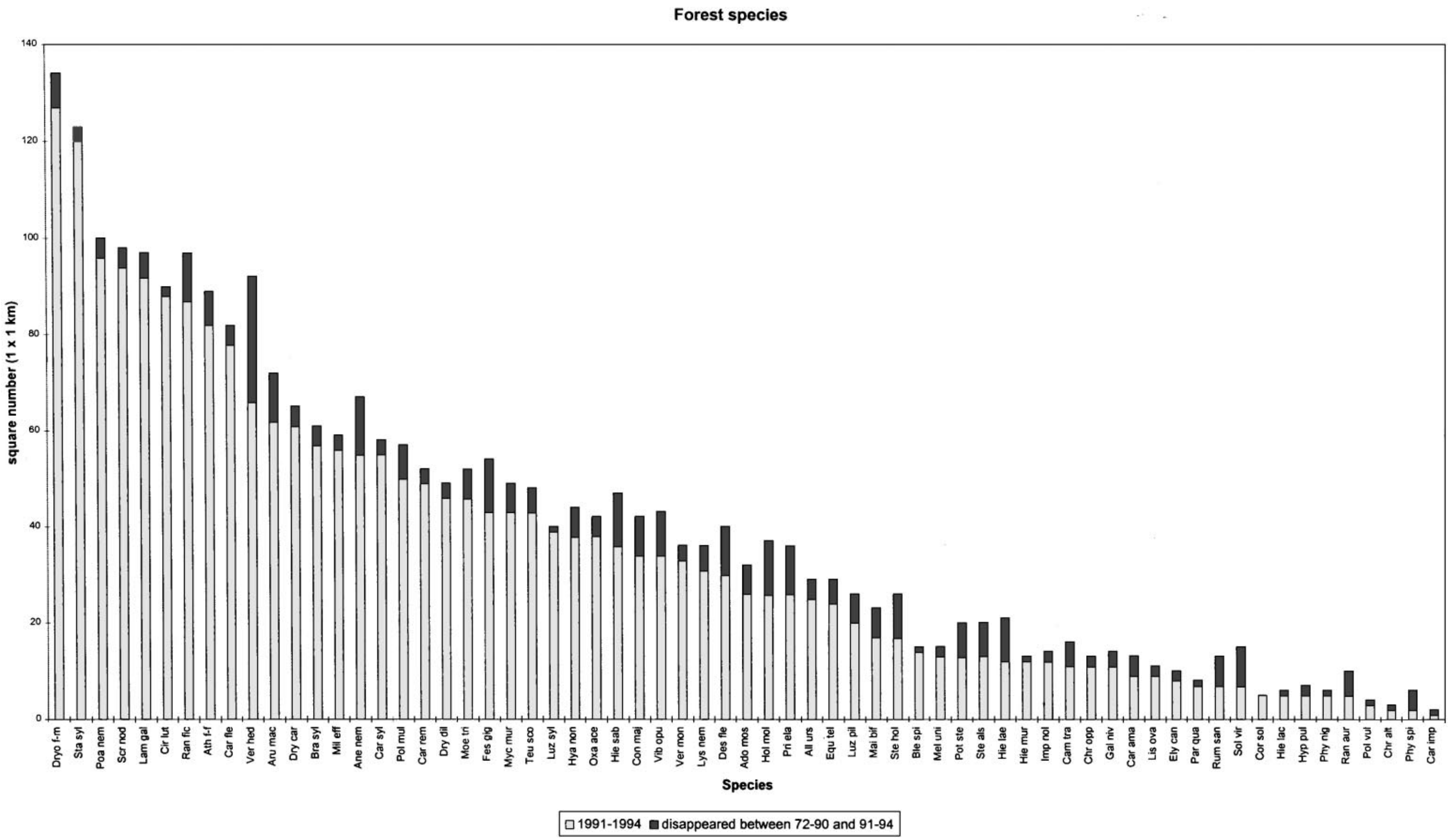

Fig. 5. Importance of the regression of forest species in Brussels between 1972–1990 and 1991–1994. Each taxa is represented by the first three letters of the genera and the species, excepted when confusion is possible.

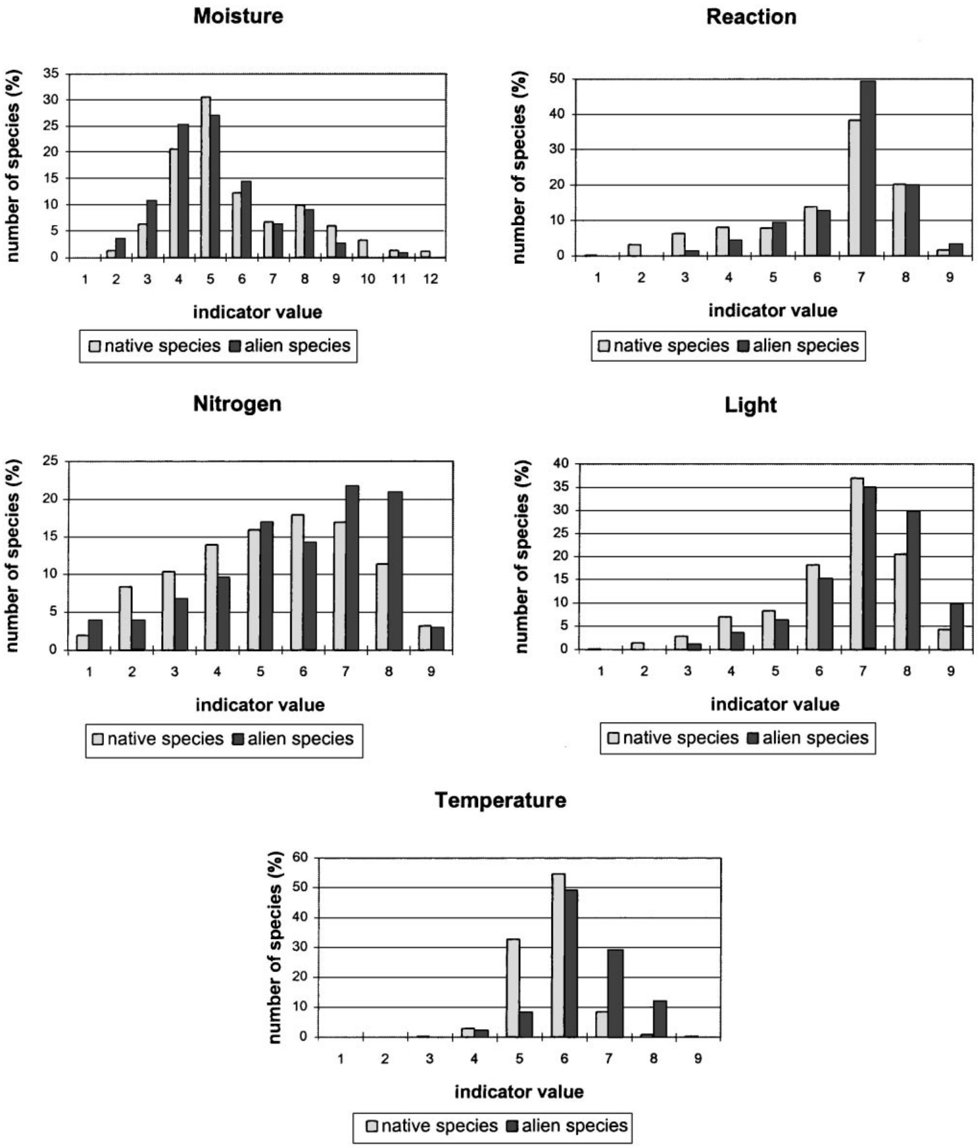

Fig. 6. Frequency distribution of Ellenberg's indicator values for native and alien species in Brussels (1991–1994).

Even if historical flora lists are not complete, and information about frequency and distribution of plants does not cover towns at all, they can still be used to demonstrate tendencies in the development of flora (Sudnik-Wojcikowska, 1987).

Those analysis not only provide information about the size of decline in species numbers but also about the potential causes of the decline. Hence, they supply a basis for decisions in landscape planning and particularly in the protection of species and biotopes (Schaepe, 1990).

5.2. The advantages of the Brussels approach

Most of the methods developed for studying urban plant species do not cover the whole city. They concern floristic or vegetation surveys for a specific number of sites. This is for instance the case for

Table 3
Types of lawns in Brussels urban parks (surface = 1 m^2)

Types of lawns	Recording number (species richness)																				Presence
	TOU1 (9)	PAR2 (12)	PAR1 (15)	FON2 (13)	FON1 (13)	SCH2 (14)	SCH1 (17)	TEN2 (13)	TEN3 (17)	TEN1 (11)	WOL2 (14)	MEL1 (18)	WOL1 (10)	MEL2 (17)	WOL6 (9)	WOL5 (18)	WOL4 (17)	WOL3 (24)	WOL7 (24)	LEY1 (9)	
Arrhenatherion																					
Poa trivialis	1	–	–	+	+	–	+	–	+	+	+	–	–	–	+	+	1	1	1	+	IV
Holcus lanatus	–	–	1	2	1	1	1	–	2	–	–	3	–	1	1	–	–	1	2	3	III
Cerastium fontanum	–	2	1	–	+	–	–	–	1	–	1	1	+	1	–	–	–	–	+	–	III
Festuca rubra	–	–	–	–	–	2	+	1	1	1	–	+	1	2	–	–	–	+	–	–	III
Plantago lanceolata	–	–	–	–	–	–	–	1	+	1	–	–	–	–	–	–	2	1	2	–	II
Achillea millefolium	–	2	2	–	–	–	–	+	–	1	–	–	–	–	–	–	–	–	–	–	I
Arrhenatherum elatius	+	–	–	1	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Dactylis glomerata	–	–	–	2	1	1	–	–	–	–	+	–	–	–	–	–	–	–	–	–	I
Festuca pratensis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	+	–	1	1	–	I
Ranunculus acris	–	–	–	1	2	–	–	–	–	–	–	–	–	1	–	–	–	–	1	–	I
Rumex acetosa	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	I
Stellaria graminea	–	–	–	–	–	–	–	1	2	–	1	–	–	–	–	–	–	–	1	–	I
Trifolium dubium	–	1	+	–	–	2	1	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Trifolium pratense	–	–	–	1	–	2	–	–	–	–	–	–	–	–	–	–	1	1	–	–	I
Anthoxanthum odoratum	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	I
Centaurea jacea s.l.	–	–	–	–	–	–	–	+	–	2	–	–	–	–	–	–	–	–	1	–	I
Heracleum sphondylium	1	–	–	3	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Hypochoeris radiata	–	2	1	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	I
Prunella vulgaris	–	–	–	–	–	–	–	–	2	–	–	1	–	1	–	–	–	–	–	–	I
Alopecurus pratensis	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Crepis capillaris	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Galium mollugo	–	–	–	–	–	–	–	3	1	–	–	–	–	–	–	–	–	–	–	–	I
Veronica chamaedrys	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Vicia sativa	–	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Poa pratensis	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Lolio-Cynosurion																					
Trifolium repens	–	–	–	–	–	1	2	2	4	1	2	1	3	2	–	2	+	+	+	1	IV
Ranunculus repens	–	–	–	–	–	–	1	–	–	–	3	3	2	3	–	2	2	1	2	3	III
Lolium perenne	–	2	1	–	–	+	1	+	2	2	–	–	–	–	–	–	–	–	–	+	II
Bellis perennis	–	–	1	–	–	+	+	1	1	1	–	–	–	–	–	–	–	–	–	–	II
Phleum pratense	–	–	–	–	–	3	4	–	–	–	–	–	–	–	+	–	1	1	+	–	II
Taraxacum officinale	–	+	–	+	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1	1	II
Poa annua	–	–	–	–	–	1	–	–	+	–	–	–	1	–	–	–	–	–	–	–	I
Veronica filiformis	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	I

Table 3 (*Continued*)

Types of lawns	Recording number (species richness)																				Presence
	TOU1 (9)	PAR2 (12)	PAR1 (15)	FON2 (13)	FON1 (13)	SCH2 (14)	SCH1 (17)	TEN2 (13)	TEN3 (17)	TEN1 (11)	WOL2 (14)	MEL1 (18)	WOL1 (10)	MEL2 (17)	WOL6 (9)	WOL5 (18)	WOL4 (17)	WOL3 (24)	WOL7 (24)	LEY1 (9)	
Agrostietea stoloniferae																					
Carex hirta	–	–	–	–	–	–	–	–	–	1	3	1	2	1	2	1	1	3	2	–	III
Juncus articulatus	–	–	–	–	–	–	–	–	–	–	2	1	2	1	–	2	–	2	1	–	II
Agrostis stolonifera	–	–	–	–	–	–	–	–	–	–	–	2	–	2	–	2	2	1	–	2	II
Lysimachia nummularia	–	–	–	–	–	–	–	–	–	–	–	1	–	+	–	–	–	+	+	–	I
Juncus inflexus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	3	–	–	–	I
Juncus tenuis	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	+	–	–	–	I
Potentilla anserina	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	1	–	–	I
Alopecurus geniculatus	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	I
Festuca arundinacea	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	I
Juncus compressus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	I
Molinietalia																					
Lotus pedunculatus	–	–	–	–	–	1	–	–	–	–	–	2	–	3	–	–	1	3	1	–	II
Cardamine pratensis	–	–	–	–	–	–	–	–	–	–	–	1	+	+	–	–	–	–	+	+	II
Myosotis scorpioides	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	2	+	+	+	–	II
Juncus effusus	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	+	–	1	–	–	I
Cirsium oleraceum	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	I
Galium uliginosum	–	–	–	–	–	–	–	–	–	–	–	2	–	1	–	–	–	–	–	–	I
Hypericum quadrangulum	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	+	–	–	–	–	I
Scirpus sylvaticus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	1	–	–	–	–	I
Equisetum palustre	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	I
Filipendula ulmaria	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Lychnis flos-cuculi	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	I
Lythrum salicaria	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	I
Phragmitetea																					
Epilobium parviflorum	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	1	–	1	1	–	I
Glyceria fluitans	–	–	–	–	–	–	–	–	–	–	1	–	1	+	–	–	–	–	–	–	I
Glyceria notata	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	2	I
Lycopus europaeus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	1	–	–	–	I
Polygonum amphibium	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1	–	–	–	–	–	I
Eleocharis palustris	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	2	–	–	–	–	I
Carex acutiformis	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Galium palustre	–	–	–	–	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–	–	I
Rorippa amphibia	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	I
Isoeto-Nanojuncetea																					
Sagina apetala	–	2	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Hypericum humifusum	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Artemisietea																					
Equisetum arvense	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1	1	2	1	1	–	II
Agrostis gigantea	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Cirsium arvense	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Daucus carota	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	I

Elymus repens	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Eupatorium cannabinum	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	I
Geranium molle	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Urtica dioica	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Chenopodietea																					
Conyza canadensis	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Cerastium glomeratum	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	I
Geranium dissectum	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Sonchus asper	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Festuco-Brometea																					
Medicago lupulina	–	–	–	–	–	–	–	3	+	3	–	–	–	–	–	–	–	–	–	–	I
Carex flacca	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	I
Galium verum	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	I
Nardo-Callunetea																					
Agrostis capillaris	–	3	4	1	–	1	+	2	3	1	2	–	4	–	–	–	–	1	1	–	III
Luzula campestris	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	I
Secalietea																					
Aphanes arvensis	–	+	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Vicia hirsuta	–	–	–	1	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Autres																					
Geum urbanum	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I
Rubus fruticosus	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	I

Birmingham (Haigh, 1980) and Wooster, OH (Whitney, 1985). The Brussels example seems to be an interesting approach in the sense that it deals with a systematic sampling of the whole surface of the city, including large private properties (e.g. government or royal domains, private parks, property around castles, marshalling yards, sorting depots, etc.). A similar pilot project was developed for Warsaw (Sudnik-Wojcikowska, 1987). Of course, a flora inventory of the whole city and compilation of such data is a cost-effective, time-consuming and labour-intensive task. For these reasons, and as far as we are aware, such a phanerogamic intensive inventory has not yet been performed for many other cities.

Most of historical studies dealt with comparisons over long periods of time, such as 100 years (Sachse et al., 1990; Fudali, 1995), 150 years (Sudnik-Wojcikowska, 1987). Although these studies are of great historical and botanical value, they seem rather sterile for present-day conservation and development planning as they reflect the situation before most anthropogenic interventions. Original site conditions in urban biotopes have changed tremendously and present living conditions for plants are completely different from those in last century. Hence, studies comparing the flora after World War II with present situation are more relevant to management purposes.

5.3. Brussels plant species richness

Our results have shown that 730 phanerogamic plants are present in Brussels. This is approximately half of the Belgian flora. This high number of species may be largely explained by the following factors (Sukopp and Werner, 1983): (a) the great diversity of the urban landscape, including different structures of settlements, various uses of open areas and many small-scale habitats, produces a great variety in ecological environments; (b) cities are important immigration areas for alien plants introduced either with or without the help of man.

Moreover, the high number of species is probably related not only to the typical mosaic pattern of the urban environment, but also to the geographic position of the area where the city has developed, in a valley in the middle of Belgium, at the meeting point of the Atlantic and Middle European biogeographical regions. The city also has a diversified topography and substrate and is characterised by the proximity of woodlands.

Nevertheless, it should be noted that plant species richness of the Brussels region seems to be lower than that of Central or Southern European towns. For example, 1243 species are quoted for Berlin (Sukopp et al., 1982) and 1400 are recorded in the city of Rome (Celesti Grapow, 1995 in Zapparoli, 1997). For cities with 1 million inhabitant, like Brussels, Sukopp (1997) quotes an approximate number of 1300 species, that is to say about twice as much as for Brussels.

In Brussels, mean number of species in 1 km $\times$ 1 km grids ranges from 140 in the outskirts to 80 in the inner city, with a maximum of 337 and a minimum of 28. This is much less than, e.g. in Warsaw (Sudnik-Wojcikowska, 1987) or in Berlin (Kunick, 1982). It means that Brussels flora is poor in comparison to other European cities. This is probably due to the fact that the whole country is biologically poor, with about 1300 vascular plants.

According to Kowarik (1990), more intensive impact leads to decreasing species richness, because the pool of species adapted to very high rates of disturbance is small. Nevertheless, the total number of species in the flora of Brussels has not changed since 1940, but the floristic similarity between both lists is only 79% (Sörensen index), indicating that 21% of species has exchanged during this period. In 1940–1971, there were 147 species (Appendix A) occurring within the city territory that were not recorded in the present study. On the contrary, 148 species (Appendix B) found in 1991–1994 are absent from the 1940–1971 species list.

5.4. Ecological requirements of the urban flora

Having compared these two species sets, we found significantly higher mean indicator values for nitrogen and lower indicator values for light in the period 1991–1994. For a small industrial town of the Czech Republic, Mandak et al. (1993) did not found significantly differences for these two factors but they pointed out significantly lower mean indicator values for temperature and reaction at the present time compared to this 20 years ago. This could, at least in part, be explained by the size of the city, the density of industries and the situation in Western or Eastern Europe (different management practices). However, ecological requirements of the Brussels urban flora are approximately the same as for many European cities as pointed out by Kunick (1982). He found a certain aridity tolerance and a slight tendency towards a relatively high demand for nitrogen. Sukopp et al. (1979) also reported high nitrogen and phosphate contents for the soils in West Berlin and a lowering of the groundwater table. However, an increase in alkalinity was also recorded. This phenomenon is less clear for Brussels.

Neophytes are demonstrated to indicate more light and, despite an increase in neophytes, the overall results show more shade. One might say that these results seem to be conflicting. It could be argued that aliens are not sufficiently numerous to reverse the present trend of having more closed habitats and thus more shade species than formerly. Two reasons can explain this evolution: (1) during the period 1940–1971, the city was characterised by many open habitats, because agriculture was dominant in the outskirts and a great number of building sites had started for the modernisation of the city (road projects, viaducts and tunnels construction and other prestige works in order to prepare the 1958 Universal Exhibition); (2) now, many herbaceous biotopes are not systematically mown any more (grasslands, reed-beds, etc.), because this traditional management has disappeared. Thus, a great deal of these habitats were progressively transformed into shrubs with, consequently, a local regression or extinction of light plants, for the benefit of shade species.

5.5. The success of alien species

Our results have shown that the proportion of native species is increasingly reduced by urbanisation while the proportion of neophytes increases. This was also demonstrated for some cities in Poland (Falinski, 1971 in Sukopp and Werner, 1983) and in Berlin (Kowarik, 1990; Sykora, 1990). We found that exotic species prefer nutrient rich, dry, well-lit, alkaline and warm sites. These conditions are created by human impact through eutrophication, drainage, deforestation, soil enrichment with construction rubble and climate warming. Hence, a general rule emerges from this, according to Sukopp et al. (1979): the proportion of non-native species can be used as an indicator for the intensity of disturbances caused by human activities. For this reason, it was decided to draw a distribution map of the alien species proportions (Fig. 7). By this approach, and in comparison with ecological or human parameters, it is possible to discriminate the factors that significantly affected native flora from those that did not. Those descriptive maps can be transformed into maps which provide the basis for management decisions.

Many European cities are concerned by the spectacular extension of some aliens (Sukopp and Sukopp,

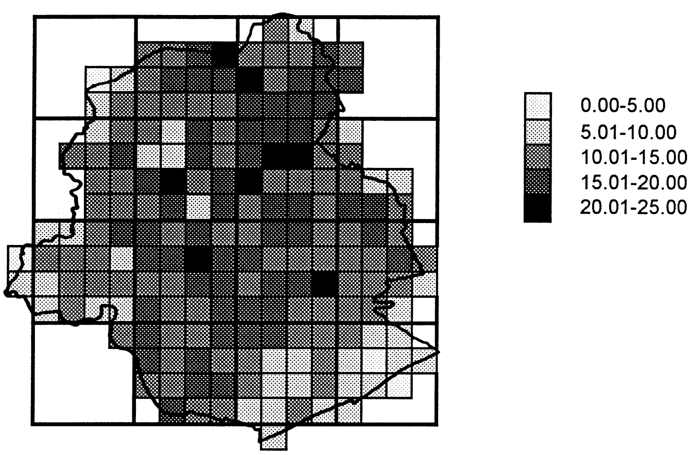

Fig. 7. Percentage of alien species found relative to a system of 1 km × 1 km grid squares covering the city of Brussels. Black line represents the limits of the Brussels-Capital Region.

1988; Trepl, 1990; Sukopp and Schick, 1991; Pysek, 1995; Sukopp and Starfinger, 1995; Dickson, 1998).

The high proportion of aliens in cities is partly due to the fact that cities are centres of spread, because new species arrive there. On the other hand, anthropogenic changes to growing conditions facilitate their spread because many non-natives originate from warmer regions and depend on the higher temperature in cities (Sukopp, 1997). Alien seeds have either been unintentionally transported in Brussels by the increase of means of transport (train, cars, water), by animals (e.g. birds), or intentionally introduced for horticultural reasons, as crop plants, or medicinal herbs. Neophytes which are best distributed in Brussels are not the same as in central Europe (Table 4), presumably as a consequence of a different climate.

Despite the fact that Moret et al. (1997) promote the conservation of native species rather than keeping our attention on the expansion of invasive exotic species, we think that it is important to monitor the dynamic of introduced species in order to know when a species is likely to become a ''pest''. Our analysis has proved the growing success of exotic species but in spite of these results, Brussels authorities are not sufficiently aware of the extension of those particularly competitive species. Actually, this problem requires attention and efforts should be made in order to limit the spreading of those invasive taxa and to maximise the chances of development of a native vegetation adapted to the local phytogeographic context. Detailed information about the ecology of these species exists, particularly for *Fallopia japonica* (Sukopp and Sukopp, 1988; Child et al., 1992), *F. sachalinensis* (Sukopp and Starfinger, 1995) and *Heracleum mantegazzianum* (Tiley et al., 1996). These data should be used to make an attempt to limit and control the extension of these species at the whole region scale.

Table 4
Most successful neophytes (+frequency) in Brussels (present study) and in Berlin (Kowarik, 1990)

Brussels	Berlin
Conyza canadensis (78.61%)	*Acer negundo*
Acer platanoides (73.80%)	*Ailanthus altissima*
Matricaria discoidea (73.26%)	*Bidens frondosa*
Fallopia japonica (70.59%)	*Clematis vitalba*
Buddleja davidii (69.52%)	*Matricaria discoidea*
Mercurialis annua (67.91%)	*Parietaria pensylvanica*
Robinia pseudoacacia (66.84%)	*Prunus serotina*
Galinsoga ciliata (66.31%)	*Robinia pseudoacacia*
Oxalis fontana (52.94%)	*Rumex thyrsiflorus*
Solidago gigantea (51.34%)	*Sisymbrium loeselii*
Lamium galeobdolon subsp. *Montanum* (49.20%)	*Solidago canadensis*

5.6. Rare and endangered species

Our results have demonstrated that rare species can, in fact, occur within highly urbanised, densely populated zones. In Brussels, nevertheless, most of these rare or endangered species were found in non-protected areas (e.g. wasted lands, cemeteries, railways, public parks, etc.). Although these areas play an important role in maintaining regional biodiversity, they are threatened because their value is ignored by the decision-makers. Hence, the existence of rare species within these areas supply arguments for keeping them and starting a resource management program. Urban natural areas from New York State seem to be under the same situation (Stalter et al., 1996).

Red Data Lists of endangered flora are particularly valuable tools for urban nature conservation (Sukopp, 1997). For Berlin, the first Red List appeared in 1982 (Sukopp et al., 1982). In Brussels, a detailed examination of present and former data suggested the elaboration of such a Red List which has been recently published by Saintenoy-Simon (1998). Endangered species are forming three categories:

- species which are protected at national and regional level by Royal decree of 16 February 1976; those are *Anacamptis pyramidalis*, *Dactylorhiza maculata*, *D. fuchsii*, *Epipactis phyllanthes*, *Listera ovata*, *Neottia nidus-avis*, *Ophrys apifera* and *Tamus communis*;
- some particularly interesting native species which are subsisting in only very few localities, such as *Aristolochia clematitis*, *Asplenium scolopendrium*, *Atropa bella-donna*, *Carex paniculata*, *Ceterach officinarum*, *Equisetum sylvaticum*, *Jasione montana*, *Helleborus foetidus* subsp. *occidentalis*, *Oreopteris limbosperma*, *Pyrola minor*, *R. ficaria* subsp. *Ficaria*;
- two species of great phytogeographical importance (*Hyacinthoides non-scripta* and *Narcissus pseudonarcissus*) which might suffer from unseasonably

picking; total protection would be politically and juridically difficult to apply, yet a strict regulation of picking is desirable.

5.7. Practical implications of the findings

We have seen that political and economic development of Brussels, capital of Europe, have often lead to the destruction of valuable ecosystems and habitats. Although mentalities are changing since the creation of the Brussels Capital administrative region in 1989 and the Brussels Institute for Environmental Management (BIEM), it is still difficult to meet the challenge of conserving biological diversity in a city which is the capital of Europe and, therefore, wants to sustain economic growth and to keep a certain prestige. Nevertheless, circumstances where plant monitoring permits the avoidance of potential disaster and the saving of valuable biological resources occurred recently. Three examples will be outlined. The first one concerns the management project of the ''Scheutbos park'' in a semi-natural area, which would have decimated a big population of *Epipactis helleborine*, a protected orchid. We advised the park's administration and the management plans were modified in order to protect the area occupied by the species. A second example deals with the maintenance works of the ''Pond park'', which threatened a population of *Dactylorhiza fuchsii*, another protected orchid. The European Floristic Association then informed the gardeners of the presence of this sensitive species, its importance in the urban ecosystem and its ecological requirements. At the present time, the plant population is still subsisting as the gardeners pay attention to it. The third example concerns the establishment of specific management actions, in areas that have been identified as potentially interesting for the coming back of a quality flora, by comparing historical and present inventories. This was particularly the case in a special area of the ''Soignes Forest'', where a new pond was artificially created in 1977. One year later, a very interesting flora appeared in this place with some new species for the Brussels area, such as *Cyperus fuscus*, and others which had disappeared long ago, such as *Oenanthe aquatica* and *Potamogeton lucens*, or which are extremely rare, such as *Carex pseudocyperus* and *Sagittaria sagittifolia* (Weyembergh, pers. comm.). Many other European cities develop such measures for the encouragement of spontaneous vegetation (Sukopp, 1997).

With our data base, it is possible to map the spatial patterns of different ecological attributes of the Brussels flora. It permits rapid data visualisation, an efficient presentation of complex information for planners and park managers. Species distribution maps, which have been recently published in an Atlas (IBGE, 1998), represent a useful tool for defining gaps in the ecological network and for guiding managers and ecologists as to where and how management interventions on different ecosystems should be implemented. Until now, only nine sites had obtained the status of Nature Reserves or Forest Reserves, covering a total surface of 130 ha, that is to say 5% of the sites having a high biological value and 0.8% of the total Region's acreage. A better knowledge of Brussels nature resources through this floristic data base has been instrumental in helping the Brussels region to propose, in 1996, three Special Conservation Zones to the European Union, within the framework of the European Directive concerning the conservation of natural habitats and wildlife. It aims at the establishment of a coherent European ecological network (called Natura 2000) in order to guarantee or enhance the restoration and the establishment of species or habitats for man's well-being.

In a few years, a complete new survey of the whole city will have been carried out, to evaluate the effects of recent planning actions on native and alien flora. At the present time, we focus on rare species by monitoring the evolution of their populations (e.g. by permanent plots or individuals counting).

5.8. Evolution of Brussels nature management policy

Compartmentalisation and fragmentation of the organisation of knowledge, which is reflected in the structures and ways in which both academic and government institutions work, has tended to lead to an incomplete understanding of complex human situation and to the formulation of unwise, strongly sectorial policies (Celecia, 1997). This was particularly the case for Brussels before the creation of the BIEM in 1989. Now, most of environmental problems in the city are dealt with by this institute which centralises the information and has research programmes with scientific teams from universities.

During the last 40 years, three stages have appeared successively in Brussels nature management. The first one was a battle against nature, from 1960s till the end of 1970s. It has implied the suppression of most spontaneous vegetation elements as the population wanted a controlled and "improved" nature. Most species quoted as extinct now (Appendix A) disappeared during this disastrous period. From the end of 1970s to the end of 1980s, new management perspectives were created. They were in a strict nature conservation mould, in a museological sense. It was not yet a global perception of the urban ecosystem as it concerned the species conservation (e.g. by prohibiting the hunting), the biotope conservation (e.g. by prohibiting the use of weed-killers on public domain) and the site conservation (e.g. by creating nature reserves). From 1989 to the present day, the perception of urban biological resources has become more embracing, going beyond the protection of species, biotopes and sites, even to the extent of integrating the conception of landscape management. The major goal is to improve inhabitants' living conditions. Therefore, at the present time, nature integration in urban planning does not only correspond to the protection of plants and animals any more, but aims essentially at the elevation of the quality of urban environment. Hence, after having denied the existence of spontaneous nature in the city and by trying to destroy it, after having separated it from the rest by enclosing it in nature reserves, present strategies for nature development are essentially based on three different actions: (1) the increase in total surfaces of green spaces; (2) the increase in ecological quality of green spaces; (3) the development of ecological networks.

At the present time, there is also a trend to promote some green sites with a more "natural" aspect. Indeed, urban parks have often been created according to an ideal image governed by order, regularity, cleanliness and salubrity criteria, which were particularly unfavourable to spontaneous flora. This can be carried out by the help of better ecological management practices such as mechanical methods (e.g. mowing) in place of chemical techniques. Our phytosociological data collected in some lawns in urban parks have emphasised the presence of an interesting flora among dominant Gramineae (Table 3). This natural potential is important for the urban context. It foresees a favourable evolution of these biotopes by mowing which may contribute to the regression of some undesirable taxa such as Gramineae and to the development of mown-meadows and marshland, whose status is more precarious, as previously mentioned.

Hence, our methodology represents an interesting tool for natural land-use planning, but other tools exist and are used by planners. 25 years ago, Duvigneaud et al. (1976) drew a greenness map of the city, based on aerial pictures, presenting a typology of the urban space and showing principal vegetation types. An up-to-date version of this map was elaborated in 1991 by the BIEM (Onclincx and Gryseels, 1994), in order to study the greenness evolution. Other studies were also performed, such as: a phytosociological analysis of 80 semi-natural sites (Vancraenenbroeck et al., 1993), different surveys of animal species (birds, mammals, reptiles and amphibians), a complete inventory of the street trees (e.g. Geerinck, 1995), a survey of the corticolous macrolichens (Tanghe et al., 1996) and a bryological survey (Vanderpoorten, 1997). Brussels environmental planning and management are based on effective integration of biological data from all these surveys. The development of such practical planning conservation tools is essential if the loss of interesting sites is to be avoided in the future (Freeman, 1999).

6. Conclusion

From the second half of the 19th century until now, considerable management, sanitation and "embellishment" works accomplished in the Brussels-Capital Region, have strongly damaged the semi-natural environment of the city. The map of greenness degrees drawn by Duvigneaud et al. (1976) and actualised by the BIEM (Onclincx and Gryseels, 1994) — data concerning forest and park areas or the density of green — is not able to provide enough information on the quality and evolution tendency of the Brussels flora. In 1991, the Brussels-Capital Region has created an information structure based on the quality of plants, vegetation, animals and habitats scattered over its whole territory. This tool, which is an observation network of the biological environment, combines the work of naturalists and professionals by means of analysis by a research team.

Therefore, we recommend urban planners bear in mind, the results produced by a scientific survey of the composition of the urban flora, as it may become a useful tool for landscape management and allows an evaluation of the botanical patrimony of the city on both a qualitative and quantitative basis.

This survey has enabled:

- the recording of plant species which form the flora of the Brussels region so as to make descriptive maps which provide the basis for management decisions; the analysing of these species and the indexing of those of very high phytogeographical or ecological interest; the proposing of protection of the rarest among them;
- the monitoring of flora fluctuation and the emphasising of species extinctions, regressions, increases and introductions;
- and, in terms of those fluctuations, the monitoring of the evolution of the environment, the highlighting of threats, and the formulating of protection, conservation and planning proposals.

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Appendix A. Species occurring in Brussels during the first period (1940–1971) that were not recorded in the present study

Agrimonia repens, *A. githago*, *A. praecox*, *Alchemilla xanthochlora*, *Alopecurus aequalis*, *Althaea hirsuta*, *A. officinalis*, *Amaranthus viridis*, *Ambrosia artemisiifolia*, *Anthemis arvensis*, *Apium repens*, *Arnoseris minima*, *Artemisia campestris*, *Artemisia maritima*, *Asperugo procumbens*, *Avenula pratensis*, *Baldellia ranunculoides*, *Brassica nigra*, *Briza media*, *Bromus arvensis*, *B. commutatus*, *B. erectus*, *B. inermis*, *B. secalinus*, *Camelina sativa*, *Campanula rapunculoides*, *Carduus acanthoides*, *Carex appropinquata*, *C. nigra*, *C. panicea*, *C. rostrata*, *C. vesicaria*, *C. vulpina*, *Carlina vulgaris*, *Centaurea calcitrapa*, *Chenopodium ambrosioides*, *Chenopodium murale*, *Chenopodium urbicum*, *Cirsium eriophorum*, *Clinopodium vulgare*, *Coincya cheiranthos*, *Corispermum leptopterum*, *C. canescens*, *Crataegus laevigata*, *Crepis nicaeensis*, *C. setosa*, *Cuscuta gronovii*, *Cynodon dactylon*, *Cystopteris fragilis*, *Dactylorhiza fistulosa*, *Danthonia decumbens*, *Delphinium ajacis*, *Descurainia sophia*, *Epilobium lanceolatum*, *E. obscurum*, *E. palustre*, *E. tetragonum* subsp. *lamyi*, *Equisetum hyemale*, *Eriophorum gracile*, *Euphorbia cyparissias*, *E. esula* subsp. *esula*, *E. esula* subsp. *tommasiniana*, *Euphrasia officinalis*, *E. stricta*, *Festuca ovina*, *Festuca pallens*, *Gagea spathacea*, *Galeopsis angustifolia*, *Galium sylvaticum*, *G. tricornutum*, *G. uliginosum*, *Geranium palustre*, *Geum rivale*, *Hieracium maculatum*, *Hippuris vulgaris*, *Holosteum umbellatum*, *Hottonia palustris*, *Hypericum maculatum*, *H. montanum*, *Hypochoeris maculata*, *Inula conyzae*, *Inula helenium*, *Juncus acutiflorus*, *Kickxia elatine*, *Lamium maculatum*, *Lemna gibba*, *Leonorus cardiaca*, *Lepidium latifolium*, *Lithospermum arvense*, *Lithospermum officinale*, *Lolium temulentum*, *Luzula luzuloides*, *Lycopodium clavatum*, *Malva alcea*, *Medicago arabica*, *Mentha longifolia*, *Menyanthes trifoliata*, *Minuartia hybrida*, *Misopates orontium*, *Monotropa hypopitys*, *Myosotis cespitosa*, *Myosotis ramosissima*, *Myriophyllum verticillatum*, *Nicandra physalodes*, *O. aquatica*, *Ophrys insectifera*, *Oxalis corniculata*, *Petrorhagia prolifera*, *Poa bulbosa*, *P. palustris*, *Polygala serpyllifolia*, *Polystichum aculeatum*, *P. lucens*, *P. pectinatus*, *P. pusillus*, *Potentilla neumanniana*, *Prunella laciniata*, *Pulmonaria officinalis*, *Quercus pubescens*, *Ranunculus aquatilis*, *R. arvensis*, *R. circinatus*, *Rhinanthus angustifolius*, *Rumex maritimus*, *R. palustris*, *R. triangulivalvis*, *Ruppia maritima*, *Salsola kali*, *Sanguisorba minor*, *S. pecten-veneris*, *Senecio sylvaticus*, *Setaria verticillata*, *Silene conica*, *Sinapis alba*, *Sium latifolium*, *Sparganium emersum*, *Spartina maritima*, *Stachys recta*, *Succisa pratensis*, *Teesdalia nudicaulis*, *Vaccaria pyramidata*, *V. vitis-idaea*, *Valerianella* *eriocarpa*, *Veronica opaca*, *Vicia lathyroides*, *Viola canina*, *Xanthium strumarium*.

Appendix B. Species found recently in Brussels (1991–1994) that are absent from the 1940–1971 list

Achillea ptarmica, *A. altissima*, *Allium schoenoprasum*, *Amaranthus blitum*, *A. hybridus*, *Aquilegia vulgaris*, *Arctium nemorosum*, *A. clematitis*, *Artemisia verlotiorum*, *Arum italicum*, *Aster lanceolatus*, *A. novae-angliae*, *A. novi-belgii*, *A. filiculoides*, *Barbarea stricta*, *Bidens frondosa*, *Borago officinalis*, *Brassica napus*, *B. oleracea*, *Bromus carinatus*, *Bupleurum rotundifolium*, *Buxus sempervirens*, *Campanula persicifolia*, *Cannabis sativa*, *Cardamine impatiens*, *Carex cuprina*, *C. pendula*, *Centaurea montana*, *C. scabiosa*, *C. serotina*, *Cerastium fontanum* subsp. *vulgare*, *C. officinarum*, *Chenopodium ficifolium*, *Clematis viticella*, *Consolida regalis*, *Cornus alba*, *Coronopus squamatus*, *D. fuchsii*, *Duchesnea indica*, *Echinops exaltatus*, *E. nuttallii*, *Elymus caninus*, *E. repens*, *Epilobium ciliatum*, *Erigeron annuus* subsp. *septentrionalis*, *Erodium cicutarium* subsp. *cicutarium*, *Fagopyrum esculentum*, *Festuca rubra* subsp. *commutata*, *Fragaria viridis*, *Galanthus nivalis* var. *nivalis*, *Geranium endressii*, *G. sanguineum*, *Glyceria declinata*, *Helianthus tuberosus*, *Hemerocallis fulva*, *H. mantegazzianum*, *Herniaria hirsuta*, *Hieracium murorum*, *Hirschfeldia incana*, *Hypericum dubium*, *Juglans regia*, *Laburnum anagyroides*, *Lactuca virosa*, *Lagurus ovatus*, *Lathyrus hirsutus*, *Lepidium sativum*, *Leucojum vernum*, *Ligustrum ovalifolium*, *Linaria repens*, *Linum usitatissimum*, *Lobularia maritima*, *Lonicera caprifolium*, *L. xylosteum*, *Lunaria annua*, *Lysimachia punctata*, *Mahonia aquifolium*, *Malus sylvestris*, *Medicago minima*, *Mentha×piperita* nsubsp. *piperita*, *M.× villosa*, *Mimulus guttatus*, *Muscari atlanticum*, *Myriophyllum spicatum*, *Myrrhis odorata*, *Nepeta cataria*, *Oenothera erythrosepala*, *Ononis repens*, *O. limbosperma*, *Ornithogallum pyrenaicum*, *Panicum capillare*, *P. miliaceum*, *Parietaria judaica*, *Parthenocissus inserta*, *Pentaglottis sempervirens*, *Phacelia tanacetifolia*, *Phalaris arundinacea*, *Phleum arenarium*, *P. bertolonii*, *Potentilla anglica*, *Primula veris*, *Prunus cerasus*, *P. insititia*, *P. mahaleb*, *Pyrus communis*, *Quercus petraea*, *Ranunculus flammula*, *Rapistrum rugosum*, *Ribes alpinum*, *R. nigrum*, *Rorippa austriaca*, *Rosa rubiginosa*, *R. rugosa*, *Rubia tinctorum*, *Rumex patientia*, *R.×pratensis*, *Salix atrocinerea*, *S. eleagnos*, *S. purpurea* subsp. *lambertiana*, *S.×multinervis*, *S.×rubens*, *S.×rubra*, *S.×sericans*, *Scrophularia vernalis*, *Sedum rupestre*, *S. spurium*, *Senecio inaequidens*, *S. vernalis*, *Sisymbrium austriacum*, *S. orientale*, *Solidago canadensis*, *S. gigantea*, *Sorbus aria*, *S. intermedia*, *Sorghum halepense*, *Spiraea×vanhouttei*, *Stachys sylvatica*, *Symphytum×uplandicum*, *Syringa vulgaris*, *Taxus baccata*, *T. speciosa*, *Teucrium chamaedrys*, *Thymus pulegioides*, *Trifolium dubium*, *Typha angustifolia*, *Ulmus laevis*, *Veronica filiformis*, *Vinca major*, *Viola tricolor*.

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