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DIVERSITY OF SPONTANEOUS FLORA OF UNUSED INDUSTRIAL BUILDINGS IN WARSAW, POLAND

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Abstract

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City industrial zones are densely built and lack large green spaces. The plants in such zones can develop without human interference and are able to re-establish within a foreseeable period of time. This is known as "spontaneous" vegetation. The aim of the paper is to characterize flora established on the roofs of several abandoned buildings in the main industrial areas of Warsaw, Poland. The field studies were performed in 2006–2008 and 2009–2010. There were 26 plants recorded in 11 syntaxonomic classes, with companion species in the herb layer. Spontaneous plants belong not only to syn-anthropogenic communities but also to natural and semi-natural ones. Economic factors currently play a major role in restoring and designing new urban green areas. Restoration of abandoned and new industrial and commercial buildings via spontaneous vegetation has been proposed as a cheap alternative to extensive technical reclamation.

Key words: spontaneous flora, industrial areas, city

Introduction

Many human activities are decreasing plant diversity and affecting the natural environment on which people rely (Czech et al., 2000; Jeffrey et al., 2001; Yao-qin, et al., 2008). Environmental factors of anthropogenic origin indicate clear gradients of urbanization. These include pollution level, increased temperature (or the urban heat island effect) and soil compaction along transect lines from rural to urban areas (Collins et al., 2000; Margaret, 2006). The urban areas are often characterized by low biodiversity, the introduction of non-native species and simplified species composition and community structure (Grimm et al., 2000; McKinney, 2002; Lundholm, Marlin, 2006). Despite the massive and pervasive human perturbation, urban ecosystems can provide a variety of substrata for colonization by vegetation and wildlife (Forman, Godron, 1986; Niemelä, 1999; McKinney, 2002). Generally, city industrial zones are densely built and lack large green areas. The plants in these zones can develop without human interference and can re-establish in a foreseeable period of time (Wiegleb, Felinks, 2001). This vegetation type is called spontaneous vegetation. Millard (2004) accurately describes this plant group as communities which have developed in an urban landscape, mainly in the 20th century. This paper aims to characterize the flora on the roofs of several abandoned buildings in the main industrial areas of Warsaw, Poland.

Material and methods

This study was conducted in the capital city of Warsaw, Poland, EU. Warsaw is located in the central part of Poland in the Vistula river valley, latitude 52°18'–52°06', longitude 20°55'–21°08', at 77 m to 89 m a.s.l. (Fig. 1). The climate is temperate with low snow cover in winter. Mean annual temperatures range between 7.5 and 9 °C, with annual precipitation between 500 and 600 mm (Matuszkiewicz, 2001). All 9 examined stands were located in the urban industrial zones. These were: building A – on the area of FSO Car Factory, Praga Północ district; building B – on the area of FSO Car Factory, Praga Północ district; building C – on the area of FAELBET concrete factory, Białołęka district; building D – on the area of former House Factory DOMBET Tarchomin, Białołęka district; building E – one building of the steel foundry Arcelor Mittal Warsaw, Bielany district; building F – abandoned office-building on the area of the steel foundry Arcelor Mittal Warsaw complex, Bielany district; building G – office-building in the industrial area of TRANSBUD, Wola district; building H – on the area of former tractor factory URSUS, Ursus district and building I – a building of the STOLBUD house plant, Ursynów district. These were all built in the 1950's and 1960's, and the total surface area of each roof was between 2,200 m^2 to 2,500 m^2. All buildings were abandoned in the early 1990's, except building G which has never been finished.

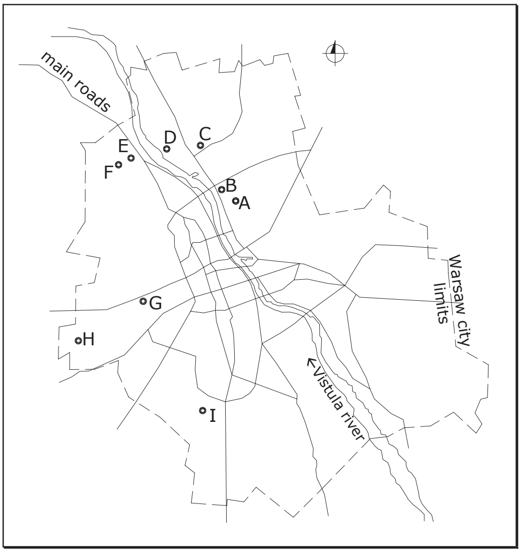


Fig. 1. Research stands (industrial buildings) in Warsaw, Poland: A – FSO Car Factory (Praga Północ), B – FSO Car Factory (Praga Północ), C – FAELBET concrete plant, (Białołęka), D – former House Factory DOMBET (Białołęka), E – steel foundry ArcelorMittal Warsaw (Bielany), F – steel foundry Arcelor Mittal Warsaw (Bielany), G – office building TRANSBUD (Wola), H – former tractor factory URSUS (Ursus), I – STOLBUD house plant (Ursynów).

The field studies were carried out in 2006–2010. In each year, 270 phyto-sociological records were made on the roofs of the buildings; 30 on each of the 9 buildings. These recordings were performed on 25 m^2 as in Braun-Blanquet's method (1951). Plant species were grouped under the phyto-sociological system of Matuszkiewicz (2001), analysis of plant life-forms was made according to Raunkiaer (1934) and species' historical–geographical classification was performed following Richardson et al. (2000). Indicator values of plants growing on the study areas were presented according to Ellenberg et al. (1992). Ecological behaviour of plants has been expressed by figures representing nine degrees of behaviour with regard to the environmental factors of light, moisture and temperature. For example L – light figure: 1 – fully-shaded plant; 2 – between 1 and 3; 3 – shaded plant; 4 – between 3 and 5; 5 – half-shaded plant; 6 – between 5 and 7; 7 – half light plant; 8 – between 7 and 9; 9 – full light plant; X – neutral plant for light intensity or the other factors. Classification of the dispersion type was also made. Data was subjected to ANOVA 1 using STATGRAPHICS® (version Plus 4.1) and differences between the means were compared with the Duncan test at probability level, P = 95%. The mean data from all observation years is presented herein.

Results

There were 26 plant species belonging to 11 syntaxonomic classes (Table 1) with companion species in the herb layer. These plants were recorded from the syn-anthropogenic, semi-natural and natural communities; *Stellarietea mediae, Epilobietea angustifolii, Artemisietea*

T a b l e 1. Plant species on study areas.

Plant species	Buildings								
	A	B	C	D	E	F	G	H	I
Acer negundo	x	x	x	x	x	x	x	x	x
Acer platanoides			x						
Aegopodium podagraria			x						
Agrostis gigantea	x	x	x	x	x	x	x	x	x
Artemisia vulgaris			x	x	x	x	x	x	x
Betula pendula	x	x	x	x	x	x	x	x	x
Bromus inermis			x	x	x	x	x	x	x
Bryum argeneteum	x	x	x	x		x	x	x	x
Calamagrostis epigejos	x	x	x	x	x	x	x	x	x
Calluna vulgaris			x						
Carpinus betulus			x						
Erigerion canadensis	x	x	x	x	x	x	x	x	x
Oenothera biennis			x	x	x	x	x	x	x
Pinus sylvestris	x	x	x	x	x	x	x	x	x
Poa pratensis		x	x	x	x	x	x	x	x
Populus alba	x	x	x	x	x	x	x	x	x
Populus canescscens	x	x	x	x	x	x	x	x	x
Populus nigra	x	x	x	x	x	x	x	x	x
Populus tremula	x	x	x	x	x	x	x	x	x
Sambucus nigra			x	x	x	x	x		x
Sedum acre					x	x			
Solidago canadensis	x	x	x	x	x	x	x	x	x
Solidago virgaurea			x	x	x	x	x	x	x
Taraxacum officinale	x	x	x	x	x	x	x	x	x
Thlaspi arvense	x	x	x	x	x	x	x	x	x
Tussilago farfara			x	x	x	x	x	x	x

Note: X – plant species which occurred on study area.

vulgaris, Molinio-Arrhenatheretea, Koelerio glaucae-Corynephoretea canescentis, Vaccinio-Piceetea, Salicetea purpureae, Nardo-Callunetea, Thlaspietea rotundifolii, Agropyretea intermedio-repentis and *Querco-Fagetea* (Fig. 2). In addition, six plant species from *Stelarietea mediae* class were distinguished: *Bryum argeneteum, Populus canescscens, Populus nigra, Tussilago farfara, Thlaspi arvense* and *Erigerion canadensis.*

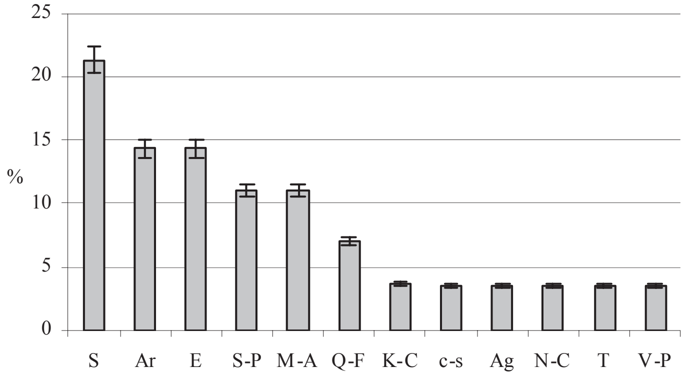
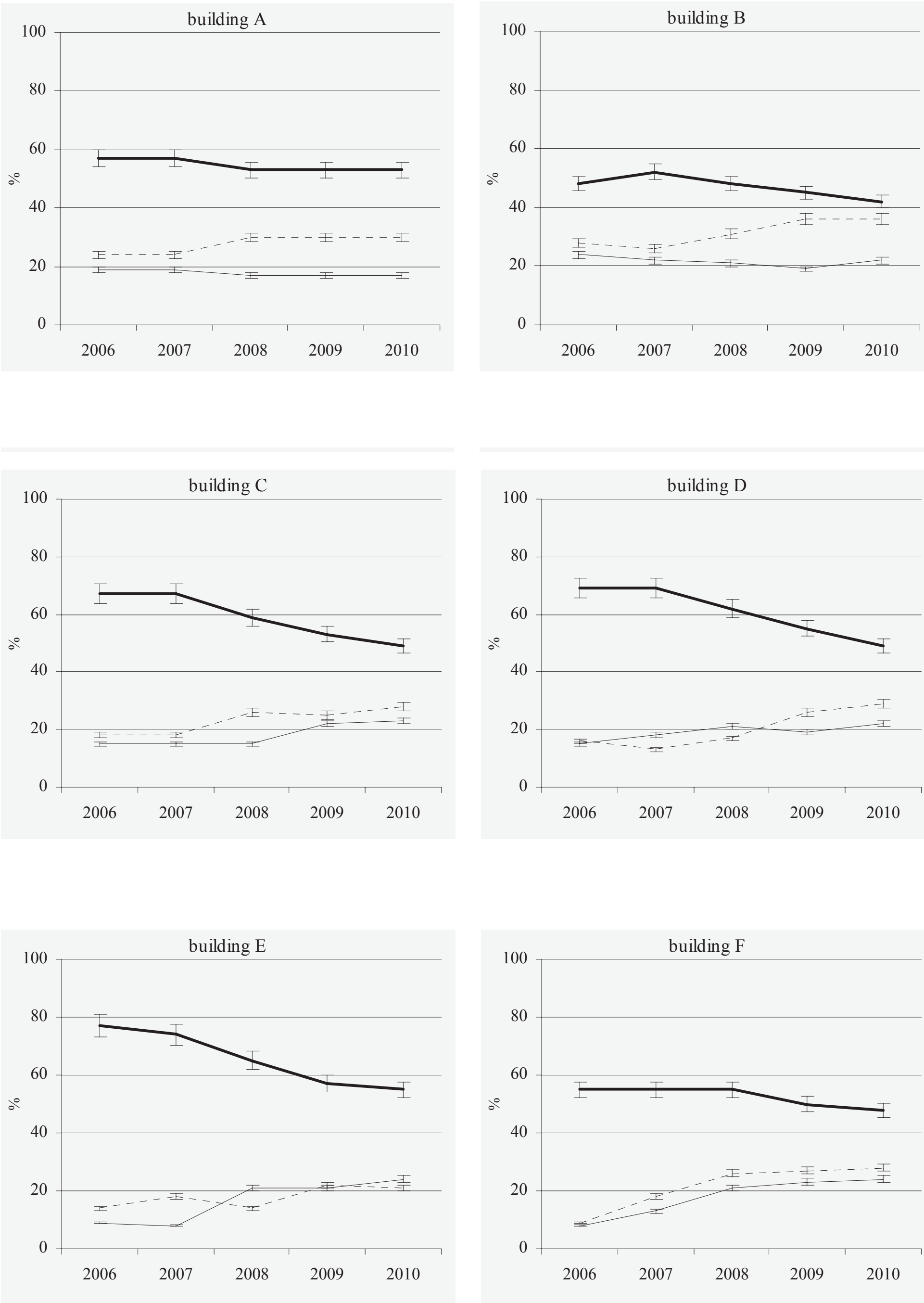


Fig. 2. Percentage cover of plant species in different syntaxonomic units: S – *Stellarietea mediae*, Ar – *Artemisietea vulgaris*, E – *Epilobietea angustifolii*, S-P – *Salicetea purpureae*, M-A – *Molinio-Arrhenatheretea*, Q-F – *Querco-Fagetea*, K-C – *Koelerio glaucae-Corynephoretea*, c-s – companion species, Ag – *Agropyretea intermedio-repentis*, N-C – *Nardo-Callunetea*, T – *Thlaspietea rotundifolii*, V-P – *Vaccinio-Piceetea*. Bars represent the standard deviation.

Most species on the examined sites produce light seeds which can be dispersed by wind, and just the one *Sambucus nigra* species produced succulent fruits eaten by birds (epizoochory). Syn-anthropenic plants had the highest frequency on the building roofs in 2006–2010. Grassland and forests plants also grew there, and succession processes were observed there since the semi-natural and natural plants exhibited higher frequency in 2009–2010 than in 2006–2008 (Fig. 3).

Plant life-forms provide the basic structural components of vegetation stands, being the most obvious level of subdivision for describing and explaining vegetation structure. The plant cover growing on the examined buildings represented the following four classes: chamephytes, hemicryptophytes, phanerophytes and therophytes (Fig. 4). Hemicryptophytes dominated in this study – except on buildings A and B – and were represented by: *Aegopodium podagraria, Agrostis gigantea, Artemisia vulgaris, Bromus inermis, Calamagrostis epigejos, Erigeron canadensis, Oenothera biennis, Poa pratensis, Sedum acre, Solidago canadensis, Solidago virgaurea, Taraxacum officinale* and *Tussilago farfara*, with more than 40% of total coverage on every building. The following phanerophytes significantly predominated on buildings A and B: *Acer negundo, Betula pendula, Pinus sylvestris, Populus alba, P. canescens, P. nigra and P. tremula*. Small shrubs of *Sambucus nigra* were found on all the remaining roofs (buildings C to I) and seedlings of *Acer platanoides* and *Carpinus betulus* were growing


building A
building B
building C
building D
building E
building F
%
100
80
60
40
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2006
2007
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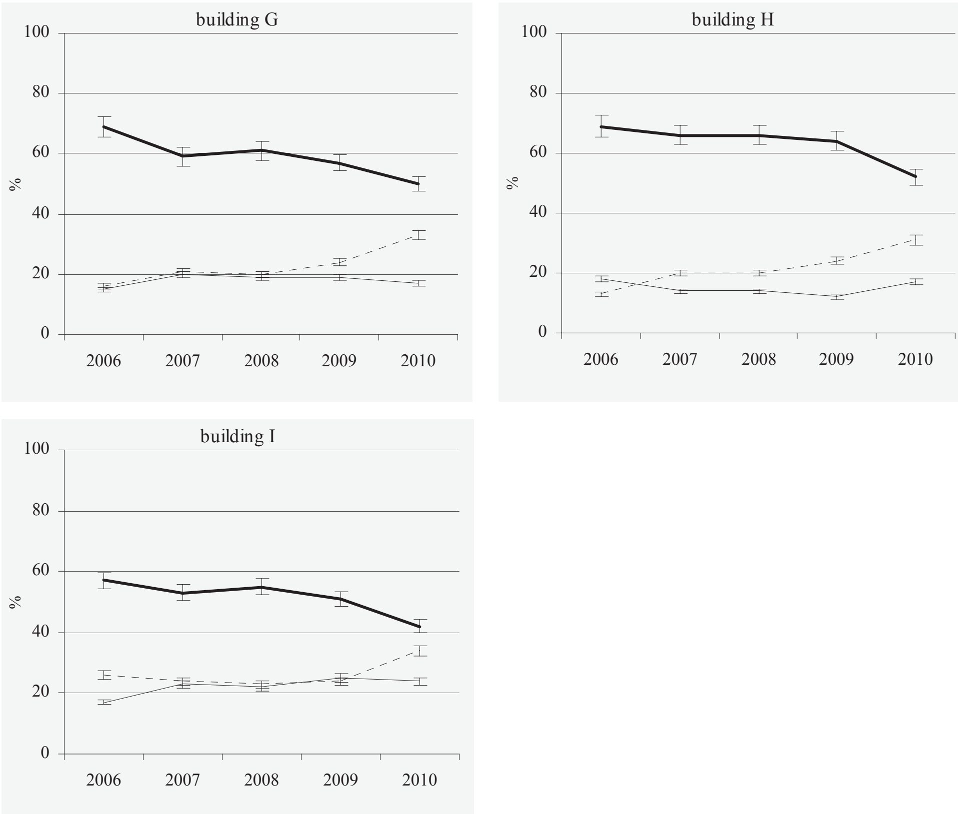

Fig. 3. Phytosociological frequently of synantropic, (**–**) grassland (–) and forest (···) plants in years 2006–2010. Bars represent the standard deviation.

only on C. Chamaephytes (*Bryum argenteum, Calluna vulgaris*) and therophytes (*Thlaspi arvense*) had the lowest coverage of all plants species on these buildings' roofs.

According to the historical-geographical classification of plant species suggested by Richardson et al. (2000), both native species (apophytes) and non-native ones (anthropophytes) occurred on the examined sites (Fig. 5), with apophytes dominating 78% on building A to 84% on building C. The following antropophyte species were found in all examined sites: *Acer negundo*, *Erigeron canadensis*, *Solidago canadensis* and *Oenothera biennis*. All of these non-native species are of North American origin.

The majority of plants on the roofs exhibit considerable requirements regarding light, preferring fresh sites and a medium temperature. The following light-loving plants dominated study roofs: *Agrostis gigantea, Betula pendula, Calamagrostis epigejos, Sedum acre, Solidago canadensis* and *Tussilago farfara* (7, 8 index value, Fig. 6). Plants such as *Calamagrostis epigejos, Populus tremula, Sambucus nigra, Sedum acre, Thlaspi arvense, Acer platanoides,*

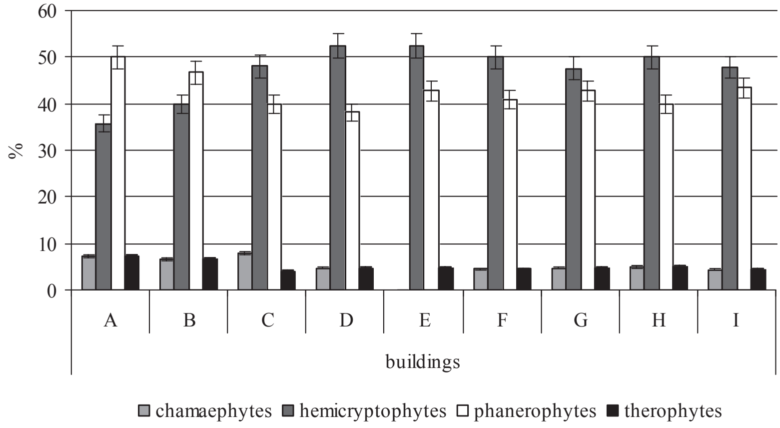

Fig. 4. Percentage of life-forms on each building. Bars represent the standard deviation.

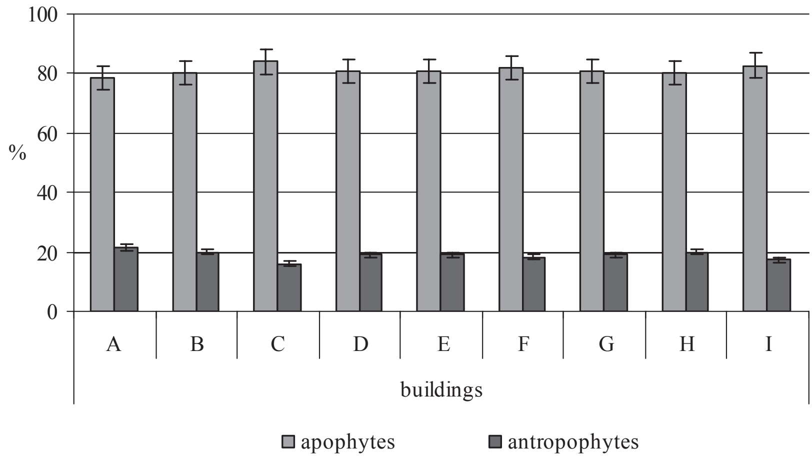

Fig. 5. Historical-geographical classification according to Richardson et al. (2000). Bars represent the standard deviation.

Oenothera biennis prefer a medium temperature (5, 6, 7 index value, Fig. 7). 50% of plants *Agrostis gigantea, Betula pendula, Bromus inermis, Poa pratensis, Pinus sylvestris, Solidago canadensis and Taraxacum officinale* are neutral for temperature (X – index value).

Plants which grew on poor and fresh habitats were recognized. Species as *Poa pratensis, Populus alba, Sambucus nigra* and *Taraxacum officinale* preferred fresh sites and dominated the study areas with a 5, 6 – index value.

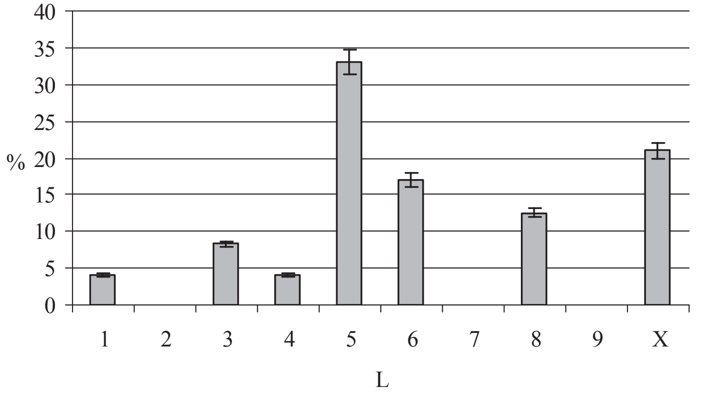

Fig. 6. Mean cover of plant species depend of light condition (L – light index). Bars represent the standard deviation.

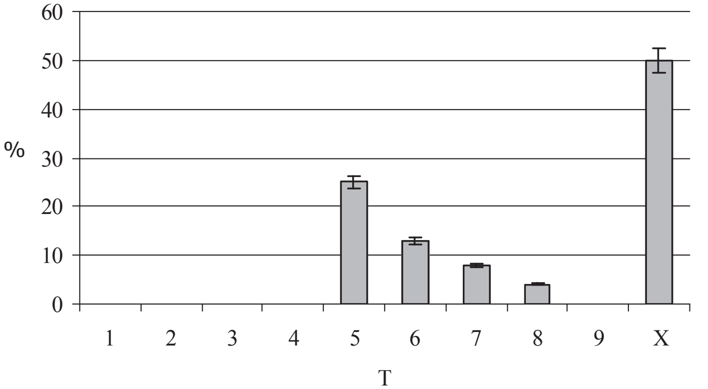

Fig. 7. Mean cover of plant species depend of temperature condition (T – temperature index). Bars represent the standard deviation.

Discussion

Cities represent a particular habitat complex, where plant species adapted to high light conditions and to temperatures higher than that in the city environs are favoured. These are also not bound to wet soils, they are indifferent to soil reaction and prefer a soil pH not lower than 6, and with some exceptions, they are adapted to eutrophication (e.g. Wittig, Durwen, 1982; Wittig, 2002). Generally, city industrial zones are densely built and lack large green spaces. Plants can develop in such zones without human interference and can re-establish in a foreseeable period of time (Wiegleb, Felinks, 2001). Urbanization dynamics have resulted in establishment of new urban vegetation communities. Spontaneous flora was noted growing around trees in the city streets (Wittig, Becker, 2010), and this type of vegetation has been observed on roofs of industrial building in Warsaw. Spontaneous plants belong not only to syn-anthropogenic communities but also to semi-natural and natural ones. Most of these, including *Betula pendula, Calamagrostis epigejos, Sedum acre, Solidago canadensis, Tussilago farfara,* were observed on industrial building roofs from 2006 to 2010. Moreover plants growing on the studied roofs had higher percentage cover in 2009–2010 than during 2006–2008 (Fornal-Pieniak, Chyliński, 2007). It was interesting to see plants typical of natural communities, such as *Querco-Fagetea*, on these roofs. The majority of species found on the examined sites produce light seeds dispersed by wind from surrounding areas, such as from forests. Only the *Sambucus nigra* species, occurring on six of the nine buildings (C, D, E, F, G and I), produce a succulent fruit often eaten by birds (epizoochory). This is the most successful method for this species' dispersal. However, Wiegleb and Felinks (2001) reported anemochory is the main mechanism of dispersal, and that zoochory plays only a minor role at the beginning of primary succession. The vitality and survival of the diasporas, including their germination rates and early seedling mortality, are the most important factors in vegetation establishment. These parameters depend strongly on the variable climatic conditions which have a more drastic influence in open sites (as on roofs, in this case) than in closed woodland sites. Animal existence on the roofs of former industrial buildings was also proven by bird nests on two of the examined stands.

Indigenous vegetation plays a quite important role in natural, cultivated and urban ecosystems (Breuste, 2004). Investigators such as Pyšek et al. (2003), Grapow et al. (2001), Wittig (2004) and Millard (2004) showed a decrease in indigenous vegetation and its replacement by invasive non-native plants often emanating from remote regions of the world and adapting to the new urban conditions better than indigenous plants. Although apophytes dominated every examined stand in our trial, antropophytes accounted for appproximately 20% of the total number of species. It should be noted that one of these (*Solidago canadensis*) exhibits the highest stability of all these species. The results show that spontaneous vegetation is a type of "green island" in the industrial urban landscape, and that this green island provides sanctuary to plant species from syn-anthropogenicl, semi-natural and natural plant communities.

The system proposed by Raunkiaer (1934) has been widely applied to classify plant species in life-forms from deserts (Ghazanfar, (1997) and Flores et al. (2004), all the way to the tropics. The plant cover growing on the examined buildings was represented by four of these classes: chamephytes, (plants with renewable buds which are located on shoots less than 25 cm above ground level), hemi-cryptophytes (hemi-cryptogamous plants with buds and shoots located directly above the ground), phanerophytes (phanerogamous plants with renewable buds located on the shoots more than 25 cm above ground level) and therophytes (annual plants that survive hostile events, such as drought or low temperatures by protection in their seeds) (Fig. 4).

Economic factors currently play a major role in the restoration and design of new urban green areas. The restoration of abandoned quarries and large areas of new industrial and commercial buildings, including shopping centres, by spontaneous vegetation has been proposed as a cheap alternative to extensive technical reclamation (Jochimsen, 2001; Novák, Konvička, 2006). These research results will be very useful in designing green gardens on roofs of buildings, including "cheap" spontaneous plants.

Conclusion

Spontaneous vegetation provides a "green island" in industrial urban landscapes, encouraging the diversity of syn-anthropogenic, grassland and forest plant species. A majority of native plants was noted in all stands in this research, with hemi-cryptophytes and phanerophytes prevailing among these classes. Spontaneous vegetation should certainly be considered and proposed by designers and planners as a 'cheap' alternative in the development of new green areas in urban landscapes.

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