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Short Communication

Using GIS Methods to Investigate Urban Parks within Industrial Regions

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Abstract

The aim of our paper is to identify the main trends in changes in land use of select urban parks in Sosnowiec and Będzin towns during 1927-2009 in light of changes to the urban areas. Research included two urban parks: Sielecki in Sosnowiec and Góra Zamkowa in Będzin. The analysis was based on old maps (from 1927, 1960s/70s, and 1990s) and the latest available orthophotomaps of the study area (2009). The results obtained on the basis of geographical information systems (GIS) shows significant differences, both in terms of spatial and quality changes in the land use in all urban parks, conditioned by their location in the different types of landscapes. The identified changes are linked to the wider range of functions taken over by parks, and also of changes in urban planning strategies. The GIS methods were helpful in interpretation of identified changes. Increasing forest areas is observed in the last research period and has a connection with the flora of both parks. The role of urban parks is particularly noticeable in strongly urbanized and industrialized areas – in the urban-industrial agglomeration and conurbation. The urban parks in these areas are an interesting problem in terms of geographical, botanical, and landscape ecology research. The documentation, monitoring, and protection of the oldest and the most valuable parts of the urban parks (urban forests) are important in light of the fact that urban parks are linked with local history.

Keywords: urban parks, land use, GIS methods, park species, cultural landscape

Introduction

The broadly understood aspects of urban parks are interesting as historical, geographical, and botanical issues in urban planning. These problems may be dealt with in light of cultural landscape forming also. The concept of the natural system of the city is connected with problems of urban parks. The natural system of the city is understood as a package of planning concepts whose common goal is identifying spatial and functional structures of related areas within the towns. Special emphasis is placed on the natural and landscape aspects of urban spaces [1-3].

The first urban parks at the area of Zagłębie Dąbrowskie Basin were created in the 19th century. One of these objects is Góra Zamkowa Park in Będzin, which was created in 1801 by Jan Gręborski, the administrator of Będzin District. Sielecki Park in Sosnowiec was created in 1835 [4]. However, the major part of contemporary urban parks in the investigated region was created beginning at the turn of the 20th century. Parks in Zagłębie Dąbrowskie Basin have very different areas and genesis [5].

The urban park, as a component of the natural system of the city, is an independently operating object despite its

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anthropogenic origin. The park areas included biotic elements (natural character vegetation, decorated greens) and social elements (infrastructure: alleys, playgrounds, sports fields, benches, cafes, etc.) [6]. The major part of urban parks is characterized by a partly maintained natural structure, and plays an important role in ecological functions of a city's natural system. These functions can be observed especially within river valleys, forest complexes, and open areas [7-9]. The spatial-temporal changes of urban parks are connected with demographic and urban development, especially in the area of urban-industrial agglomeration and conurbation [10]. These conditions have caused changes in urban park areas, functional changes, taking new functions by parks and changes within the park internal structure. Similar transformations can be observed at the area of former excavations in Zagłębie Dąbrowskie Basin [11].

So far, most research has concerned the diversity of urban park functions [6, 12] and the history of park complees in Poland [5] and other countries [9, 13]. Park areas can be indicated as objects reflecting the history of towns and the culture of a region [8]. However, most attention has been devoted to the park architecture in terms of urban greens [9, 14]. Natural aspects of urban parks include multi-aspect analysis of flora [15-18]. Urban parks, due to their partly maintained natural structure, play a role in ecological functions in a city's natural system. If clear barriers (among others high building areas) do not exist, these functions interact with nearby landscapes [19] and vice versa [20], especially in the context of urban greens [21].

The important significance of applying geographical information systems (GIS), old maps, and current cartographic materials in landscape studies was mentioned [22, 23]. Despite research, spatial-temporal problems of urban parks have been poor. The analysis of changes within urban parks enables us to understand the function of the environment under the influence of various internal and external conditions. The use of GIS methods and cartographic materials from different periods significantly facilitates such research. The aim of this paper is to identify main trends in spatial-temporal changes within selected urban parks in Sosnowiec and Będzin during 1927-2009, as one part of a component of cultural landscape. The identified changes were dealt in light of changes in the area of Zagłębie Dąbrowskie Basin.

Materials and Methods

Study Area

The study included two urban parks in Sosnowiec and Będzin towns in Zagłębie Dąbrowskie Basin (southern Poland, Fig. 1). The selection of research objects was based on two criteria: creation date and functional change over time. The analysis period was 1927-2009.

Góra Zamkowa Park in Będzin is about 6.7 ha. The park boundaries were changed due to reconstruction, including in its area new terrains, including the Jewish cemetery in the eastern part of the current park area. The park is protected by law as a protected landscape area.

Park Sielecki in Sosnowiec is about 10.4 ha. Park Sielecki is the greatest urban park in Sosnowiec and it has two parts: the older (so-called Renard's part) and new part on the west bank of the Czarna Przemsza River. Renard's part – registered in the natural monuments register – was created around Zamek Sielecki Palace, the seat of the Renard magnate family. This part of the urban park is located on east bank of the Czarna Przemsza River and expanded to the southeast in 1902. A pond was added in the north the same year. The new part of Park Sielecki was created in 1952 in the area about 8.0 ha. In the 1960s the green park landscape system was destroyed by construction of the amphitheater on the site of the pond and the ice rink in the old part of the park. Almost half of the old part of the park was used for the construction of a housing estate [24].

GIS Analysis

The analysis of spatial-temporal changes of urban parks is based on old maps and contemporary ortophotomaps of the study area. Research was conducted using a monochromatic map of Zagłębie Dąbrowskie Basin from 1927 (in scale 1:10,000, Fig. 2), colored topographic maps from the 1960s/70s and 1990s (in scales 1:10,000, 1:25,000, and 1:50,000), and contemporary ortophotomaps (2009, scale 1:5,000).

All cartographic materials were calibrated and registered in the Polish CS92 coordinate system (EPSG: 2180). Maximum registration errors do not exceed 10 pixels in maps from 1927 and 0-1 pixels in topographic maps and ortophotomaps. The registered rasters were digitalization in term of land use forms [25] in MapInfo Professional GIS software. The obtained vector layers then were visualized as land use maps in all research periods (Figs. 3 and 4). The final comparative analysis included the spatial variability and quantitative changes within the identified land use forms.

Fig. 1. Location of the study area.

The vascular flora of both urban parks also was researched. Nomenclature of plant species is given according to Mirek et al. [26] and the biological spectrum of flora was identified by Rutkowski [27]. The age assessment of select trees and shrub species was determined using the dendrochronological method.

Results

The results obtained on the basis of geographical information systems (GIS) show significant differences, both in terms of spatial and quality changes in land use in both urban parks, conditioned by their location in the different types of landscapes. We can observe the changes in the whole research period (1927-2009) in all identified linear and polygonal land use forms (Tables 1 and 2). We also found the changes of area and range changes of identified units (Figs. 3 and 4) in the research period.

The clearest change was marked in main road length, and the river network experienced significant changes, too (Tables 1 and 2). The changes of polygonal forms were clearly marked in residential areas – constant increase of this area and range of this land use form. Other significant changes we can observed in forest areas. It should be

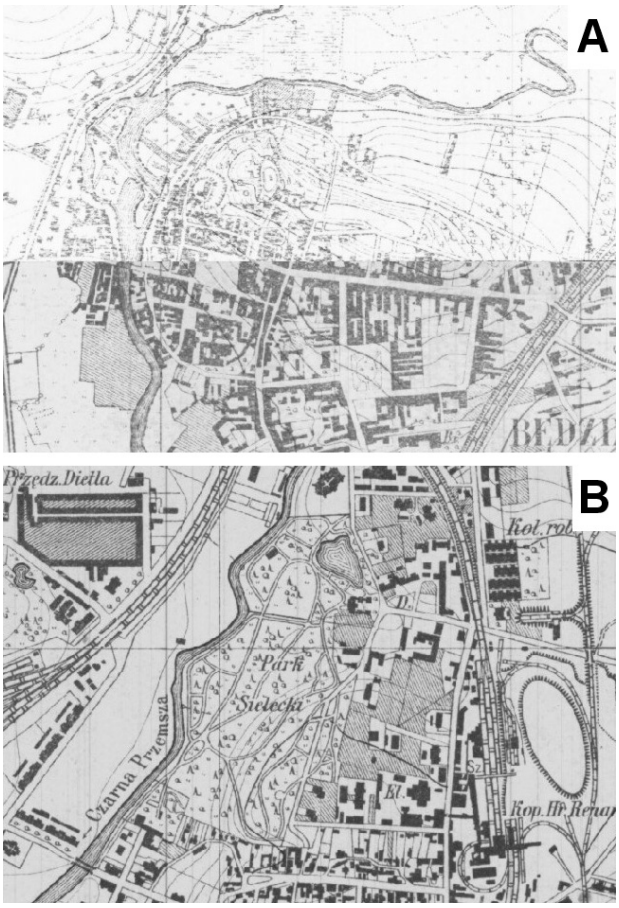

Fig. 2. The fragments of monochromatic map of Zagłębie Dąbrowskie Basin from 1927 (A – Urban Park "Góra Zamkowa" in Będzin, B – Urban Park "Park Sielecki" in Sosnowiec).

Table 1. Changes of land use forms in the surrounding area of Urban Góra Zamkowa Park.

Land use forms	Years			
	1927	1960s/70s	1990s	2009
Linear forms [km]				
River network	6.96	4.12	3.34	2.48
Main road network	15.71	25.36	31.90	34.96
Railways	1.31	1.66	1.66	1.27
Tram lines	-	4.41	5.51	5.51[A]
Polygonal forms [ha]				
Forests*	10.10	32.13	27.01	39.45
Residential areas**	62.21	124.30	212.40	244.0
Industrial areas	1.62	6.92	8.66	6.24
Allotment gardens***	8.50	8.70	8.70	8.70
Great-areas service terrains	-	-	-	-
Water reservoirs	-	0.32	0.47	-
Cemeteries	4.09	4.65	4.65	5.49
Other forms	285.98	195.48	110.61	77.32

* included urban parks
** included the associated infrastructure
*** at map from 1927 – gardens
[A] included inactive tram lines

Table 2. Changes of land use forms in the surrounding area of Park Sielecki.

Land use forms	Years			
	1927	1960s/70s	1990s	2009
Linear forms [km]				
River network	3.86	2.90	2.90	2.90
Main road network	43.42	44.97	46.90	52.85
Railways	22.29	11.36	9.57	5.68
Tram lines	-	7.56	9.33	9.33
Polygonal forms [ha]				
Forests*	25.90	42.83	38.54	53.70
Residential areas**	145.80	189.45	290.30	313.80
Industrial areas	35.64	88.35	90.92	38.20
Allotment gardens***	13.30	28.45	28.90	25.93
Great-areas service terrains	-	-	-	33.44[A]
Water reservoirs	1.80	2.87	2.87	0.33
Cemeteries	-	-	-	-
Other forms	326.36	196.85	97.27	83.40

* included urban parks
** included the associated infrastructure
*** at map from 1927 – gardens
[A] the new form identified only in 2009

emphasized that in the last analyzed year (2009) for both parks we found quite a significant increase of forest areas. The share of identified units shown Tables 1 and 2.

In Góra Zamkowa in Będzin 194 vascular plant species were found, in 47 families and 144 genus (Table 3). The following dominate vascular flora respectively: hemicryptophytes (H, 46.1%), therophytes (T, 27.9%), and megaphanerophytes (M, 9.6%). The flora is represented by species from different biogeographical regions, which are characterized by wide ecological tolerance. The most commonly found species have a decorative character.

The age assessment of select tree and shrub species were determined in 2011 and used to identify main age groups of tree species. The relatively young trees (age 0-60 years, 44% of the forest stand) were classified to the first age group, while the mature trees (age 61-100 years) are

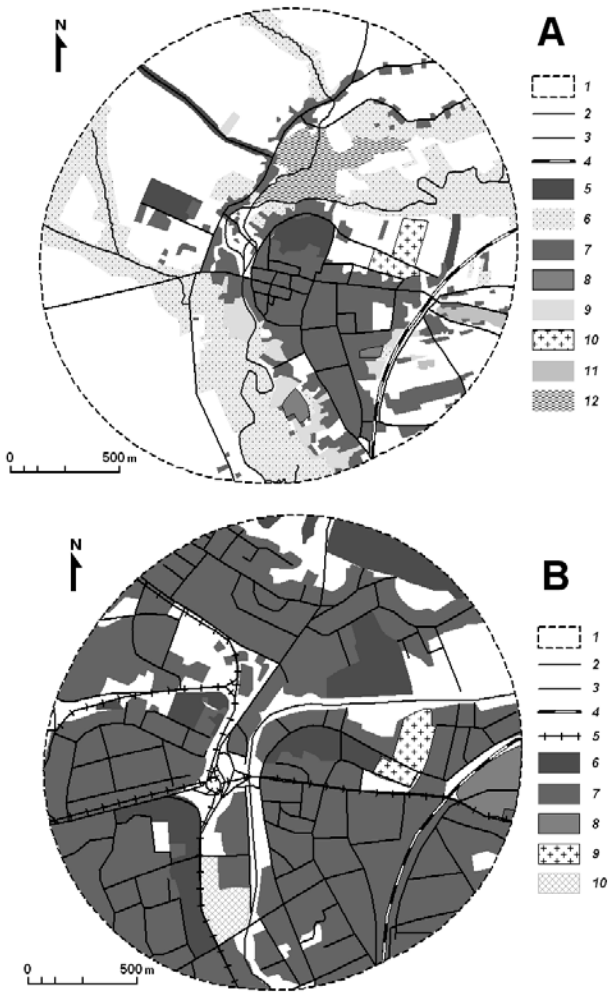

Fig. 3. Land use forms in the surrounding area of Góra Zamkowa Park (A – in 1927: 1 – area of digitization, 2 – rivers, 3 – main roads, 4 – railways, 5 – forest areas, 6 – meadows, 7 – residential areas, 8 – industrial areas, 9 – gardens, 10 – cemeteries, 11 – post-industrial degraded areas, 12 – wetland areas, indefinites – other land use forms; B – in 2009: 1 – area of digitization, 2 – rivers, 3 – main roads, 4 – railways, 5 – tram lines, 6 – forest areas, 7 – residential areas, 8 – industrial areas, 9 – cemeteries, 10 – sports and recreational areas, indefinites – other land use forms).

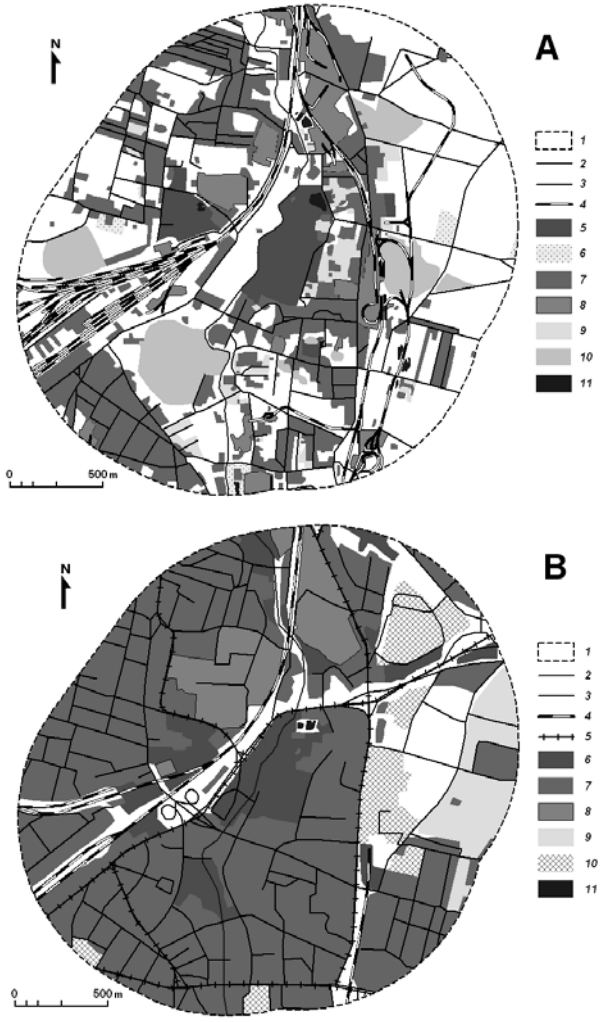

Fig. 4. Land use forms in the surrounding area of Park Sielecki (A – in 1927: 1 – area of digitization, 2 – rivers, 3 – main roads, 4 – railways, 5 – forest areas, 6 – meadows, 7 – residential areas, 8 – industrial areas, 9 – gardens, 10 – post-industrial degraded areas, 11 – water reservoirs, indefinites – other land use forms; B – in 2009: 1 – area of digitization, 2 – rivers, 3 – main roads, 4 – railways, 5 – tram lines, 6 – forest areas, 7 – residential areas, 8 – industrial areas, 9 – allotment gardens, 10 – great-areas service terrains, 11 – water reservoirs, indefinites – other land use forms).

about 46% of the forest stand. Other age groups have a small share. Trees aged 101-130 years represent only 8.2% of the forest stand, and the oldest trees, >131 years, are represented only by three specimens (share 0.4%). These trees are native species of flora.

In the area of Park Sielecki in Sosnowiec 155 vascular plant species were found, in 51 families and 111 genus, including more than 50 tree and shrub species (Table 3). Within the park flora hemicryptophytes (H, 42.9%), therophytes (T, 25.8%) and megaphanerophytes (M, 14.3%) are dominant. The oldest tree is 110 years, and the total age structure of the forest stand in this urban park is varied: 50-60 years in the new part (on the west bank of the Czarna Przemsza River) and 80-90 years in the old part (so-called Renard's, on the east bank of the river).

Table 3. The share of families and genus of vascular plants within investigated urban parks.

Family	Genus	Number of species	
		Góra Zamkowa	Park Sielecki
Adoxaceae	*Sambucus*	2	1
	Viburnum	-	1
Amaranthaceae	*Amaranthus*	1	-
	Atriplex	1	-
	Beta	1	-
	Chenopodium	-	1
Anacardiaceae	*Rhus*	-	1
Apiaceae	*Aegopodium*	1	1
	Aethusa	2	-
	Anthriscus	1	-
	Carum	1	-
	Chaerophyllum	1	-
	Daucus	1	-
	Libanotis	1	-
	Pastinaca	1	-
Apocynaceae	*Vinca*	-	1
Araliaceae	*Hedera*	1	-
Aspleniaceae	*Asplenium*	1	-
Asteraceae	*Achillea*	1	1
	Arctium	3	1
	Artemisia	2	1
	Aster	1	-
	Bellis	1	1
	Carduus	1	-
	Centaurea	2	-
	Chamomilla	1	1
	Cirsium	2	-
	Conyza	1	-
	Crepis	2	-
	Erigeron	1	-
	Galinsoga	-	1
	Helianthus	1	-
	Lactuca	1	-
	Lapsana	1	-
	Leucanthemum	1	-
	Matricaria	1	-
	Mycelis	1	-
	Onopordum	1	-
	Rudbeckia	1	-
	Senecio	1	1
	Solidago	2	2
	Sonchus	2	3
	Tanacetum	1	-
	Taraxacum	1	1
	Tragopogon	1	-
	Tussilago	1	-
	Xanthium	1	-
Balsaminaceae	*Impatiens*	2	1
Berberidaceae	*Berberis*	-	3
	Mahonia	-	1
Betulaceae	*Alnus*	-	2
	Betula	-	1
	Carpinus	1	1
	Corylus	1	1
Bignoniaceae	*Catalpa*	-	1
Boraginaceae	*Echium*	1	-
	Myosotis	1	1
Brassicaceae	*Alliaria*	1	1
	Armoracia	1	-
	Berteroa	1	-
	Brassica	1	-
	Capsella	1	-
	Lepidium	1	1
	Raphanus	1	-
	Sisymbrium	2	-
Campanulaceae	*Campanula*	2	-
Cannabaceae	*Humulus*	1	-
Caprifoliaceae	*Lonicera*	1	-
	Symphoricarpos	-	1
Caryophyllaceae	*Agrostemma*	1	-
	Arenaria	1	-
	Melandrium	1	1
	Saponaria	1	1
	Silene	2	1
	Spergula	1	-
	Stellaria	1	-
Celastraceae	*Euonymus*	-	1
Convolvulaceae	*Calystegia*	1	-
	Convolvulus	1	1

Table 3. Continued.

Family	Genus	Number of species	
		Góra Zamkowa	Park Sielecki
Cornaceae	*Cornus*	-	1
Crassulaceae	*Sedum*	2	-
Cupressaceae	*Juniperus*	-	1
	Thuja	-	1
Cyperaceae	*Carex*	1	-
Dryopteridaceae	*Dryopteris*	1	-
Elaeagnaceae	*Hippophae*	-	1
Equisetaceae	*Equisetum*	-	1
Euphorbiaceae	*Euphorbia*	2	1
Fabaceae	*Astragallus*	1	-
	Caragana	-	2
	Gleditsia	-	1
	Laburnum	-	1
	Lathyrus	1	2
	Lotus	1	-
	Medicago	2	2
	Melilotus	1	1
	Robinia	1	1
	Trifolium	3	3
	Vicia	4	2
Fagaceae	*Fagus*	1	1
	Quercus	1	2
Geraniaceae	*Geranium*	2	1
Grossulariaceae	*Ribes*	-	1
Hydrangeaceae	*Deutzia*	-	1
	Philadelphus	-	1
Hypericeae	*Hypericum*	1	-
Iridaceae	*Iris*	1	-
Juglandaceae	*Juglans*	1	3
	Pterocarya	-	1
Lamiaceae	*Ballota*	1	-
	Glechoma	1	1
	Lamium	3	2
	Leonurus	1	-
	Prunella	-	1
Malvaceae	*Malva*	1	-
	Tilia	1	2
Moraceae	*Morus*	-	1
Oleaceae	*Forsythia*	-	1
	Fraxinus	2	2

Table 3. Continued.

Family	Genus	Number of species	
		Góra Zamkowa	Park Sielecki
Oleaceae	*Ligustrum*	1	1
	Syringa	-	1
Onagraceae	*Epilobium*	2	-
	Oenothera	1	1
Oxalidaceae	*Oxalis*	3	-
Papaveracea	*Chelidonium*	1	-
	Papaver	1	1
Pinaceae	*Abies*	1	1
	Larix	-	1
	Picea	-	3
	Pinus	-	3
Plantagineceae	*Veronica*	2	1
	Plantago	2	2
Poaceae	*Agrostis*	1	1
	Apera	1	-
	Arrhenatherum	1	1
	Avena	1	-
	Bromus	2	1
	Calamagrostis	2	1
	Cynosurus	-	1
	Dactylis	1	1
	Echinochloa	1	-
	Elymus	1	1
	Festuca	1	-
	Holcus	-	1
	Lolium	1	1
	Panicum	1	-
	Poa	3	1
	Triticum	1	-
Polygonaceae	*Fallopia*	1	-
	Polygonum	3	-
	Reynoutria	1	1
	Rumex	2	2
Ranunculaceae	*Ranunculus*	2	1
	Anemone	1	-
Resedaceae	*Reseda*	1	-
Rhamnaceae	*Rhamnus*	-	1
Rosaceae	*Agrimonia*	-	1
	Chaenomeles	-	1
	Cotoneaster	-	1

Table 3. Continued.

Family	Genus	Number of species	
		Góra Zamkowa	Park Sielecki
Rosaceae	*Crataegus*	1	2
	Geum	1	-
	Malus	1	1
	Physocarpus	-	1
	Potentilla	3	-
	Prunus	1	3
	Pyrus	-	2
	Rosa	2	2
	Sorbus	-	1
	Spiraea	1	3
Rubiaceae	*Galium*	-	2
Rutaceae	*Phellodendron*	-	1
Salicaceae	*Populus*	2	3
	Salix	1	3
Sapindaceae	*Acer*	3	7
	Aesculus	1	2
Simaroubaceae	*Ailanthus*	-	1
Scrophulariaceae	*Scrophularia*	1	-
	Verbascum	2	-
Solanaceae	*Datura*	1	-
	Hyoscyamus	1	-
	Lycopersicon	1	-
	Solanum	2	-
Ranunculaceae	*Anemone*	1	-
Taxaceae	*Taxus*	1	1
Ulmaceae	*Ulmus*	-	2
Urticaceae	*Urtica*	2	1
Valerianaceae	*Valeriana*	-	1
Violaceae	*Viola*	3	-
Vitaceae	*Parthenocissus*	-	1
	Vitis	-	1
Woodsiaceae	*Athyrium*	1	-

Within Park Sielecki, in contrast to Góra Zamkowa Park,we can observe numerous alien tree and shrub species: *Aesculus carnea*, *Laburnum anagyroides*, *Gleditsia triacanthos*, *Catalpa bignonioides*, *Juglans cordifornis*, *Juglans nigra*, *Caragana arborescens* cv. *Pendula*, and *Crataegus coccinea*. The biggest share are shrubs: *Phellodendron amurense*, *Sambucus nigra*, *Symphoricarpos albus,* and *Taxus baccata*. *T. baccata* is a protected and rare species in Poland.

Discussion

The spatial changes identified within the components of the two parks have been conditioned by historical and economical processes. The areas of both urban parks were changed in two aspects – spatial and functional. So far, there is no further information about investigated objects, the previous studies concerned on old thematic maps, but without their digitization [28]. The use of GIS methods makes easy studies on the basis of old maps and contemporary cartographic materials and their comparative analysis. The GIS analysis allows the identification of changes in both urban parks. The identifying process using the colored topographic maps was the easiest. Some problems in digitalization in the monochromatic map of Zagłębie Dąbrowskie Basin from 1927 were found. The doubts were compared with the results of unit identification at ortophotomaps from 2009. The boundaries of identified land use forms also were corrected in the field works.

All quantitative and qualitative changes within the parks and their surroundings are associated with urbanization and industrialization at the area of towns in Zagłębie Dąbrowskie Basin. This is clearly visible, especially in the case of Park Sielecki in Sosnowiec. The development of industry led to the influx of people for work purposes and the dynamic development of residential areas with infrastructure (schools, shops, recreational areas, etc.). The development of residential areas and – connected with them – the main road network resulted in a decrease of forest and open areas. The length of river network has been significantly reduced also. This is a result of regulation of the Czarna Przemsza River Valley and the disappearance of small tributaries of this river [28].

It should be emphasized that in the last analyzed year (2009) we can observe quite a significant increase of the area occupied by forest, and the residential areas continued to increase, too. A significant increase of forest areas was most likely due to overgrowth of degraded areas, wasteland, and areas previously covered by some form of agricultural use (meadows). Some role had the reclamation processes within the degraded areas also. Similar results were obtained by Rahmonov and Parusel [29].

The detailed analysis and comparison of architectural-landscape units distinguished at the study area significantly facilitate the application of GIS methods. The GIS systems allow for easy collection, processing, analysis, and visualization of landscape and other data. Similar aspects were indicated by Wrochna [30] in cultural landscapes and in natural landscapes also [23, 31-34]. Carrying out analysis of changes within investigated towns were possible because the analyzed parks are the oldest objects in the study area. The databases created in this way will be used in the future in the study of investigated parks and their comparison with other of objects this type, not only within the area of Zagłębie Dąbrowskie Basin.

The vegetation difference of investigated urban parks is conditioned by ground character and landforms in park areas. Góra Zamkowa has a character of elevated area, with fairly steep and sunlit slopes, while Park Sielecki is com-

pletely flat and heavily shaded. This object is used for intensive recreation, sports, and leisure. In comparison, this object has larger areas of decorated greens, which influence the species composition of flora in this urban park.

A characteristic feature of Góra Zamkowa is grass-forest character, different in relation to the most of typical parks in the investigated region of Poland. The open fragments of the hill were dominated by areas sown with grass mixtures and regularly mown lawns, while non-cultivated parts see natural vegetation succession [11].

The investigated parks are two separate types of cultural landscapes that are connected with their location, type of use, and functions. At Góra Zamkowa we can observe a small fragment of the forest with native species (*Carpinus betulus*, *Tilia cordata*, *Fraxinus excelsior*, and others). Park Sielecki has many alien species of decorative and ornamental character [15]. The differentiation of species composition is connected with anthropogenic landforms [35, 36].

Differences and similarities in species composition should be only one criterion when comparing urban parks in different areas. This type of data, however, should be taken for interpretation of results obtained from the analysis of archival maps with applying GIS tools. Location of old trees in parks and forests can be helpful in reviewing and updating the ranges of forest areas identified by digitalization processes of old maps and contemporary cartographic materials [34]. Due to this fact, the studies of urban parks should also include – in addition to map analysis – for studies of the forest stand species composition.

Conclusions

Our analysis shows the significant spatial-temporal changes, both within investigated urban parks and in the area of Będzin and Sosnowiec towns. The observed changes in the last 80 years are closely linked to industrial development and urbanization of urban areas in the Zagłębie Dąbrowskie Basin. The changes in urban park structure and the succession of their functions are generally linked with location of the parks in the town settlement system.

The use of GIS methods makes easier studies on the basis of old maps and contemporary cartographic materials and their comparative analysis. The GIS analysis was helpful for the identification of changes in both urban parks. The GIS systems allows for easy collection, processing, analysis, and visualization of landscape and other data. The databases created in this way will be able to be used in the future for studies of investigated parks and their comparison with other objects of this type, not only within the area of Zagłębie Dąbrowskie Basin.

A very important aspect is the fact that the investigated parks are important points in the natural system of study area. However, this fact should not be interpreted as the only positive phenomenon. Urban parks, especially the oldest among them, can be a source of synanthropization of vegetation in surrounding areas. Due to this fact, the spatial-temporal changes of such areas should be a constant point of interest for researchers and local governments responsible for a park's management. The documentation, monitoring, and protection of the oldest and most valuable parts of urban parks (urban forests) are important in light of the fact that urban parks are linked with the history of their towns.

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