sciendo

Folia Forestalia Polonica, Series A – Forestry, 2024, Vol. 66 (2), 118–128

ORIGINAL ARTICLE

DOI: 10.2478/ffp-2024-0010

The share of anthropophytes in the tree stands of urban forests in Katowice (Silesian Upland, S Poland)

Krzysztof Wysiński, Barbara Fojcik ✉

Institute of Biology, Biotechnology and Environmental Protection, University of Silesia in Katowice, Jagiellońska 28, 40-032 Katowice, Poland, e-mail: fojcik@us.edu.pl

Abstract

Urban forests are an important element of nature in highly urbanised areas. Due to their specificity (e.g. fragmentation, disturbances, alien propagule pressure), they are particularly susceptible to the penetration of alien species. The aim of this study was to determine the share of alien species in the tree stand structure of urban forests in the city of Katowice (Upper Silesian Industrial Region). A total of 50 woody species were recorded in the analysed stands, including 31 native species and 19 of alien origin. The share of alien species in the stands of individual forests was significant, as they constituted from 15% to 44% of the total number. Among the 20 trees most frequently included in the stand, as many as six are species of alien origin (*Robinia pseudoacacia* L., *Padus serotina* (Ehrh.) Borkh., *Acer negundo* L., *Quercus rubra* L., *Juglans regia* L. and *Fraxinus pennsylvanica* Marshall). The most abundant species were *Robinia pseudoacacia*, *Quercus rubra* and *Padus serotina*. The local potential of alien woody species was determined using the index of their abundance in the understory; the highest value of the average abundance index was obtained by *Padus serotina*, *Robinia pseudoacacia*, *Acer negundo* and *Quercus rubra*. Most alien tree species were more likely to inhabit forest edges (ecotone zone).

Key words

urban areas, forest disturbance, alien plant species, ecotone zone

Introduction

Urban forests are an important element in the spatial and functional structure of cities. In a highly transformed urbanised environment, they create enclaves of a natural character, also playing an important role in shaping the urban landscape and in the lives of residents (Tyrväinen et al. 2005; Kaliszewski 2006; Kim 2016). The forest cover has a beneficial effect on the local climate (mainly in reducing temperature and wind strength) and also contributes to reducing the level of air pollution (McPherson et al. 1997; Tyrväinen et al. 2005). Urban forests are also important centres of local biodiversity, creating places of refuge for many species of plants and animals, including rare and endangered species (Alvey 2006; Lepczyk et al. 2017; Kowarik et al. 2019).

Urban forestry is defined as 'an art, science and technique of management of trees and forest resources in urban ecosystems and surrounding them with the aim to secure psychological, sociological, economical and aesthetic advantages for municipal communities'

Received 6 February 2024 / Accepted 11 March 2024

BY-NC-ND

© 2024 Author(s). This is an open access article licensed under the Creative Commons Attribution-NonCommercial-NoDerivs License (http://creativecommons.org/licenses/by-nc-nd/4.0/)

(Miller 1997). Urban woodland means a forested ecosystem of natural, semi-natural or man-made origin, used for a variety of purposes (Bell et al. 2005). The concept of the 'urban forest' itself is defined in various ways (Konijnendijk et al. 2006). In a broader sense, it includes all woody vegetation in the city, that is, forests, parks, gardens and roadside trees (Costello 1993; Konijnendijk 2003; Randrup et al. 2005). In a narrower sense, this concept refers only to typical forest ecosystems, without gardens, parks and street trees (Konijnendijk 2003; Rydberg and Falck 2000; Gundersen et al. 2005; Randrup et al. 2005).

Forests in cities may have different characters. In a broader sense, urban forests are all the forests within the legal boundaries of urban areas (Konijnendijk 2003). This also includes suburban commercial forests, often having the character of dense forest complexes with relatively little diversity of tree stands (Jaszczak and Wajchman 2014; Fojcik et al. 2019). It seems more appropriate, however, to adopt a narrower definition for the concept of 'urban forests', that is, that they are enclaves of forests in strictly urban areas (Konijnendijk 2003). This approach reflects their specificity resulting from the development of specific urban conditions (including the specific climate related to the urban heat island effect, air pollution and disturbed soils) (Sieghardt et al. 2005). Such forests are usually isolated from larger forest complexes and occupy relatively small areas (Konijnendijk 1997). They usually arise in wasteland and develop largely through spontaneous succession. The trees may partly come from plantings, especially in previously reclaimed areas or in former parks (Keil and Loos 2005; Olszewski 2009). They are usually not used commercially.

With regard to urban forests (in the strict sense), the occurrence of species of alien origin deserves special attention. The spread of alien species is one of the negative effects of urbanisation (Bierwagen 2005; Arson et al. 2015). Especially in the last century, there has been an increase in the number of alien woody species in the urban flora and also in the forest areas (Mavimbela et al. 2018; Kowarik et al. 2019). They include invasive species that reproduce intensively and spread quickly, and even belong to the category of transformers, changing the features and conditions of ecosystems (Richardson et al. 2000). Urban forests, often exposed to disturbance, fragmentation and alien propagule pressure, are particularly susceptible to the penetration of alien plant species (Wagner et al. 2017; Becerra and Simonetti 2020).

The share of alien tree species in the forest structure is particularly important. The aim of this study is to determine the scale of this phenomenon in Katowice by analysing the share of alien species in the structure of stands in the local urban forests. The following research hypotheses were formulated: 1) the share of alien species in the tree stand structure of the urban forests in Katowice is significant; 2) invasive species play an important role among alien tree taxa and 3) differences in habitat conditions on the forest edge (in the ecotone zone) and inside the forest affect the occurrence of alien tree species.

Material and methods

Study area

Katowice (50.288815 N latitude, 18.943135 E longitude) is the main city of one of the largest urban agglomerations in Central Europe and the most urbanised region in Poland (Upper Silesian Industrial Region) (Krzysztofik 2021). Until recently, Katowice was a large mining and industrial centre, but in recent decades, the economy of Katowice has been transforming from the heavy industry of steel and coal mines into one of the most attractive investment areas for modern economy branches in Central Europe. The city encompasses an area of 165 km^2 and has over 290,000 inhabitants (Województwo śląskie… 2019). The city area is characterised by a diverse relief, consisting of hills (exceeding 300 m above sea level), intersected with river valleys in the form of tectonic depressions and erosion channels (Szaflarski 1976). Over the last 200 years, humans and their economic activities have become an important factor modelling the local relief, resulting in the blurring of natural landforms and the appearance of new ones (embankments, workings, sinkholes, heaps, etc.) (Barciak et al. 2012). More than 38% of the city's area is covered by forests, so it is one of the most forested cities in Europe (Pauleit et al. 2005). Dense forest areas cover the southern part of the city. These are mainly commercial forests of a mixed forest nature (Fojcik and Stebel 2010).

Data sampling

Field research was conducted in 2021 in Katowice in the northern part of the city. The research covered 30 sites (Tab. 1), which were single urban forests, defined as small wooded areas (with an area of at least 1 ha), isolated from larger complexes of managed forest, the vegetation of which is currently developing spontaneously, even if some of the trees come from old, purposeful plantings (as part of reclamation or park development). During the field research, conducted on the entire area of individual forests, species of tree stands (over 3 m high) were inventoried, and the following information was recorded:

– occurrence of native tree species with the dominant species marked,
– occurrence of alien tree species, including their abundance in individual forests (=stands); three categories of abundance were adopted: 1 – single specimens (up to 10); 2 – not very numerous specimens (11–30) and 3 – numerous specimens (over 30).

o determine the potential of the alien species, the presence of undergrowth (up to 3 m) was also recorded, and its abundance was determined according to the scale described above. In addition, attention was paid to the location of trees of alien origin, whether they occurred deep in the forest or in the forest steppes; due to the relatively small area of the analysed forests, an area of up to 20 m into the forest was assumed as the ecotone.

Table 1. List, area and location of the analysed urban forests in Katowice

No.	District	Area (ha)	Localisation	
			N	E
1	2	3	4	5
1.	Muchowiec	2.7	50.241908	19.033019
2.	Muchowiec	3.7	50.242854	19.028191
3.	Szopienice (Borki)	8.0	50.278260	19.085934
4.	Szopienice (Borki)	3.0	50.273858	19.092457
5.	Szopienice (Borki)	2.5	50.271047	19.097414
6.	Szopienice (Borki)	9.0	50.275485	19.097414
7.	Szopienice (Borki)	2.0	50.271403	19.102413
8.	Burowiec	2.4	50.273186	19.078531
9.	Dąbrówka Mała (Norma)	1.7	50.272089	19.062395
10.	Pniaki	5.2	50.280015	19.056901
11.	Dąbrówka Mała	3.4	50.282319	19.068961
12.	Osiedle 1000-lecia	4.8	50.277237	18.968822
13.	Osiedle 1000-lecia	3.7	50.272749	18.967893
14.	Osiedle 1000-lecia	1.4	50.271082	18.972764
15.	Osiedle 1000-lecia	4.2	50.270299	18.985690
16.	Załęska Hałda	1.8	50.250420	18.994464
17.	Załęska Hałda	2.6	50.254042	18.997575
18.	Załęska Hałda	2.0	50.247090	18.984634
19.	Kokociniec	3.5	50.231153	18.958849
20.	Kokociniec (Płochy)	3.9	50.233992	18.966832
21.	Osiedle Paderewskiego	5.0	50.245109	19.048359
22.	Wilhelmina	4.9	50.249884	19.093892
23.	Nikiszowiec	3.9	50.246454	19.083292
24.	Dąbrówka Mała	7.5	50.287081	19.070160
25.	Dąbrówka Mała	7.4	50.290373	19.061810
26.	Józefowiec (Kolonia Alfred)	7.1	50.290229	19.013960
27.	Józefowiec (Kolonia Alfred)	1.9	50.292573	19.008059
28.	Brynów (Park Kościuszki)	3.0	50.239455	19.002028
29.	Osiedle Witosa	1.7	50.262051	18.963812
30.	Obroki	3.7	50.266550	18.957426

Data analysis

The general frequency of occurrence of alien tree species was determined on the basis of the number of forests (tree stands) in which they were recorded (expressed in %), as opposed to the abundance of occurrence in individual forests, characterised by the abundance scale described above.The nomenclature of species, their systematic affiliation and current status in the national flora were adopted according to Mirek et al. (2020).

Results

In the analysed stands of urban forests in Katowice, a total of 50 woody species were recorded, including 31 native species and 19 of alien origin (Tab. 2, 3). The vast majority were deciduous trees – 90.3% of the native trees and 100% of the alien trees. In individual forests, the stands ranged from 10 to 30 species, including 5–20 native species and 5–14 alien species (Fig. 1).

Table 2. The share of native species in the analysed urban forests in Katowice

No.	Tree species	Number of forests	% of forests	Number of forests where species prevaile
1.	*Acer campestre*	4	13.3	-
2.	*Acer platanoides*	28	93.3	3
3.	*Acer pseudoplatanus*	22	73.3	-
4.	*Alnus glutinosa*	10	33.3	2
5.	*Betula pubescens*	2	6.7	-
6.	*Betula pendula*	30	100	16
7.	*Carpinus betulus*	8	26.7	-
8.	*Cerasus avium*	21	70	-
9.	*Crataegus monogyna*	22	73.3	-
10.	*Euonymus europaeus*	2	6.7	-
11.	*Fagus sylvatica*	9	30	-
12.	*Fraxinus excelsior*	22	73.3	1
13.	*Larix decidua*	2	6.7	-
14.	*Padus avium*	24	80	-
15.	*Picea abies*	1	3.3	-
16.	*Pinus sylvestris*	12	40	1
17.	*Populus xcanescens*	3	10	-
18.	*Populus nigra*	20	66.7	4
19.	*Populus tremula*	30	100	11
20.	*Quercus petraea*	3	10	-
21.	*Quercus robur*	27	90	3
22.	*Salix alba*	1	3.3	-
23.	*Salix caprea*	29	96.7	1
24.	*Salix fragilis*	18	60	1
25.	*Salix purpurea*	2	6.7	-
26.	*Sambucus nigra*	16	53.3	-
27.	*Sorbus aucuparia*	25	83.3	-
28.	*Tilia cordata*	27	90	1
29.	*Tilia platyphyllos*	8	26.7	-
30.	*Ulmus laevis*	7	23.3	-
31.	*Ulmus glabra*	6	20	-

Among the native species in the forest stand, the most common were *Betula pendula* Roth and *Populus tremula* L. (in all the forests examined), and also *Acer platanoides* L., *Salix caprea* L., *Quercus robur* L. and *Tilia cordata* Mill. (Fig. 2). *Betula pendula* and *Populus tremula* also occurred most often as dominants (in terms of quantity) in the tree stands (Tab. 3). Among the alien species in the stands, the most common were *Robinia pseudoacacia* L. (29 sites), *Padus serotina* (Ehrh.) Borkh. (26) and *Acer negundo* L. (24) (Fig. 3). In terms of abundance, the dominant species were *Robinia pseudoacacia* (mean abundance index 2.7), *Quercus rubra* L. (mean abundance index 2.2) and *Padus serotina* (mean abundance index 2) (Tab. 3). In some forests, alien species were quantitatively dominant in the stand; most often, it was *Robinia pseudoacacia* (in six forests)

Table3. The share of alien species in the structure of the analysed urban forests in Katowice

No.	Tree species	Tree stand		Undergrowth	
		number of forests	sum of abundance categories (average)	number of forests	sum of abundance categories (average)
1.	*Acer ginnala*	-	-	1	1 (1)
2.	*Acer negundo*	24	44 (1.8)	25	55 (2.2)
3.	*Acer saccharinum*	2	2 (1)	-	-
4.	*Aesculus hippocastanum*	14	15 (1.1)	17	18 (1)
5.	*Caragana arborescens*	-	-	1	1 (1)
6.	*Fraxinus pennsylvanica*	17	31 (1.8)	18	33 (1.8)
7.	*Juglans regia*	19	22 (1.2)	26	46 (1.8)
8.	*Laburnum anagyroides*	-	-	1	1 (1)
9.	*Malus domestica*	12	12 (1)	1	1 (1)
10.	*Padus serotina*	26	53 (2)	29	80 (2.8)
11.	*Populus 'NE 42'*	14	21 (1.5)	-	-
12.	*Populus candicans*	4	7 (1.7)	-	-
13.	*Populus nigra 'Italica'*	4	7 (1.7)	1*	1 (1)
14.	*Populus simonii*	1	1 (1)	-	-
15.	*Populus ×berolinensis*	15	24 (1.6)	2*	3 (1.5)
16.	*Populus ×canadensis*	6	8 (1.3)	1*	1 (1)
17.	*Prunus domestica*	15	18 (1.2)	7	8 (1.1)
18.	*Pyrus communis*	4	4 (1)	1	1 (1)
19.	*Quercus rubra*	19	42 (2.2)	28	58 (2.1)
20.	*Robinia pseudoacacia*	29	78 (2.7)	29	71 (2.5)
21.	*Sorbus intermedia*	3	3 (1)	3	3 (1)
22.	*Syringa vulgaris*	1	1 (1)	2	2 (1)

* Suckers.

and less frequently, *Padus serotina* and *Quercus rubra* were dominant.

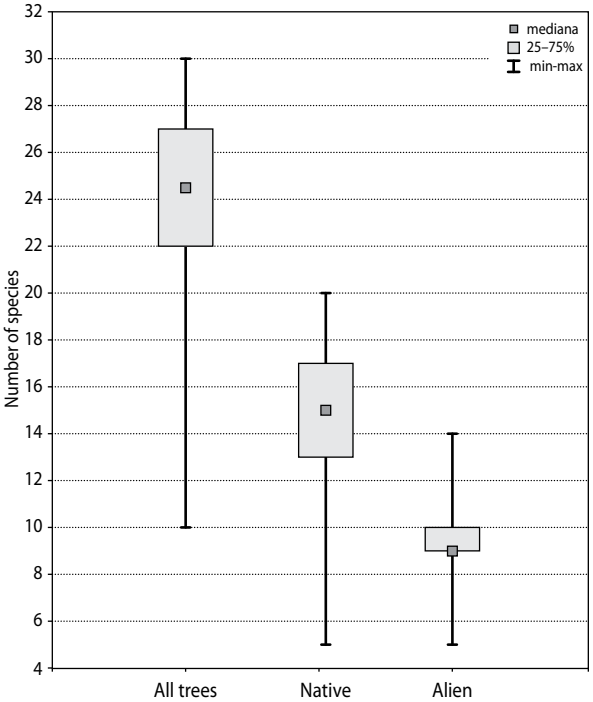


Figure 1. The average number of species in the analysed urban forests in Katowice

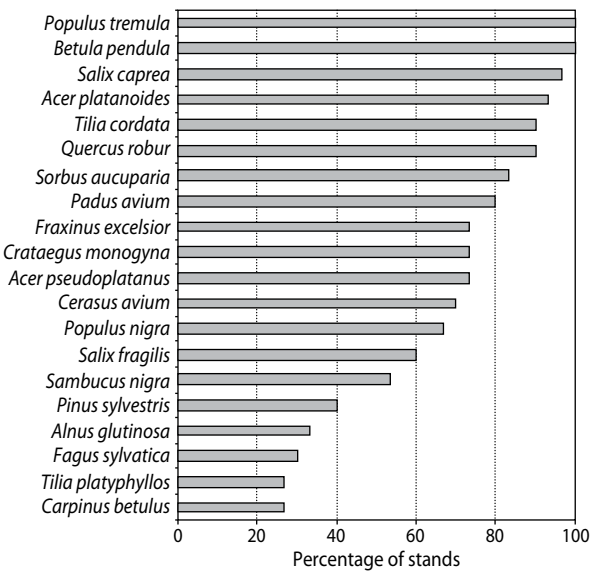


Figure 2. The most common native species in the analysed forests (above 25% of forests)

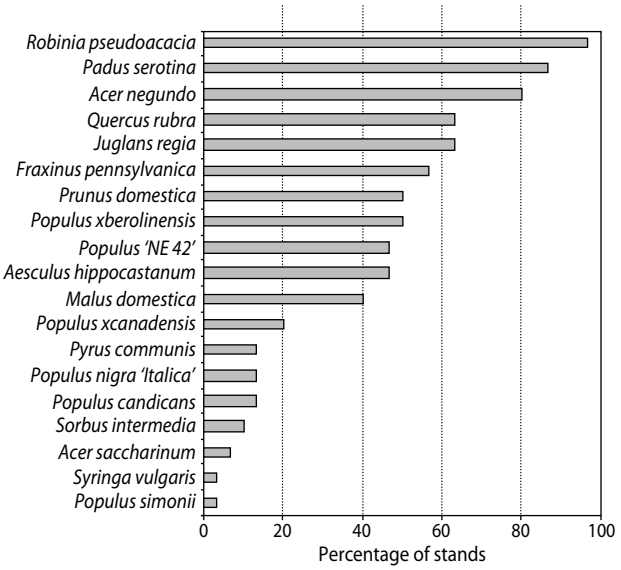


Figure 3. The most common alien species in the analysed forests (above 25% of forests)

The share of alien species in the stands of individual forests was significant, as they constituted from 15% to 44% of the total number of species (Fig. 4). Among the 20 trees most frequently included in the tree stands, as many as six are species of alien origin (Fig. 5).

The local potential of alien woody species can be determined using the abundance index of their occurrence in the understory (Tab. 3). The highest average abundance index values were obtained by *Padus serotina* (2.8), *Robinia pseudoacacia* (2.5), *Acer negundo* (2.2) and *Quercus rubra* (2.1).

Although some of the alien species were not spontaneous (some were planted), preferences for inhabiting the forest interior or its edges can be noticed. There are three groups of species:

– species recorded only in the forest ecotone zone (*Acer saccharinum* L., *Populus simonii* Carriére and *Syringa vulgaris* L.);
– species occurring more often in the ecotone zone (*Malus domestica* Borkh., *Populus* 'NE 42', *Populus candicans* Aiton, *Populus ×berolinensis* (K. Koch) Dippel, *Populus ×canadensis* Moench, *Prunus domestica* L., *Pyrus communis* L. and *Sorbus intermedia* (Ehrh.) Pers.),
– species occurring both on the edge and inside the forest (*Acer negundo*, *Aesculus hippocastanum* L.,

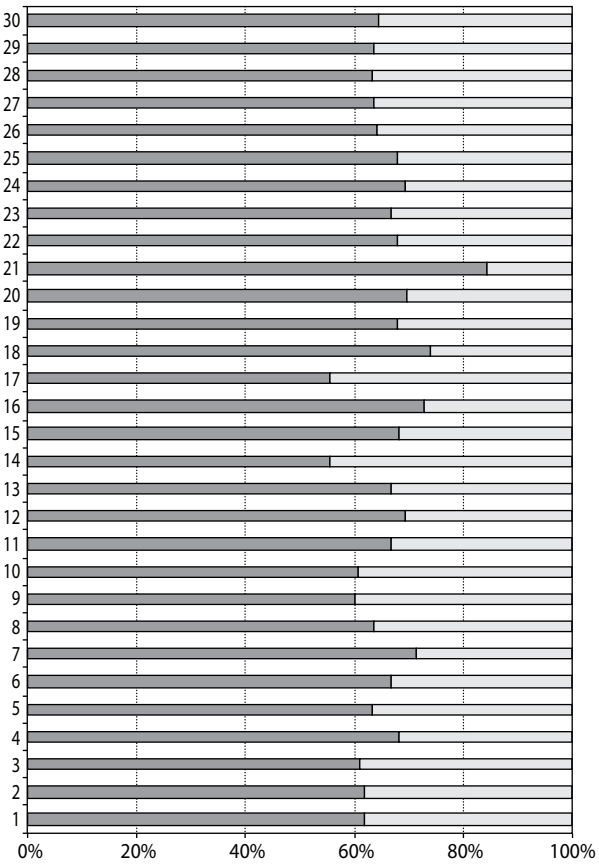


Figure 4. Percentage of native and alien tree species in the analysed forests (numbering of objects as in Tab. 1)

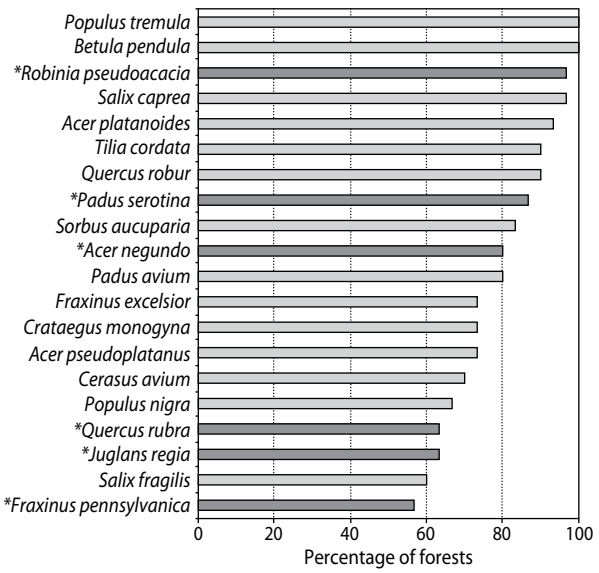


Figure 5. The most common tree species in the analysed forests; * – alien species

Fraxinus pennsylvanica Marshall, *Juglans regia* L., *Padus serotina*, *Populus* 'Italica', *Quercus rubra* and *Robinia pseudoacacia*).

No alien tree species was observed exclusively inside the forest.

Discussion

Urban forests, by definition, have a different character compared to large, dense, managed forest complexes. Urban forests (sensu stricto) are small, semi-natural woodlands, formed through natural regeneration on disturbed post-industrial sites or other neglected areas, usually not subject to systematic management measures (Konijnendijk 2003; Keil and Loos 2005; Randrup et al. 2005). This was the nature of the analysed urban forests in Katowice. Generally, these were deciduous forests with a visible share of alien species (only in some places, there was a small admixture of native coniferous species).

Many factors influence the structure of forests, including those in Katowice. On the one hand, these are general climatic and habitat conditions, and on the other, the genesis of the tree stand (planted or spontaneously formed) (McPherson et al. 1997). One of the most important habitat conditions is the type of soil. In urbanised and industrial areas (also in Katowice), anthropogenic soils dominate, shaped under the influence of human activity (Fajer 2008). Urban forests are often created on former urban and post-industrial wastelands (Keil and Loos 2005; Pietrzykowski 2016). Moreover, these are usually areas with an increased level of pollution (especially with heavy metals), which adversely affects the soil's microorganisms and biological activity (Grabińska 1988; Olszowska 2016). These soils usually also have a more alkaline reaction (Romańczyk et al. 2015). All these factors have an impact on the formation of the local vegetation, including the urban forests.

The origins of urban forests, also in Katowice, may be different. They arise either as a result of intentional human activity and the planting of specific species, or they develop spontaneously as a result of the natural colonisation of wastelands by species of various origins (Keil and Loos 2005). They may also arise as a result of a combination of these processes – reclamation plantings are supplemented by the natural succession of other

trees, something which is often observed in Katowice. Natural succession is evidenced by the large share of pioneer species such as *Betula pendula*, *Populus tremula* and *Salix caprea* (Keil and Loos 2005). In turn, old plantings are evidenced by, among others, the presence of old specimens of species used in reclamation (Keil and Loos 2005; Olszewski 2009). In Katowice, these include, for example, *Robinia pseudoacacia* and various taxa of the *Populus* genus. In the case of poplars, this applies especially to taxa that do not usually spread spontaneously, such as *Populus* ×*berolinensis*, *Populus* ×*canadensis*, *Populus* 'NE 42', *Populus* 'Italica' and *Populus simonii*. *Alnus glutinosa* (L.) Gaertn. is often used for recultivation (also in analysed stands in Katowice) – its ability to form a symbiotic relationship with nitrogen-fixing bacteria is an important factor stimulating the tree growth and soil development (Pensa et al. 2004; Wójcik and Krzaklewski 2019).

Native species usually prevail in the urban forest stands in Katowice. The most common species are *Betula pendula*, *Populus tremula* and *Salix caprea* (birch and aspen often dominate in terms of quantity). These are the important forest-forming species in disturbed habitats – light seeded, wind seeding, fast growing and usually the first to enter wastelands (Łukaszewicz 2016). They often dominate post-industrial wastelands and urban forests (Pensa et al. 2004; Kowarik et al. 2019). They are also used in the recultivation of post-industrial areas (Rostański 2006).

Particularly noteworthy, nevertheless, is the significant share of species of alien origin in the analysed stands. Among the 20 most frequently recorded trees, as many as six are alien species. Their presence in urban forests is facilitated by the fragmentation of tree stands, disturbances, earlier plantings and propagule pressure (Brothers and Spingarn 1992; Wagner et al. 2017). Therefore, they often constitute a significant element in this type of forests (Zipperer 2002; Kowarik et al. 2019). In the analysed stands, the most common alien species were *Robinia pseudoacacia*, *Padus serotina* and *Acer negundo*. In some forests, anthropophytes dominated – most often, it was *Robinia pseudoacacia*, and less frequently, *Padus serotina* and *Quercus rubra* were found.

It is worth noting that among the recorded alien tree species, there were no coniferous taxa. This is due to the fact, among others, that alien coniferous trees, although relatively often used for planting, are among the relatively few trees that establish and spread spontaneously (Křivánek et al. 2006; Danielewicz et al. 2020; Pliszko and Górecki 2022). Alien species of the *Picea* and *Pinus* genera may appear in urban forests as a result of previous plantings, as they are used for the recultivation of post-industrial areas (Mudrák et al. 2010).

The six most common trees of alien origin in the analysed stands are invasive species: *Acer negundo*, *Fraxinus pennsylvanica*, *Juglans regia*, *Padus serotina*, *Quercus rubra* and *Robinia pseudoacacia* (Tokarska-Guzik et al. 2012). These are also the most common alien trees in the European temperate forest (Lapin et al. 2019; Danielewicz et al. 2020; Langmaier and Lapin 2020; Šipek et al. 2022). Their spread was facilitated by their intensive introduction to forest cultivation and use for reclamation of post-industrial areas (Rostański 2006; Gazda 2013). Most of these species (except *Juglans regia*) are classified as 'transformers' – that is, species causing disturbances in the forest structure and habitat conditions (Richardson et al. 2000; Tokarska-Guzik 2005; Danielewicz et al. 2020). This applies especially to *Quercus rubra* – this species increases the shading of the forest floor, eliminates undergrowth plants, negatively affects the litter and the soil properties (activity of decomposing microorganisms and soil chemical properties) (Riepšas and Straigyte 2008; Woziwoda et al. 2014). The high potential of invasive species in Katowice's urban forests is evidenced by, among others, creating relatively abundant brushwood areas.

The establishment and spread of alien woody species is facilitated by climate warming (Theoharides and Dukes 2007; Robinson et al. 2020). In urbanised areas, the 'urban heat island' phenomenon also plays an important role, causing the growing season to extend (Kowarik 1995; Benedikz et al. 2005). Climate change affects the dynamics of alien species and increases the number of invasive species (Bellard et al. 2013; Robinson et al. 2020). Perfect examples of such changes are *Aesculus hippocastanum* and *Juglans regia*, relatively often found in the urban forests in Katowice. Back in the 1990s, these species were classified as cultivated and not established in Poland (Mirek et al. 1995). Currently, they have the status of established trees (Tokarska-Guzik et al. 2012; Mirek et al. 2020), and *Juglans regia* is even classified as an invasive species (Tokarska-Guzik et al. 2012). Both *Aesculus hippocastanum* and *Juglans regia* are listed among the 150 most widespread, established

alien species in Europe (Lambdon et al. 2008; Wagner et al. 2017), which is associated with the progressive warming of the climate (Loacker et al. 2007 ; Paź-Dyderska et al. 2021). They are found both in urban forests (Keil and Loos 2005) and, for example, riparian forests (Koba 2014). Interestingly, the high dynamics of the spread of *Juglans regia* is also caused by the dispersal of fruits by corvids (mainly jays), whose numbers in Poland have increased significantly in recent decades, especially in the cities (Lenda and Skórka 2009, 2018; Węgrzynowicz 2013; Cempulik and Beuch 2017).

In the urban forests in Katowice, most alien tree species occurred mainly or exclusively on the forest edges (in the ecotone). The ecotone is a zone with specific conditions – it receives more light, more wind and is warmer and drier than the forest interiors (Chen et al. 1999; Davies-Colley et al. 2000; Dovčiak and Brown 2014). Greater wind penetration also favours the influx of diaspores of wind-seeding species. This favours the success of alien species (Bierwagen 2005; Harper et al. 2005). This effect is particularly visible in smaller vegetation patches because fragmentation increases the proportion of the edge zone (Murcia 1995; Theoharides and Dukes 2007).

To better illustrate the character of urban forests in Katowice, it is necessary to mention the presence of other plants of alien origin that occur here. These include, for example, ornamental shrubs, most likely introduced as part of earlier recultivation (most often, *Philadelphus coronaries* L., *Physocarpus opulifolius* (L.) Maxim. and *Symphoricarpos albus* (L.) S.F. Blake). Among the herbaceous plants, the most common were *Reynoutria japonica* Houtt., *Solidago canadensis* L. and *Impatiens parviflora* DC. – species that are particularly able to naturalise in the forest environment and effectively compete with native species (Danielewicz et al. 2020; Langmaier and Lapin 2020; Šipek et al. 2022).

Conclusions

1. Research has confirmed the significant share of alien species in the tree stand structure of the urban forests in Katowice.
2. Invasive species are among the most common and abundant alien tree species in urban forests in Katowice (*Robinia pseudoacacia*, *Padus serotina*, *Acer negundo*, *Quercus rubra*, *Juglans regia* and *Fraxinus pennsylvanica*).
3. Conditions prevailing on the edge of urban forests (in the ecotone zone) – with more light, warmth and dryness than the forest interiors, and greater wind penetration favouring the inflow of diasporas – favour the occurrence of alien tree species.

References

Alvey, A.A. 2006. Promoting and preserving biodiversity in the urban forest. *Urban Forestry and Urban Greening*, 5, 195–201. DOI: 10.1016/j.ufug.2006.09.003

Aronson, M.F.J., Handel, S.N., La Puma, I.P., Clemants, S.E. 2015. Urbanization promotes non-native woody species and diverse plant assemblages in the NewYork metropolitan region. *Urban Ecosystems*, 18, 31–45. DOI 10.1007/s11252-014-0382-z

Barciak, A., Chojecka, E., Fertacz, S. (eds.) 2012. Katowice. Środowisko, dzieje, kultura, język i społeczeństwo. Tom 1. Muzeum Historii Katowic, Katowice.

Becerra, P.I., Simonetti, J.A. 2020. Native and exotic plant species diversity in forest fragments and forestry plantations of a coastal landscape of central Chile. *Bosque*, 41 (2), 125–136. DOI: 10.4067/S0717-92002020000200125

Bell, S., Blom, D., Rautamäki, M., Castel-Branco, C., Simson, A., Olsen, I.A. 2005. Design of urban forests. In: Urban forests and trees (eds. C. Konijnendijk, K. Nilsson, T.B. Randrup, J. Schipperijn). Springer, New York, Berlin, Heidelberg, 149–186.

Bellard, C., Thuiller, W., Leroy, B., Genovesi, P., Bakkenes, M., Courchamp, F. 2013. Will climate change promote future invasions? *Global Change Biology*, 19, 3740–3748. DOI: 10.1111/gcb.12344

Benedikz, T., Ferrini, F., Garcia-Valdecantos, J.L., Tello, M.-L. 2005. Plant quality and establishment. In: Urban forests and trees (eds. C. Konijnendijk, K. Nilsson, T.B. Randrup, J. Schipperijn). Springer, New York, Berlin, Heidelberg, 231–256.

Bierwagen, B.G. 2005. Predicting ecological connectivity in urbanizing landscapes. *Environment and Planning B: Planning and Design*, 32 (5), 763–776. DOI: 10.1068/b31134

Brothers, T. S., Spingarn, A. 1992. Forest fragmentation and alien plant invasion of central Indiana old-growth forests. *Conservation Biology*, 6, 91–100.

Cempulik, P., Beuch, S. 2017. Densities of breeding pairs of the Magpie *Pica pica* in differenthabitats of Upper Silesia in 1981–2015 (in Polish with English summary). *Ptaki Śląska*, 24, 63–73.

Chen, J. et al. 1999. Microclimate in forest ecosystem and landscape ecology. *BioScience*, 49, 288–297.

Costello, L.R., 1993. Urban forestry: a new perspective. *Arborist News*, 2, 33–36.

Danielewicz, W., Wiatrowska, B., Dajdok, Z., Tokarska-Guzik, B. 2020. Alien vascular plants established in forests of Poland (in Polish with English summary). *Fragmenta Floristica et Geobotanica Polonica*, 27 (2), 451–471. DOI: 10.35535/ffgp-2020-0027

Davies-Colley, R.J., Payne, G.W., van Elswijk, M. 2000. Microclimate gradients across a forest edge. *New Zealand Journal of Ecology*, 24 (2), 111–121.

Dovčiak, M., Brown, J. 2014. Secondary edge effects in regenerating forest landscapes: vegetation and microclimate patterns and their implications for management and conservation. *New Forests*, 45, 733–744. DOI: 10.1007/s11056-014-9419-7

Fajer, M. 2008. Gleby na obszarze Górnośląskiego Związku Metropolitalnego. In: Górnośląski Związek Metropolitalny. Zarys geograficzny (eds. R. Dulias, A. Hibszer). Polskie Towarzystwo Geograficzne, Oddział Katowicki, Sosnowiec, 119–130.

Fojcik, B., Wierzgoń, M., Chmura, D. 2019. Response of bryophytes to disturbances in managed forests. A case study from a Polish forest. *Cryptogamie, Bryologie*, 40 (10), 105–118. DOI: 10.5252/cryptogamie-bryologie2019v40a10

Gazda, A. 2013. Distribution of alien tree species in various forest communities of southern Poland (in Polish with English summary). *Zeszyty Naukowe Uniwersytetu Rolniczego w Krakowie*, 512, 1–118.

Grabińska, B. 1988. Szybkość rozkładu celulozy w glebach różnych środowisk leśnych środkowej Polski. *Archiwum Ochrony Środowiska*, 1/2, 89–98.

Gundersen, V., Frivold, L.H., Löfström, I., Jørgensen, B.B., Falck, J., Øyen, B.H. 2005. Urban woodland management – the case of 13 major Nordic cities. *Urban Forestry and Urban Greening*, 3, 189–202. DOI: 10.1016/j.ufug.2005.03.001

Harper, K.A. et al. 2005. Edge influence on forest structure and composition in fragmented landscapes. *Conservation Biology*, 19 (3), 768–782.

Jaszczak, R., Wajchman, S. 2014. Problems of forest management in municipal forests of the city of Poznań. *Civil and Environmental Engineering Reports*, 12 (1), 45–54. DOI: 10.2478/ceer-2014-0005

Kaliszewski, A. 2006. Urban forests – literature review on selected topics (in Polish with English summary). *Leśne Prace Badawcze*, 1, 103–118.

Keil, P., Loos, G.H. 2005. Urban woodland flora and vegetation on industrial fallow land in the Ruhrgebiet as a product of culture and nature – an outline of general tendencies. *Electronic Publication of the Biological Station of Western Ruhrgebiet*, 2, 1–13.

Kim, G. 2016. Assessing urban forest structure, ecosystem services, and economic benefits on vacant land. *Sustainability*, 8, 679. DOI: 10.3390/su8070679

Koba, J. 2014. Alien and invasive plant species in plant communities of floodplain forests of the Małopolska Upland. *Annales Universitatis Mariae Curie-Skłodowska*, *Sectio C*, 69 (2), 19–28. DOI: 10.1515/umcsbio-2015-0002

Konijnendijk, C.C. 1997. A short history of urban forestry in Europe. *Journal of Arboriculture*, 23 (1), 31–39.

Konijnendijk, C.C. 2003. A decade of urban forestry in Europe. *Forest Policy and Economics*, 5, 173–186. DOI: 10.1016/S1389-9341(03)00023-6

Konijnendijk, C.C., Ricard, R.M., Kenney, A., Randrup, T.B. 2006. Defining urban forestry – a comparative perspective of North America and Europe. *Urban Forestry and Urban Greening*, 4, 93–103. DOI: 10.1016/j.ufug.2005.11.003

Kowarik, I. 1995. Time lags in biological invasions with regard to the success and failure of alien species. In: Plant invasions – general aspects and special problems (eds. P. Pyšek, K. Prach, M. Rejmánek, M. Wade). Academic Publishing, Amsterdam, 15–38.

Kowarik, I., Hiller, A., Planchuelo, G., Seitz, B., Lippe, M., Buchholz, S. 2019. Emerging urban forests: opportunities for promoting the wild side of the urban green infrastructure. *Sustainability*, 11, 6318. DOI: 10.3390/su11226318

Křivánek, M., Pyšek, P., Jarošík, V. 2006. Planting history and propagule pressure as predictors of invasion by woody species in a temperate region.

Conservation Biology, 20 (5), 1487–1498. DOI: 10.1111/j.1523-1739.2006.00477.x

Lambdon, P.W. et al. 2008. Alien flora of Europe: species diversity, temporal trends, geographical patterns and research needs. *Preslia*, 80, 101–149.

Langmaier, M., Lapin, K. 2020. A systematic review of the impact of invasive alien plants on forest regeneration in European temperate forests. *Frontiers in Plant Science*, 11, 524969. DOI: 10.3389/fpls.2020.524969

Lapin, K. et al. 2019. Invasive alien plant species in unmanaged forest reserves, Austria. *NeoBiota*, 48, 71–96. DOI: 10.3897/neobiota.48.34741

Lenda, M., Skórka, P. 2009. Walnut *Juglans regia* – a new, potentially invasive species in native flora (in Polish with English summary). *Chrońmy Przyrodę Ojczystą*, 65 (4), 261–270.

Lenda, M., Knops, J.H., Skórka, P., Moroń, D., Woyciechowski, M. 2018. Cascading effects of changes in land use on the invasion of the walnut *Juglans regia* in forest ecosystems. *Journal of Ecology*, 106, 671–686. DOI: 10.1111/1365-2745.12827

Lepczyk, C.A., Aronson, M.F.J., Evans, K.L., Goddard, M.A., Lerman, S.B., MacIvor, J.S. 2017. Biodiversity in the city: Fundamental questions for understanding the ecology of urban green spaces for biodiversity conservation. *BioScience*, 67 (9), 799–807. DOI: 10.1093/biosci/bix079

Loacker, K., Kofler, W., Pagitz, K., Oberhuber, W. 2007. Spread of walnut (*Juglans regia* L.) in an Alpine valley is correlated with climate warming. *Flora*, 202, 70–78. DOI: 10.1016/j.flora.2006.03.003

Łukaszewicz, J. 2016. Znaczenie brzóz i topól w planowaniu urządzeniowo-hodowlanym na siedliskach zniekształconych. In: Siedliska leśne zmienione i zniekształcone (ed. R. Zielony). Dyrekcja Generalna Lasów Państwowych, Warszawa, 157–176.

Mavimbela, L.Z., Sieben, E.J.J., Procheş, Ş. 2018. Invasive alien plant species, fragmentation and scale effects on urban forest community composition in Durban, South Africa. *New Zealand Journal of Forestry Science*, 48, 19. DOI: 10.1186/s40490-018-0124-8

McPherson, E.G. et al. 1997. Quantifying urban forest structure, function, and value: the Chicago Urban Forest Climate Project. *Urban Ecosystems*, 1, 49–61.

Miller, R.W. 1997. Urban forestry: planning and managing urban green spaces. Prentice Hall, New Jersey.

Mirek, Z., Piękoś-Mirkowa, H., Zając, A., Zając, M. 1995. Vascular plants of Poland. A checklist. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

Mirek, Z., Piękoś-Mirkowa, H., Zając, A., Zając, M. 2020. Vascular plants of Poland: an annotated checklist. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

Mudrák, O., Frouz, J., Velichová, V., 2010. Understory vegetation in reclaimed and unreclaimed postmining forest stands. *Ecological Engineering*, 36, 783–790. DOI: 10.1016/j.ecoleng.2010.02.003

Murcia, C. 1995. Edge effect in fragmented forests: implication for conservation. *Trends in Ecology and Evolution*, 10, 58–62.

Olszewski, P. 2009. Use functions of plant cover on the sites of liquidated coal-mines in Dąbrowa Basin and their application in the process of reclamation (in Polish with English summary). *Prace Naukowe GIG. Górnictwo i Środowisko*, 3, 89–112.

Olszowska, G. 2016. Aktywność biochemiczna gleb jako wskaźnik naturalności siedliska leśnego. In: Siedliska leśne zmienione i zniekształcone (ed. R. Zielony). Dyrekcja Generalna Lasów Państwowych, Warszawa, 31–41.

Paź-Dyderska, S., Jagodziński, A.M., Dyderski, M.K. 2021. Possible changes in spatial distribution of walnut (*Juglans regia* L.) in Europe under warming climate. *Regional Environmental Change*, 21, 21–18. DOI: 10.1007/s10113-020-01745-z

Pensa, M., Sellin, A., Luud, A., Valgma, I. 2004. An analysis of vegetation restoration on opencast oil shale m in Estonia. *Restoration Ecology*, 12 (2), 200–206.

Pietrzykowski, M. 2016. Diagnoza siedlisk na gruntach pokopalnianych zrekultywowanych dla leśnictwa. In: Siedliska leśne zmienione i zniekształcone (ed. R. Zielony). Dyrekcja Generalna Lasów Państwowych, Warszawa, 89–105.

Pliszko, A., Górecki, A. 2022. The invasive potential of alien coniferous trees and shrubs grown as Christmas trees in Poland (in Polish with English summary). *Wiadomości Botaniczne*, 66, 665. DOI: 10.5586/wb.665

Randrup, T.B., Konijnendijk, C., Dobbertin, M.K., Prüller, R. 2005. The concept of urban forestry in Europe. In: Urban forests and trees (eds. C. Konijnendijk, K. Nilsson, T.B. Randrup, J. Schipperijn). Springer, New York, Berlin, Heidelberg, 9–21.

Richardson, D.M., Pyšek, P., Rejmánek, M., Barbour, M.G., Panetta, F.D., West, C.J. 2000. Naturalization and invasion of alien plants: concepts and definitions. *Diversity and Distribution*, 69 (2), 93–107.

Riepšas, E., Straigyte, L. 2008. Invasiveness and ecological effects of red oak (*Quercus rubra* L.) in Lithuanian forests. *Baltic Forestry*, 14 (2), 122–130.

Robinson, T.B., Martin, N., Loureiro, T.G., Matikinca, P., Robertson, M.P. 2020. Double trouble: the implications of climate change for biological invasions. *NeoBiota*, 62, 463–487. DOI: 10.3897/neobiota.62.55729

Romańczyk, M. et al. 2015. Opracowanie ekofizjograficzne do Planu Zagospodarowania Przestrzennego Województwa Śląskiego. Centrum Dziedzictwa Przyrody Górnego Śląska, Katowice.

Rostański, A. 2006. Spontaneous plant cover on colliery spoil heaps in Upper Silesia (Southern Poland) (in Polish with English summary). Wydawnictwo Uniwersytetu Śląskiego, Katowice.

Rydberg, D., Falck, J. 2000. Urban forestry in Sweden from a silvicultural perspective: a review. *Landscape and Urban Planning*, 47, 1–18.

Sieghardt, M. et al. 2005. The abiotic urban environment: impact of urban growing conditions on urban vegetation. In: Urban forests and trees (eds. C. Konijnendijk, K. Nilsson, T.B. Randrup, J. Schipperijn). Springer, New York, Berlin, Heidelberg, 9–21.

Šipek, M., Kutnar, L., Marinšek, A., Šajna, N. 2022. Contrasting responses of alien and ancient forest indicator plant species to fragmentation process in the temperate lowland forests. *Plants*, 11, 3392. DOI: 10.3390/plants11233392

Theoharides, K.A., Dukes, J.S. 2007. Plant invasion across space and time: factors affecting nonindigenous species success during four stages of invasion. *New Phytologist*, 176, 256–273. DOI: 10.1111/j.1469-8137.2007.02207.x

Tokarska-Guzik, B. 2005. Invasive ability of kenophytes occurring in Poland: a tentative assessment. *NeoBiota*, 6, 47–65.

Tokarska-Guzik, B. et al. 2012. Alien plants in Poland with particular reference to invasive species (in Polish with English summary). Generalna Dyrekcja Ochrony Środowiska, Warszawa.

Tyrväinen, L., Pauleit, S., Seeland, K., de Vries, S. 2005. Benefits and uses of urban forests and trees In: Urban forests and trees (eds. C. Konijnendijk, K. Nilsson, T.B. Randrup, J. Schipperijn). Springer, New York, Berlin, Heidelberg, 81–114.

Wagner, V. et al. 2017. Alien plant invasions in European woodlands. *Diversity and Distributions*, 23, 969–981. DOI: 10.1111/ddi.12592

Węgrzynowicz A. 2013. Changes in abundance and nest location of the Magpie *Pica pica* and Hooded Crow *Corvus cornix* from 1974 to 2009 in Warsaw (in Polish with English summary). *Ornis Polonica*, 54, 12–24.

Województwo śląskie. Podregiony, powiaty, gminy. 2019. Urząd Statystyczny w Katowicach, Katowice.

Woziwoda, B., Kopeć, D., Witkowski, J. 2014. The negative impact of intentionally introduced *Quercus rubra* L. on a forest community. *Acta Societatis Botanicorum Poloniae*, 83, 39–49. DOI: 10.5586/asbp.2013.035

Wójcik, J., Krzaklewski, W. 2019. Afforestation as a method of reclamation of soilless land in brown coal mining in Poland (in Polish with English summary). *Ecological Engineering and Environmental Technology*, 20 (1), 24–37. DOI: 10.12912/23920629/106204

Zipperer, W.C. 2002. Species composition and structure of regenerated and remnant forest patches within an urban landscape. *Urban Ecosystems*, 6, 271–290.