JEE Journal of Ecological Engineering
Volume 19, Issue 6, November 2018, pages 14–23
https://doi.org/10.12911/22998993/92888

Received: 2018.06.12
Accepted: 2018.08.15
Published: 2018.11.01

Invasive Species and Maintaining Biodiversity in the Natural Areas – Rural and Urban – Subject to Strong Anthropogenic Pressure

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ABSTRACT
Expansion of invasive species can be clearly seen all over Poland. Foreign tree and herbaceous plant species are effectively taking over more and more habitats competing with native vegetation. This phenomenon is strongly pronounced in the areas subject to strong anthropogenic pressure. The presence of invasive plants replacing the native vegetation is a threat for biodiversity and ecological balance. The research carried out by the authors between 2011 and 2017 on selected sites (comparatively: urban and open spaces, including a 600 ha park and a 10 km long forest strip along a river) confirms the pressure exerted by invasive species irrespective of the natural conditions of a particular site or its type – in each case it is most prominent in areas where vegetation is not properly maintained or where it is not maintained at all. The research was based on the dendrological inventories and phytosociological assessments. The inventories were used for a detailed assessment of both the condition and structure of tree-stands, including accounting for invasive species. Phytosociological assessment can, among others, form a basis for forecasting ecological stability of individual plant communities. Uncontrolled expansion of invasive species, especially in the areas of strong anthropogenic pressure, may cause unfavourable natural succession and in consequence – destabilisation of ecological system in a given area.

Keywords: anthropogenic pressure, alien plant species, biodiversity, vegetation maintenance

INTRODUCTION

Invasive plant species have been introduced into environment by man – either deliberately (by introducing utility plants) or inadvertently (accidentally introduced species). Currently, approximately 12 thousand foreign species have been identified, 10–15% of which are believed to have a negative influence of varying degree (Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22, October 2014). Such plants are mainly species cultivated in a controlled manner (agricultural cultivation, botanical gardens) which have found their way into the environment, such as *Impatiens parviflora* DC. – imported into botanical gardens in the 19th century from central Asia, now commonly seen in European forests and parks (Gwiazdowski, 2014). Some species, such as *Prunus serotina* (Ehrh.) Borkh., initially planted for practical reasons (acquiring precious wood, recreating tree-stands e.g. in industrial areas)[1], then to improve biotic communities (enriching species pool of lower forest strata), have successfully acclimatized in new areas (Sudnik-Wójcikowska, 1987). Similarly, *Quercus rubra* L. – resistant to pollution, was commonly used, among other, as a fore-crop in poor habitats, including industrial idle lands (such as afforestation in sand pits) (Strzelecki & Sobczak, 1972). Both species turned out to be extremely

[1] Its typical use include recreating forest-stands in mining break-downs, reinforcing stockpiles, ravines and their slopes, due to its resistance to dust and fumes and low soil requirements (dry, acidy soils) (Strzelecki & Sobczak, 1972; Seneta & Dolatowski, 2012).

expansive – black cherry, which in European forests has a bush form, grows into thick scrubs effectively blocking the development of other native tree species, thus hindering the forest renewal (Seneta & Dolatowski, 2012). A large number of black cherry patches have been found with a high number of specimens in each patch. This species keeps on taking over new plots and areas, easily invading the natural, semi-natural and anthropogenic vegetation communities. The areas where this species is a threat include forests, protected areas or habitats disturbed by anthropogenic pressure (Tokarska-Guzik et al., 2012). In a few decades after introduction of red oak into cultivated forests (in the beginning of 20th century [Sudnik-Wójcikowska, 1987]), its spontaneous spreading has been reported in numerous plots in various regions, as well as a large number of specimens in newly created patches (as a result of its fecundity – the species grows faster than other oaks and bears fruit already at a young age). Red oak continues expanding onto new plots and areas[2]. It may be harmful in forests and protected areas, since it easily penetrates into natural communities (Sudnik-Wójcikowska, 1987; Seneta & Dolatowski, 2012; Tokarska-Guzik et al., 2012). Another tree species – *Acer negundo* L. – was brought to Europe in the 17th century and in the 18–19th century to Poland (in Warsaw – approx. 1880). Initially, it was considered valuable due to its quick growth, and as such used in gardens (in the beginning of the 20th century, often used in parks and planted in the country). Since 1940s, its strong expansion can be seen; in the 1980s it had already become one of the most common plants in Warsaw, often seen in anthropogenic habitats, acclimated in forest communities (such as riparian forests along Vistula River, border area of oak-hornbeam forests, pine and oak forests) (Sudnik-Wójcikowska, 1987). The presence of *Acer negundo* L. in riparian forests along the Vistula river should be considered a stage of secondary replacement succession (Matuszkiewicz & Roo-Zielińska, 2000).

Foreign herbaceous plants include *Reynoutria japonica* Houtt. – found in Europe since the middle of the 19th century; first reports of this taxon in Warsaw appeared in 1964.; in 1980s it became common in anthropogenic ruderal and semi-natural habitats (along roads, at waste dumps, idle lands), but also at borders of willow riparian forests, alder forests, pine-birch-oak stands, in shrubs near water reservoirs (Sudnik-Wójcikowska, 1987). Another example includes *Echinocystis lobata*, cultivated after 1945 in Cracow; in 1980s it was commonly seen (e.g. in Warsaw) in anthropogenic habitats (along roads, waste dumps, near allotment gardens etc.) but also in semi-natural and natural communities (mainly in willow and willow-poplar riparian forests) (Sudnik-Wójcikowska, 1987).

Since the middle of the 20th century, a clear increased expansiveness of many foreign herbaceous plant species (e.g. *Reynoutria japonica, Echinocystis lobata, Solidago gigantea, Impatiens parviflora*) as well as tree species (e.g. *Acer negundo, Prunus serotina, Robinia pseudoacacia*) can be observed. Other species, such as *Quercus rubra* successfully reappear in anthropogenic habitats and forests (Sudnik-Wójcikowska, 1987).

Expansion of cities and industrial areas, exerting anthropogenic pressure over greater areas of land contributes to the transformation of habitats and their plant communities. This results in an increased number of sites with disturbed soil and water conditions, often polluted, which are suitable for highly tolerant species that continue to take over a particular ecosystem. Highly expansive foreign species may replace the local populations, leading to a reduction in the species count and finally to a change of ecosystem structure and destabilisation of the entire natural system in a given area (Gwiazdowski, 2014). As a result of introduction of foreign species into forests[3], entire forest sub-compartments became dominated by one "exot" or tree-stands composed of native species with an addition of foreign taxons with a varying degree of mix. Some foreign species may become invasive if they spontaneously spread and infiltrate natural biocenoses (Gazda & Augustynowicz, 2014). The presence of invasive vegetation replacing the native vegetation is a

[2] Red oak currently is present in approx. 3% of forest sub-compartments (nearly 5% of national forests' area). It is a dominant species in approx. 0.5% of forest sub-compartments, so 3 900 ha compared to approx. 80 ha in mid 20th century – a 50-fold increase in area (Gazda & Augustynowicz, 2014).

[3] Over 30 foreign tree species have been introduced into Polish forests, including 22 coniferous species and 9 deciduous species, some of which are more numerous than others, such as Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), red oak (*Quercus rubra* L.), white pine (*Pinus strobus* L.) (Seneta & Dolatowski, 2012; Gazda & Augustynowicz, 2014). Other species previously cultivated as ornamental species include: box alder (*Acer negundo* L.), black cheery (*Prunus serotina* (Ehrh.) Borkh), black locust (*Robinia pseudoacacia* L.) (Gazda & Augustynowicz, 2014).

threat for biodiversity and ecological balance at species level (change of ecosystem species compositions) and super-species level (threat to habitat and ecosystem diversity). Additionally, some species, especially in the locations where humans are present, pose a health hazard (such as low ragweed pollen, which causes strong allergic reactions, or Sosnowsky's hogweed causing painful burns) (Gwiazdowski, 2014)[4].

MATHERIALS AND METHODS

In order to identify the invasive plants appearing in the environment, the authors have conducted research in selected sites between 2011 and 2017. These sites included managed urban sites and rural areas, recreational (5 parks, including one with an area of approx. 600 ha) and technical (2 stripes of forests near water, inducing one 10 km long), as well as unmanaged sites (2 areas). The selected areas are subject to varying degrees of anthropogenic pressure. For the last 40 to 80 years, the vegetation succession (limited human interference) took place in whole or part of these areas. The research carried out in the sites has been preceded with the analysis of natural conditions (climate, soil, water conditions, habitat etc.) as well as functional and spatial analyses. The detailed research is based on the dendrological inventories and phytosociological assessments. The inventories were used for a detailed assessment of both condition and structure of tree-stands (spatial structure, species composition, health, age) including accounting for invasive and expansive species (e.g. Fortuna-Antoszkiewicz & Łukaszkiewicz 2017; Łukaszkiewicz & Fortuna-Antoszkiewicz 2017). These comprised: identification of taxons, their frequency and distribution, dendrometric measurements of trees/shrubs. Phytosociological assessment (phytosociological photographs using a 5-point Braun-Blanquet scale) was carried out to identify the vegetation communities and formed a basis for forecasting ecological stability of individual phytocenoses (Wysocki & Sikorski, 2009).

RESULTS

The research carried out in sites in various regions of Poland (Figure 1) resulted in identification of the following invasive species (Table 1): trees (4 taxons) – *Prunus serotina* Ehrh., *Quercus rubra* L., *Acer negundo* L., *Robinia pseudoacacia* L.; herbaceous plants (7 taxons) – *Reynoutria japonica* Houtt., *Reynotria* x*bohemica* Chrtek et Chyrtkova, *Impatiens glandulifera* Royle, *Impatiens parviflora* DC., *Solidago canadensis* L., *Solidago gigantea* Aiton, *Echinocystis lobata*[5].

The most common invasive taxons in the researched area include *Robinia pseudoacacia* L., *Acer negundo* L. and *Reynoutria japonica* Houtt. – each found in 4 sites; the least common – *Echinocystis lobata* – found in one site. In decreasing frequency: in 3 sites – *Quercus rubra* L., *Prunus serotina* Ehrh., *Impatiens parviflora* DC.; in 2 sites – *Reynotria* x*bohemica* Chrtek et Chyrtkova, *Impatiens glandulifera* Royle, *Solidago canadensis* L., *Solidago gigantea* Aiton.

In the existing tree-stands, invasive tree species can be found mainly around mother specimens, but they also invade open areas (unused park interiors, mini-interiors created after felling of dead large tree specimens, at fringes of the tree-stand). In the researched sites, invasive herbaceous plants can be found in open and well sunlit patches of land, mainly in synanthropic habitats (e.g. near communication routes).

Frequency and numbers of individual invasive taxons are varied:

- they are more numerous in the intensively utilised areas with a stronger anthropogenic pressure, unmaintained or maintained only to a minimum degree (such as Chorzów – expansive part, on a hill; Warsaw: Ursynów park – reservation part at the foot of the escarpment, Żerań Canal – in the areas with high penetra-

[4] In Poland, the management of foreign species is regulated by the Act of 16 April 2004 on protection of the environment as amended and Resolution of the Minister of Environment of 9 September 2011 on a list of alien plants and animals which if released into environment may threaten native species or habitats [Journal of Laws no. 210, item 1260], and at European level – Regulation (EU) No. 1143/2014 of the European Parliament and the Council of 22, October 2014 on the prevention and management of the introduction and spread of invasive alien species (European Union Journal of Law L 317/35).

[5] Clearly dominant herbaceous expansive species forming patches of dense monocultures have been identified in sites: they are an indication of high nitrogen (nitrite) concentration and a proper distribution of humus in the soil. These include: common nettle (*Urtica dioica*) – typical to mesophilic herbaceous communities; ground elder (*Aegopodium podagraria*) – growing among other in elm and ash forests; hemp-agrimony (*Eupatorium cannabinum*) – a rhizome plant growing in bogs formed by water containing calcium compounds and in spring water communities.

Figure 1. Location of research polygons in Poland (prepared by: P. Wiśniewski)

tion, Exhibition Canal; Radziejowice – eastern periphery near expressway; Sopot park);

- in the areas with weaker anthropogenic pressure, the invasive plants are less numerous (such as Southern escarpment in Bydgoszcz, Kobyłka pond and scrub complex, Żerań Canal – in less used locations) and are less varied in terms of species (e.g. Wielgie park – only one taxon: *Echinocystis lobata*; grows seasonally in a depression, within the water way area on a patch with full sun exposition, covering 100% of available space);
- in the heavily used sites with strong anthropogenic pressure in plots subject to maintenance activities (such as mowing, clearing/correction of small trees in lower forest strata), the invasive plants are basically absent (e.g. Ursynów park in escarpment crown) or are present only in controlled spots (e.g. Silesia Park – western intensive zone).

SILESIA PARK IN CHORZÓW – CASE STUDY

Silesia Park is a special site, it has an area of 600 ha, and was established (in 1950–1968) on post-industrial and degraded lands within the Silesia agglomeration. It is an area subject to strong anthropogenic pressure (approx. 3 million users annually). The current species structure of the park is a consequence of 60 years of often spontaneous growth, i.e. secondary succession. In the initial stage of Park establishment, the tree and shrub species were introduced for the purpose of reclamation and phytoremediation. This decision was made because most of the Park area had poor soil (e.g. podzol), additionally degraded by mining and heavy industry. Forests were planted using pioneering species, hoping that as they grew, favourable conditions (habitat transformation) for more demanding and long living species would be created. The used native species included: birch, some poplars (aspen, black, white) as well as willows, hazel and elder. Two foreign species, already present in the area were also planted: *Quercus rubra* L. and *Prunus serotina* Ehrh. (Łukaszkiewicz & Fortuna-Antoszkiewicz 2017). In this period, these species were commonly used in western Poland for afforestation and as a forecrop for poor and degraded soils.

In 2013–2014, the authors conducted an evaluation of Silesia Park vegetation. The tree-stand structure analysis carried out within its current boundaries covered: spatial and species structure, age and health. Additionally, phytosociological evaluation was carried out in selected plots (Figure 2); the species composition and spatial structure of communities was analysed with special attention given to undergrowth strata (herbaceous plants). In general, the following phytocenoses are present in Silesia Park: a/ xerothermic turfs; b/ pasture-like and near pasture meadows – in the areas of expansive park lawns; c/ wet meadows, e.g. in terrain depressions or near water reservoirs; d/ water and near water communities

Table 1. Invasive plants in the investigated objects (elaborated: B. Fortuna-Antoszkiewicz, J. Łukaszkiewicz, E. Rosłon-Szeryńska, P. Wiśniewski, 2011–2017)

Object / location / surroundings / type of object / characteristics / years of research / area covered by research		
Phytosociological communities (dominant)	**Invasive plants occurring in the area**	**Maintenance of vegetation**
PARKS AND GARDENS		
1/ Silesia Park (The Gen. George Ziętek Voivodship Park of Culture and Recreation) / Chorzów, Upper Silesian region, in the triangle of three large industrial cities: Chorzów, Katowice and Siemianowice Śląskie / in the neighborhood: urban areas with multi-family housing + main traffic routes / area recultivated – city park (formerly: the so-called folk park) of a supralocal (regional) character (1950s - 1960s) / **the south-west part -** composed classical forms of vegetation; **east part** - with a compact, dense stand / **2013-2016** / ca. **600 ha**		
Actual vegetation: xerothermic grasslands; meadows with pasture and semi-pasture features - in the area of extensive park lawns; wet meadows - eg in depressions of the area, or in the vicinity of water reservoirs; by-water and water communities (peripheral zone of park ponds); communities having the features of alder-ash carrs, riparian forests, oak-hornbeam-linden forest, oak woods and forest fringe communities - in the area of extensive park stands; synanthropic or semisynanthropic communities - in areas developed extensively or completely abandoned to secondary plant succession.	**Woody species:** *Quercus rubra* L., *Prunus serotina* (Ehrh.) Borkh. **Herbaceous species:** *Reynoutria japonica* Houtt., *Reynotria xbohemica* Chrtek et Chyrtkova, *Impatiens glandulifera* Royle, *Impatiens parviflora* DC., *Solidago canadensis* L., *Solidago gigantea* Aiton	**Not occurring on a larger part of the area** (in the eastern extensive zone, on the hill - an area with a dense forest stand)
2/ Park in Radziejowice / central Mazovia, open areas (agricultural) / the neighborhood : rural areas, on fragments - single-family housing / a historic palace and park complex (landscape park - beginning of the 19th century) / **west part -** composed classical forms of vegetation; eastern part – naturalistic / **2015** / ca. **25 ha**		
Potential vegetation: subcontinental oak-hornbeam forests of the Middle Polish variety. **Actual vegetation:** [forest communities] *Ribeso nigri-Alnetum; Fraxino-Alnetum; Tilio cordatae-Carpinetum betuli caricetosum remotae; Tilio cordatae - Carpinetum betuli typicum*; [meadow communities] *Cirsietum rivularis; Caricetum gracilis;* *Arrhenatheretum elatioris.*	**Woody species:** *Prunus serotina* (Ehrh.) Borkh. - in open areas of the terrain (mini interiors); *Quercus rubra* L. - occurs singly on peripheral fragments (East); **Herbaceous species:** *Reynoutria japonica* Houtt., *Impatiens glandulifera* Royle, *Impatiens parviflora* DC	**Not occurring on a peripheral zone of park** (naturalistic zone, eastern)
3/ Park in Wielgie / southern Mazovia / surrounded by: open and agricultural areas / **2012** / ca. **8 ha /** historic landscape park (middle of 19th century) / garden's composition forms in decline; throughout the area - natural succession		
Potential vegetation: *Fraxino-Alnetum* - in the lowest part; *Tilio-Carpinetum* - in the upper part. **Actual vegetation:** domination of plants from *Circeo-Alnetum* i *Tilio-Carpinetum;* on a part of the area - monoculture of herbaceous species, e.g. *Urtica dioica* (from mesophilic herbs), *Aegopodium podagraria* (occur. among others in riparian forests), *Eupatorium cannabinum* (occur. on swamps with water incl. Ca compounds and in communities accompanying w spring areas).	**Herbaceous species:** *Echinocystis lobata* - 1. position	**Not occurring in the whole area** (compact tree stand) **/** neglected since the 1940s.
4/ Park Ursynów - SGGW (WULS) / Warsaw / on top of Warsaw Escarpment, the southern part / from the south - intense multi-family housing; from north - open areas with investment pressure / historical palace- park ensemble (18th century) / headquarters of the university / on the top of escarpments - composed garden forms; at the foot of the escarpment - a naturalistic part **(nature reserve) / 2011-2012** / ca. **8 ha**		
Potential vegetation: top of the escarpment: *Tilio-Carpinetum typicum;* an escarpment area (slopes and lower terrace): stand similar to the stand of potential vegetation. **Actual vegetation:** communities of eutrophic deciduous forests (class *Querco-Fagetea*); meadow and pasture communities (class *Molinio-Arrhenatheretea*); ruderal communities (class *Artemisietea vulgaris*) + associated species.	**Herbaceous species:** *Reynoutria japonica* Houtt., *Impatiens parviflora* DC. - occur at the foot of the escarpment	**Continuous maintenance** care on the crown of the escarpment / **the part of the area without maintenance** - on the slope and at the foot of the escarpment
5/ Historical palace- park ensemble in Sopot / a part of the North Park - a clearing and woodland around the lime pleaching (so called "*bindage*") / the Skarpa Sopocka Upland, Franciszka Goyka str. 1-3 / surrounded by: Skarpa Sopocka forests, residential development / historical park by estate of Wilhelm Jüncke (1903 r.) / garden's composition in landscape style / **2011** / ca. **0,5 ha**		

Table 1 cont.

Object / location / surroundings / type of object / characteristics / years of research / area covered by research		
Phytosociological communities (dominant)	**Invasive plants occurring in the area**	**Maintenance of vegetation**
Potential vegetation: *Galio odorati-Fagetum* in the lower part and on slopes of the escarpment; *Stellario-Carpinetum* - in the part of the upland. **Actual vegetation:** Overgrowing of glades with a degenerative form of substitute forest and shrub communities, mainly of features of oak-hornbeam forests.	**Woody species:** *Robinia pseudoacacia* L.	**No maintenance** for about 40 years
BELT PLANTINGS AND UNDEVELOPED AREAS		
6/ Area along the Wystawowy Canal [Exhibition Canal] / Warsaw, Saska Kępa / in neighborhood: allotments (East) and multi-family housing (West) / water-side woodlots / spontaneous with the remaining composed plantings from the 1970s / **2017** / strip of land ca. **5,0 ha (**length 1170 m, wide 27-60 m)		
Potential vegetation: communities of deciduous forests with maples and robinia similar to reach oak-hornbeam forests with elements of *Carpinion* (All.) i *Robinietea* (Cl.). **Actual vegetation:** a complex of poorly developed segetal and ruderal communities (with the domination of *Galinsogo-Setarietum*) in the allotment gardens.	**Woody species:** *Acer negundo* L.	**Sporadic / periodic** along both banks of the Canal
7/ South Escarpment in Bydgoszcz / Bydgoszcz, South Escarpment, Toruńska str./ surroundings: multi-family buildings / undeveloped land / spontaneous plants communities - habitat of slope oak-hornbeam / **2017** / ca. **0.6 ha** (slope with a length of 200 m and a width of 30 m)		
Potential vegetation: subcontinental oak-hornbeam forests from the belt of the great valleys of the Wielkopolska-Kujawska Region, from the Kujawski District. **Actual vegetation:** *Tilio-Carpinetum typicum* sub-continental forest of the slope variety with a small amount of invasive plants in the undergrowth and undergrowth.	**Woody species:** *Robinia pseudoacacia* L., *Acer negundo* L.)	**Lack of maintenance/** limited penetration (the path along escarpment's slope)
8/ The area along the Żerański Canal / fragment - west bank / Warsaw, Żerań / municipality Nieporęt / open areas; development of single and multi-family housing / / water-side, protective woodlots / spontaneous vegetation with the remaining composed plantings from the 1960s / **2015 -2016** / ca. **25 ha** (strip of land length ca. **10 km** / average wide 20,0 [30,0] m)		
Potential vegetation: communities of deciduous forests with robinia similar to poor oak-hornbeam forests and mixed coniferous forests with elements of classes: *Querco-Fagetea, Vaccinio-Piceetea* and *Robinietea* (Cl.); communities of thermophilic deciduous forests with robinia, similar to bright oakwood forests (with elements of *Quercetalia pubescetis* order (O.) and *Robinietea* class (Cl.). **Actual vegetation**: degenerative forms of substitute forest and shrub communities, including subcontinental and mixed coniferous forest (*Querco roboris-Pinetum* sensu lato, *Pino-Quercetum* / *Vaccinio-Picetea* class) with a significant proportion of neophytes; locally: anthropogenic robinia forest (association *Chelidonio–Robinietum,* class *Robinietea*); locally: communities of compact sandy grasslands with sheep's fescue (mainly associations: *Diantho-Armerietum, Sileno-Festucetum* and others).	**Woody species:** *Quercus rubra* L., *Prunus serotina* (Ehrh.) Borkh., *Robinia pseudoacacia* L., *Acer negundo* L. **Herbaceous species:** *Reynoutria japonica* Houtt., *Reynotria xbohemica* Chrtek et Chyrtkova, *Solidago canadensis* L., *Solidago gigantea* Aito	**Not occurring in the whole area** / negligence since the 1980s.
9/ Ponds - thicket complex in Kobylka (wasteland) / Kobylka, Napoleona street - green in the industrial zone / surrounded by: industrial plants, railway track / undeveloped land / by-water vegetation in the area of ponds formed in the former channel of the Długa river in Kobyłka / **2015** / ca. **2 ha**		
Potential vegetation: sedge and swamp communities of the class *Phragmitetea;* riparian forest (*Salici-Populetum*) - in the lower part; oak-hornbeam forests of low variety (*Tilio-Carpinetum*) - in the upper part. **Actual vegetation:** water and by-water communities (peripheral zone of ponds); nitrophilous shrub-thicket communities (*Sambuco-Salicilion*), being a further stage of succession in the forest regeneration process; communities with the characteristics of riparian forests and low oak-hornbeam forests.	**Woody species:** *Robinia pseudoacacia* L., *Acer negundo* L	**Lack of maintenance -** no penetration

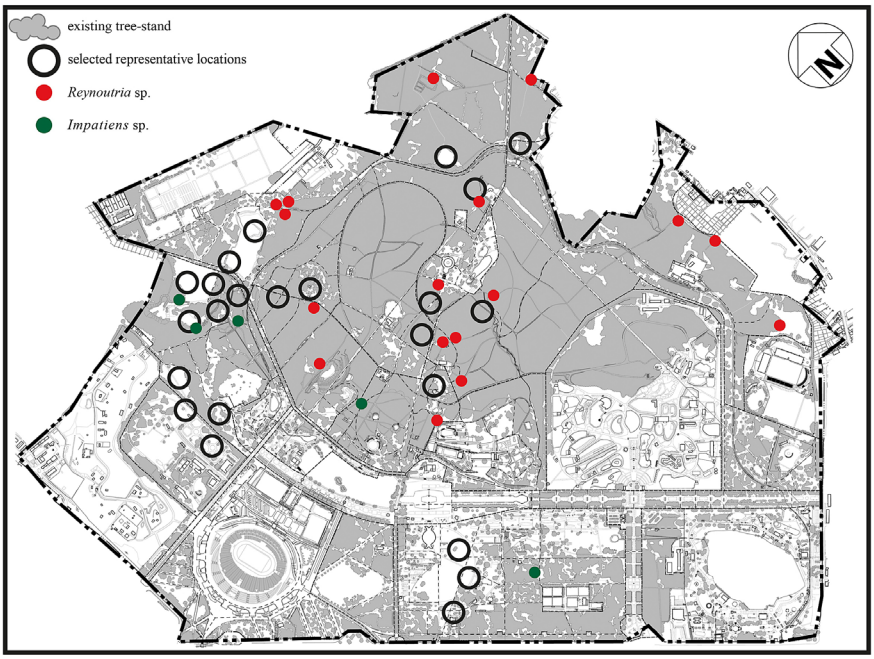

Figure 2. Silesia Park – phytosociological evaluation and location of selected invasive herbaceous plants (prepared by: B. Fortuna-Antoszkiewicz, J. Łukaszkiewicz, P. Wiśniewski, 2013/2014)

(bank area of park ponds); e/ communities similar to alder riparian, oak-hornbeam, oak forests and forest fringe communities – within expansive park tree-stands; f/ synanthropic and semi-synanthropic communities – in the areas with an expansive management plan or where secondary succession was allowed.

Currently, among the pioneering tree species used for recultivation and as a fore-crop in Silesia Park, red oak and black cherry can be described as expansive. Numerous species grow in large parts of the area, especially in the extensive part of the Park (on the hill, where vegetation maintenance is limited) – in tree (A) as well as in other strata, and what is important – in the underbrush strata (B) – especially near older mother species (e.g. representative red oak specimens with breast height circumference of: 120/ 126/150/ 152/ cm and approx. 25.0 m high and representative specimens of black cherry with trunk circumference of: 130 / 132 cm and approx. 20.0 m high) or their clusters; they are also intensively renewing in the undergrowth strata (C) practically in the entire tree-stand area (Figure 3, 4). Highly concerning is that locally, the seedlings of both taxons cover 100% of area with no seedlings of other native tree species, which are also growing nearby.

The phytosociological evaluation (Figure 1) shows that there are 6 species of herbaceous plants, within the Park which are considered as highly

Figure 3. Monoculture of *Quercus rubra* L. seedlings in the herb layer – Silesia Park, Chorzów (photo: J. Łukaszkiewicz, 2014)

Figure 4. An unrestrained renewal of *Prunus serotina* Ehrh. – Silesia Park, Chorzów (photo: P. Wiśniewski, 2013)

invasive country-wide (Tokarska-Guzik et al., 2012; Regulation of Minister of Environment of 9 September, 2011): *Reynoutria japonica* Houtt., *Reynotria* x*bohemica* Chrtek et Chyrtkova, *Impatiens glandulifera* Royle, *Impatiens parviflora* DC., *Solidago canadensis* L., *Solidago gigantea* Aiton. The identified invasive species are expansive; they are highly competitive and oust other plant species which had occupied a particular spot in a given phytocenosis (Figure 5, 6). They are present mainly in the western part of the Park (extensive part on a hill).

Generally, the phytocenoses in Silesia Park have reached a level of certain self-regulation and ecological stability, among other due to large area and compactness of the Park (approx. 600 ha). Due to subsoil recultivation (renewal of physical and chemical properties) and formation of a particular phytoclimate within the Park, secondary succession takes place, which involves substitution of pioneering tree species (such as birch, robinia, poplars etc.), planted as a forecrop for more demanding trees. Generally, the tree species typical to oak-hornbeam, sometimes riparian and oak forest communities (mezo- and eutrophic deciduous forests – *Querco-Fagetea* class) are renewed. Simultaneous succession of expansive and invasive species is an undesired phenomenon; this pertains to both tree and herbaceous plants (such as red oak, black cherry, knotweeds, balsams, goldenrods). This issue is problematic and casts doubt on the optimistic forecast of tree-stand development via succession (towards natural, stable and undisturbed phytocenoses).

Figure 5. Extensive clusters *Reynoutria japonica* Houtt.- Silesia Park, Chorzów (photo: B. Fortuna-Antoszkiewicz, 2014)

Figure 6. *Impatiens glandulifera* Royle displacing native herbaceous plants in the border zone of the stand – Silesia Park, Chorzów (photo: B. Fortuna-Antoszkiewicz, 2014)

DISCUSSION

High number of the researched taxons: *Robinia pseudoacacia* L., *Acer negundo* L., *Quercus rubra* L., *Prunus serotina* Ehrh., *Impatiens parviflora* DC. found within researched sites are consistent with the results of research carried out in forest areas in entire Poland. For example: in the eastern part of Opoczyńskie Hills, the same species have been found to have highest frequency and expansiveness potential (*Quercus rubra* L. – 99 plots, *Prunus serotina* Ehrh. – 98, *Robinia pseudoacacia* L. – 95, *Impatiens parviflora* DC. – 84, *Acer negundo* L. – 78). are mixed and deciduous forests (Trojecka-Brzezińska, 2014) are most vulnerable to the invasion by antropophytes, similarly to the tree-stands in researched sites (deciduous and mixed).

The research on the spreading of invasive species e.g. in Ladzka primeval forest (bordering Białowieża primeval forest on south-west) also confirm that the most numerous species include *Impatiens parviflora* DC. and *Prunus serotina* Ehrh. (the species showing preference for non-fresh and poor habitats and pine tree-stands aged from 20 to 60 years growing in the area). In context of anthropogenic factors, the identified species showed preference for the areas with a dense road network (>50 m/ha) and areas less than 0.5 km away from buildings and forest border (Fyałkowska et al., 2014). The research on the expansion of *Prunus serotina* Ehrh. in Kampinos National Park (covering the entire Park

with an area of 385 km²) shows that the species is frequently[6] found in the ecosystems which underwent anthropogenic transformation of soil conditions and vegetation. The disturbances caused by human interference may be a decisive factor for the vulnerability of a given ecosystem to invasive species (Otręba & Kondras, 2014).

The analysis of invasive species in 9 research sites (Table 1), in the context of natural conditions and anthropogenic pressure shows the necessity of taking preventive actions (vegetation maintenance, tree-stand management) – following many years of negligence or no maintenance whatsoever – to protect native phytocenoses and maintain local biodiversity.

Other examples of areas which require adapting a rational vegetation maintenance and tree-stand management plan are the areas protected by law (such as thermophilous oak forest *Potentillo albae-Quercetum* in King John Sobieski reservation in Warsaw – under recession [Ciurzycki et al., 2014]), or locations were secondary succession develops towards forest communities – due to the abandoning of land (e.g. secondary forest succession in the meadows in Małe Pieniny [Frączek & Dziepak, 2014]). In such cases, a permanent destruction of cultural landscape and local decrease of biodiversity may result, similarly as in the case of uncontrolled invasive plant introduction.

CONCLUSIONS

- Generally, the presence of invasive plant species is symptomatic of an unfavourable vegetation succession in a given area. To a large degree, it is connected with increasing anthropogenic pressure on the environment.
- Excessive expansion of invasive species may disturb the ecological balance of an ecosystem in a given area, replacing less expansive and less competitive species. This may lead to impoverishing of the species structure and decreasing biodiversity. The current research proves (Tokarska-Guzik et al., 2012) that the environmental functions are best achieved by afforestation composed of native species, especially if they are of a free and non-schematic structure.
- In the selected sites which are subject to anthropogenic pressure, the presence of invasive species was detected to a varying degree and was most prominent in intensively utilised areas. This resulted in alarger area taken over by individual species and greater species variety. In the case of tree species, all tree-stand strata have been taken over, with intensive renewal in the undergrowth strata.
- The authors' own research carried out in the selected sites confirms invasive species' pressure is present irrespective of location, natural conditions of terrain and site type – in each case, it is most prominent in the plots where vegetation is not properly maintained or is not maintained at all.
- In order to maintain optimum vegetation systems (stable native phytocenoses) in the areas subject to strong anthropogenic pressure (urban, recreational and tourist areas) it is necessary to introduce systemic supporting activities: constant monitoring of succession and a rational, planned maintenance of vegetation to reduce negative impact of environmental changes, and in the case of invasive species – elimination in the early stages of expansion.

[6] Spreading of black cherry lasts relatively short (approx. 60 years) and its dispersion is closely tied to the locations where it had been previously introduced (Otręba & Kondras, 2014).

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