PUBLIC INVESTMENT POLICY AS A DRIVER OF CHANGES IN THE ECOSYSTEM SERVICES DELIVERY BY AN URBAN GREEN INFRASTRUCTURE

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Abstract: The presented study considers the impact of public expenditure related to land development on the potential of an urban green infrastructure to provide ecosystem services (ES). The study site (Szachty) is located in Poznań, the fifth largest city in Poland. In the article, we recognised the type of expenditure (permanent infrastructure and ongoing maintenance), the costs and the influence on ES (stimulating, weakening or no relevant). The study shows that the financial policy concerning the study area is focused on creating an infrastructure that enhances cultural ecosystem services (CES). However, the creation of recreational facilities weakens the potential of the area for supplying regulating services concerning maintaining nursery populations and habitats. The results highlight the need for scientific support for policymakers in understanding the synergies and trade-offs between ES, resulting from financial decisions. This is particularly important in the decision-making process in the areas of high natural value, in which full, long-term effects of the decisions may be barely visible and incomprehensible for the society. Showing the impact of financial decisions on the structure and level of ES may provide arguments supporting a more complex and high-quality social dialogue, including balancing the interests of various stakeholders.

Key words: spatial development, urban areas, water-dependent ecosystems

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Introduction

As urbanisation expands, policymakers need to consider how urban ecosystems can be strategically managed to meet the needs of urban populations. Natural and semi-natural areas located within the cities provide many services increasing the well-being of the inhabitants. The so-called green infrastructure (EEA 2011, Tzoulas et al. 2011, Chenoweth et al. 2018) improves the quality of the air and water, reduces noise, mitigates extreme summer temperatures and peek flood events, provides habitats for wildlife and provides ecological connectivity; it also delivers cultural services, such as recreation, education, aesthetic experiences and the maintenance of social relations (Pietilä et al. 2015, Gunawardena et al. 2017, Schweitzer et al. 2018, Wang et al. 2018).

Whilst the role of green infrastructure (GI) for maintaining a healthy, resilient and liveable

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urban environment receives increased recognition (Chen 2015, Maes et al. 2016, Pulighe et al. 2016, Zardo et al. 2017), there is a shortage of knowledge on the influence of financial decisions related to their development on the structure and level of the provided benefits. Developing a better understanding of feedback relationships between the financial policy concerning land development and the multi-layered values provided by urban GI can be beneficial for planning and governance processes in a variety of ways. Assessing the status quo, as well as the synergies and trade-offs resulting from various financial scenarios, may support setting goals and prioritising approaches to securing the functionality of urban ecosystems (de Wit et al. 2012, Schäffler and Swilling 2013). This contributes to the reduction of environmental degradation and biodiversity loss, whilst ensuring an effective and efficient provision of ecosystem services (ES) (Hansen et al. 2015, Galler et al. 2016).

In this article, we investigate how public expenditure on land development influences the potential of urban GI to provide ES on the example of the Szachty area in Poznań, western Poland. The place-based perspective offers a considerable potential for the better understanding of the issues of multifunctionality, promoting decision-making that is grounded in and fits the particular social–ecological systems it serves (Potschin and Haines-Young 2013, Grêt-Regamey et al. 2015, Kremer et al. 2015, Vollmer et al. 2016). The research was inspired by growing interest in the study site amongst citizens and decision-makers. Until recently, the Szachty area was used for recreation only to a small extent. However, in the recent years, the inhabitants have been using this blue-green space located within walking distance from their houses more and more intensively; this is accompanied by increased public spending on the site arrangement. The implemented infrastructure increases recreational opportunities, whilst simultaneously influencing the potential of the Szachty area in various ways to provide other, non-cultural benefits. The main objectives of the study included (1) recognition of the size and directions of public expenditure on the arrangement and maintenance of the Szachty area; (2) identification of the impact of public expenditure on the potential of the study site for supplying key ES; (3) providing recommendations to policy-makers for further management of the site. The inspiration for the research was a growing interest in the study area by the citizens who more and more often and, in a more diverse way, use the Szachty area. It is accompanied by the decisions of city policy-makers about the increase in public spending on the site arrangement.

The article proceeds as follows. Section 2 introduces the study area. Section 3 describes the methodological approach adopted in the study. Section 4 presents the expenditure on the development of the Szachty area in 2013–2017 and the rapid assessment of their impact on the level of ES. In Section 5, we discuss lessons learnt and conclude with recommendations for a further management strategy.

Study area

Poznań is the fifth-largest city in Poland (Główny Urząd Statystyczny 2017) with about 541,600 inhabitants. Its administrative area covers 262 km^2, of which about 57% is green infrastructure (EEA 2012). The city is located within the transition zone between oceanic and continental temperate climate zones with mainly oceanic influences. The average annual temperature is 8.3°C, with the coldest month being January (−1.6°C) and the hottest being July (18.1°C) (Woś 2010). The average annual precipitation is 517 mm, with the lowest precipitation in February (26 mm) and the highest in July (75 mm) (Majkowska et al. 2017).

The Szachty area is located in the south-western part of Poznań (Fig. 1). The study site covers 114.1 ha, and nearly all of it (113.8 ha) is situated in the administrative boundaries of Poznań. The remaining fragment is situated within the boundaries of the town of Luboń. In Poznań, the study site is located in the neighbourhood of the Fabianowo-Kotowo, Świerczewo and Górczyn housing estates, inhabited by 27,700 people (Urząd Miasta Poznania 2018).

In the hydrographical system, the area of the research is located in the Junikowski Stream Valley, which is the tributary of the River Warta (Kaniecki 2001). The total length of the Junikowski Stream is 11.7 km; within the limits of the study area, it flows on the stretch of 1.65 km from the north-west to the south. The study site

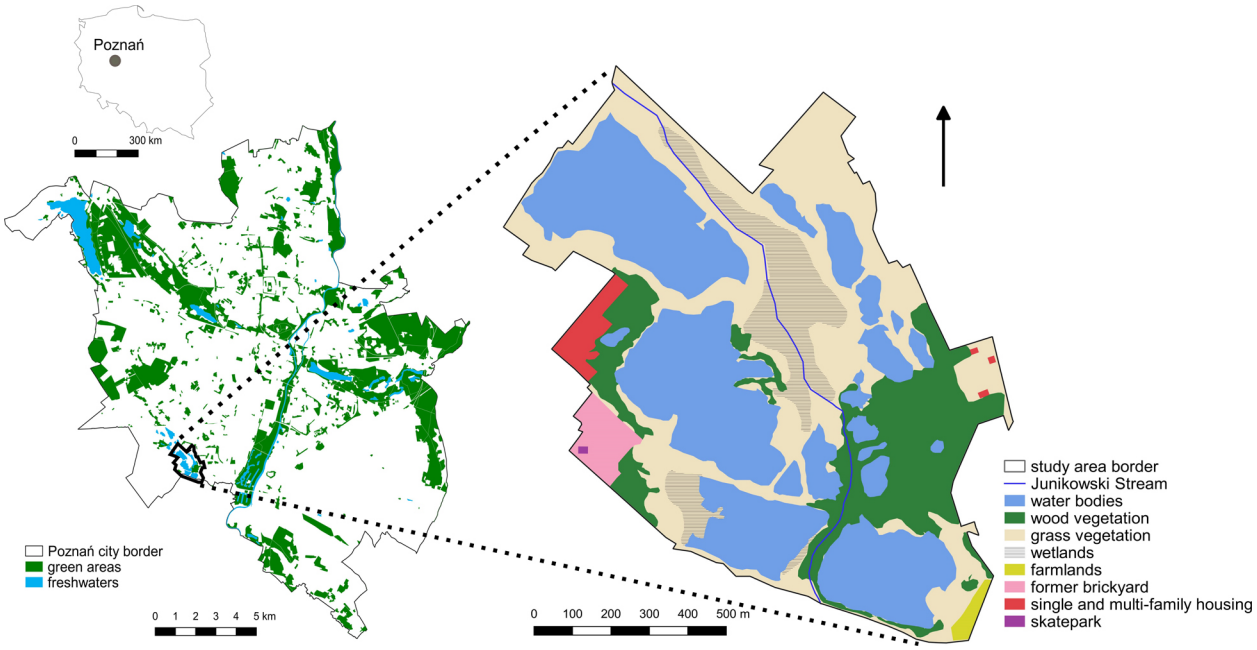

Fig. 1. Study area (according to Urban Atlas 2012).

is located within high terrace of the River Warta (Krygowski 1961), covered with fluvoglacial deposits (dammed clays and muds, peats, sands, gravels and glacial tills) (Chmal 1996).

The name *Szachty* comes from the German word *der Schacht*, that is, *shaft*; this name refers to the transformation of this area that lasted from the second half of the 19th century to the 1960s of the 20th century (Graf 2014). Back then, ceramic raw materials – glacial tills and varved clays – were extracted from here for the brick-making industry. This led to the creation of clay pits, that is, post-mining excavations that have later filled up with groundwaters and rainwaters (Matuszyńska 2001). After the discontinuation of mining activities, no remediation actions have been taken in the Szachty area. However, the natural succession process led to positive landscape changes, which resulted in a mosaic of water bodies, waterlogged areas, grass vegetation and woodlands. At present, the study area is a significant component of the urban GI, being a part of the network of green wedges burned in the river valleys (Urząd Miasta Poznania 2014).

Methods

To fulfil the goals, we collected information about the expenditure on the development and maintenance of the study area incurred by local authorities in 2013–2017. We analysed the financial expenditure regarding the amount and type (permanent infrastructure and ongoing maintenance). We based our reports on expenses made available by the City of Poznań and the Town of Luboń. Then, we considered the impact of public spending on the level of ES. We selected 10 ES as being highly related to the Szachty area, taking into account both the views of the natural capital experts (Kaniecki et al. 1995, Ptaszyk 1995, Borysiak, Markiewicz 2005, Jackowiak 2011, Wrońska-Pilarek 2016) and the social perception of the values of the study site (Stępniewska, Abramowicz 2016). In the terminology of CICES (*Common International Classification of Ecosystem Services*) V.5.1 (Haines-Young, Potschin 2018), the set of analysed ES included (i) provisioning ES, wild animals (non-commercial fishing); (ii) regulating and maintenance ES, filtration/sequestration/storage/accumulation by microorganisms, algae, plants and animals; hydrological cycle and water flow regulation; maintaining nursery populations and habitats; regulation of the chemical condition of freshwaters; and regulation of temperature and humidity; and (iii) cultural ecosystem services (CES), activities promoting health, recuperation or enjoyment through active/immersive or passive/observational interactions; education and training; and aesthetic experiences.

We applied a rough and expert-based assessment of the impact of a particular expenditure

Table 1. The underpinnings of individual ecosystem services taken into account and source of data

Underpinnings of ES potential	Source of data
Wild animals used for nutritional purposes (non-commercial fishing)	
Water quality Water flow conditions Infrastructure for fishing	Gogołek et al. 1995, Kaniecki et al. 1995, Borysiak, Markiewicz 2005, Biegała 2014, Zarząd Zieleni Miejskiej 2014b
Filtration/sequestration/storage/accumulation by microorganisms, algae, plants, and animals	
Ecosystems quality (biotic and abiotic components)	Burchardt, Szeląg-Wasielewska 1995, Gogołek et al. 1995, Kaniecki et al. 1995, Borysiak, Markiewicz 2005, Biegała 2014, Zarząd Zieleni Miejskiej 2014b, Wrońska-Pilarek 2016
Hydrological cycle and water flow regulation	
Water flow conditions	Gogołek et al. 1995, Kaniecki et al. 1995, Biegała 2014, Zarząd Zieleni Miejskiej 2014b
Maintaining nursery populations and habitats	
Ecosystems quality (biotic and abiotic components) Species abundance and diversity	Rudawski, Kusiak 1994, Ptaszyk 1995, Matuszyńska 2001, Ptaszyk, Dziabaszewski 2002, Borysiak, Markiewicz 2005, Michałowska 2005, Jackowiak 2011, Abramowicz 2016, Urząd Miasta Poznania 2016, Wrońska-Pilarek 2016, Rada Osiedla Fabianowo-Kotowo 2018, Rada Osiedla Świerczewo 2018, Zarząd Dróg Miejskich 2018
Regulation of the chemical condition of freshwaters by living processes	
Condition of water and water-dependent ecosystems	Gogołek et al. 1995, Kaniecki et al. 1995, Borysiak, Markiewicz 2005, Biegała 2014, Zarząd Zieleni Miejskiej 2014b
Regulation of temperature and humidity, including ventilation and transpiration	
Differentiation of radiation temperature according to land use and land cover	Majkowska et al. 2017, Półrolniczak et al. 2017, Zwierzchowska 2017
Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions	
Ecosystems quality (biotic and abiotic components) Species abundance and diversity Infrastructure for passive or observational interactions	Kaniecki et al. 1995, Ptaszyk 1995, Borysiak, Markiewicz 2005, Urząd Miasta Poznania 2013, 2014, 2015, Rada Osiedla Fabianowo-Kotowo 2014, 2015, 2016, Rada Osiedla Świerczewo 2014, 2015, 2016, Zarząd Zieleni Miejskiej 2013, 2014, 2015, 2016, 2017a, 2017b, 2017c, 2017d, Florkiewicz et al. 2015, Urząd Miasta Lubonia 2015, 2017, Stępniewska, Abramowicz 2016
Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through active or immersive interactions	
Infrastructure for active or immersive interactions	Kaniecki et al. 1995, Ptaszyk 1995, Borysiak, Markiewicz 2005, Urząd Miasta Poznania 2013, 2014, 2015, Rada Osiedla Fabianowo-Kotowo 2014, 2015, 2016, Rada Osiedla Świerczewo 2014, 2015, 2016, Zarząd Zieleni Miejskiej 2013, 2014, 2015, 2016, 2017a, 2017b, 2017c, 2017d, Florkiewicz et al. 2015, Urząd Miasta Lubonia 2015, 2017
Characteristics of living systems that enable education and training	
Ecosystems quality (biotic and abiotic components) Species abundance and diversity Infrastructure for education and training	Kaniecki 1995, Kaniecki et al. 1995, Ptaszyk 1995, Borysiak, Markiewicz 2005, Urząd Miasta Poznania 2013, 2014, 2015, Rada Osiedla Fabianowo-Kotowo 2014, 2015, 2016, Rada Osiedla Świerczewo 2014, 2015, 2016, Zarząd Zieleni Miejskiej 2013, 2014, 2015, 2016, 2017a, 2017b, 2017c, 2017d, Florkiewicz et al. 2015, Urząd Miasta Lubonia 2015, 2017, Stępniewska, Abramowicz 2016, Abramowicz 2018
Characteristics of living systems that enable aesthetic experiences	
Landscape aesthetic values Infrastructure for landscape admiring	Urząd Miasta Poznania 2013, 2014, 2015, Rada Osiedla Fabianowo-Kotowo 2014, 2015, 2016, Rada Osiedla Świerczewo 2014, 2015, 2016, Zarząd Zieleni Miejskiej 2013, 2014, 2015, 2016, 2017a, 2017b, 2017c, 2017d, Florkiewicz et al. 2015, Urząd Miasta Lubonia 2015, 2017, Stępniewska, Abramowicz 2016

on the potential of the Szachty area to deliver ES. The study area is not under systematic ecosystem monitoring. Existing data on the state of the ecosystems come from individual studies on chosen biotic and abiotic elements, which have been conducted during very different time periods. There is also no solid quantitative data concerning the impact of the investment on the ecosystems of the Szachty area. Those investments did not constitute projects likely to have significant effects on the environment as defined in the provisions of the Polish law (*Ustawa o udostępnianiu informacji*... 2008); for this reason, the Environmental Impact Assessment administrative procedure was not conducted for them, as part of which the influence of the investment on the diversity of the species and reproductive capacity of the ecosystems is identified in detail. Owing to data constraints, we rank the impact of investments on the potential for ES provision with the use of three rough levels: stimulating, not relevant or weakening.

In our assessment, we took into account reference scenario, that is, vision of spatial development of the study area accepted by the local government. According to the study of the conditions and directions of the spatial development of Poznań (Miejska Pracownia Urbanistyczna 2014), the existing natural potential of the Szachty area should be protected against urbanisation processes and arranged and unarranged green areas should be subjected to special conditions of development.

To capture changes in the ES potential, we used the information derived from scientific literature concerning the study area as well as expert reports and documentations drawn up for the purpose of the processes of spatial planning and investment. To a varying degree, these studies characterise − qualitatively, semi-quantitatively or quantitatively − the biotic and abiotic settings of the study site, major pressures and the expected response of ecosystems to the actual and potential drivers of changes. Table 1 presents the underpinnings of ES potential, which we considered with reference to individual ES and source of data for the study area. For regulating ES, we linked the potential of the study area to supply services with ecosystems' conditions. However, for most provisioning ES and CES, the capacity for ES supply is determined by a combination of ecosystem properties and human contribution (Burkhard et al. 2014, Remme et al. 2015). Hence, with reference to those services, we included human contribution related to technical infrastructure through interaction with which the benefits from ecosystems are realised (Costanza et al. 2017).

Public expenditure as the driver of changes in the ecosystem services

The size and directions of the public expenditure

The increasing interest of residents in the recreational use of the Szachty area is reflected in public spending on the site arrangement. In total, PLN 3,947,900 was spent for the development and maintenance of the area in 2013–2017. These works were financed mainly by the authorities of the city of Poznań (Rada Osiedla Świerczewo, Rada Osiedla Fabianowo-Kotowo, and Zarząd Zieleni Miejskiej of Poznań), and, in a small part, by the authorities of the town of Luboń. The expenditures of particular authorities are presented in Table 2.

We grouped all the analysed expenditures into those related to permanent infrastructure and ongoing maintenance (Table 3). The most

Table 2. Public expenditure on the arrangement and maintenance of the Szachty area by years and institutions.

Financing institutions	Costs (PLN)						
	2013	2014	2015	2016	2017	Σ 2013–2017	Σ%
City of Poznań – Rada Osiedla Świerczewo	21,997	378,141	396,988	84,528	17,000	898,655	22.8
City of Poznań – Rada Osiedla Fabianowo-Kotowo	0	21,999	316,000	431,384	34,250	803,633	20.3
City of Poznań – Zarząd Zieleni Miejskiej	320	69,514	342,291	310,076	1,394,476	2,116,677	53.6
Town of Luboń	0	1,300	8,503	119,110	0	128,913	3.3
Total	22,317	470,954	1,063,782	945,098	1,445,726	3,947,878	100

Source: On the basis of Rada Osiedla Fabianowo-Kotowo 2014, 2015, 2016, Rada Osiedla Świerczewo 2014, 2015, 2016, Zarząd Zieleni Miejskiej 2013, 2014a, 2015, 2016, 2017a, 2017b, 2017c, 2017d, Urząd Miasta Lubonia 2015, 2017.

expensive was the construction of pedestrian and bicycle paths with small architecture, including 35 benches, 33 waste bins, 74 protective barriers, 3 information boards, 2 bulletin boards and 5 signposts. The observation tower was located in the south-east section of the study area, in close vicinity to a former brick factory. Another permanent infrastructure included two viewing terraces, lake jetties, barbecue area with small architecture and 12 educational boards (Fig. 2). In addition, the Szachty area was secured against the entry of cars by the construction of 15 vehicle barriers. The remediation of ponds (1.1 ha altogether) and the renovation of 3 culverts between ponds included water bodies located in the south-eastern part of the study site. The goal of the conducted works was to eliminate internal load in the ponds through an elimination of suspended matter and bottom deposit as well as an improvement of the flow between the ponds and the Junikowski Stream.

Ongoing maintenance included regular trimming of branches, tree cutting, removal of storm damage and maintenance of cleanliness. In order to improve aesthetic values of the alleys, 200

Table 3. Public expenditure in 2013–2017 by type and costs.

Type of expenditures	Costs		
	PLN	%	Σ%
Permanent infrastructure			
Pedestrian and bicycle paths with small architecture	1,627,776	41.2	95.5
Observation tower	1,375,100	34.8	
Renovation of culverts between ponds	314,022	8.0	
Remediation of ponds	291,534	7.4	
Lake jetties	69,350	1.8	
Viewing terraces	40,000	1.0	
Educational boards	21,448	0.5	
Barbecue area with small architecture	18,696	0.5	
Vehicle barriers	8,950	0.2	
Ongoing maintenance			
Tree branch trimming	72,141	1.8	4.6
Cleanliness and order	57,002	1.4	
Tree cutting	31,280	0.8	
Symphoricarpos Duhamel plantation	15,000	0.4	
Removal of storm damage	5,578	0.1	
Total	3,947,878	100	100

Source: On the basis of Rada Osiedla Fabianowo-Kotowo 2014, 2015, 2016, Rada Osiedla Świerczewo 2014, 2015, 2016, Zarząd Zieleni Miejskiej 2013, 2014a, 2015, 2016, 2017a, 2017b, 2017c, 2017d, Urząd Miasta Lubonia 2015, 2017

Fig. 2. The examples of the investments made in the Szachty area.
(A) Pedestrian and bicycle paths with small architecture; (B) viewing terrace; (C) lake jetty; (D) barbecue area; (E) educational path; (F) vehicle barrier; (G) observational tower; (H) renovated culvert between ponds.

bushes of *Symphoricarpos Duhamel* were planted along some of the alleys.

The impact of the expenditure on key ecosystem services

The actions that were taken had a diverse impact on the potential of the study site to provide particular ecosystem services. We classified this impact as stimulating, no relevant or weakening (Table 4), which are discussed below.

The investments in pedestrian and bicycle paths with small architecture were assessed by us as supporting CES of the study site. Their goal was to strengthen the capabilities of recreational use of the area (Urząd Miasta Poznania 2013, 2014, 2015). A similar effect was attributed to the construction of observation tower, lake jetties and viewing terraces. They were designed in a way allowing to emphasise selected elements of the Szachty landscape. The vantage points can be used for ornithological observations, especially in the north-eastern part of the area (Borysiak,

Table 4. Impact of public expenditure on the potential of the Szachty area for the provision of key ecosystem services.

Ecosystem services (CICES v. 5.1)	CICES Code	Pedestrian and Bicycle Paths With Small Architecture	Renovation of Culverts	Remediation of Ponds	Observation Tower, Lake Jetties, Viewing Terraces	Educational Boards	Barbecue Area With Small Architecture	Vehicle Barriers	Tree Branch Trimming and Tree Cutting	Cleanliness and Order	Symphoricarpos Duhamel Plantation	Removal of storm damage
Provisioning												
Wild animals used for nutritional purposes (non-commercial fishing)	1.1.6.1	→	↑	↑	→	→	→	→	→	→	→	→
Regulation and maintenance												
Filtration/sequestration/storage/accumulation by microorganisms, algae, plants, and animals	2.1.1.2	→	↑	↑	→	→	→	→	→	→	→	→
Hydrological cycle and water flow regulation	2.2.1.3	→	↑	↑	→	→	→	→	→	→	→	→
Maintaining nursery populations and habitats	2.2.2.3	↓	↑	↑	↓	→	↓	↑	→	→	→	→
Regulation of the chemical condition of freshwaters by living processes	2.2.5.1	→	↑	↑	→	→	→	→	→	→	→	→
Regulation of temperature and humidity, including ventilation and transpiration	2.2.6.2	→	↑	↑	→	→	→	→	→	→	→	→
Cultural												
Characteristics of living systems that that enable activities promoting health, recuperation or enjoyment through active or immersive interactions	3.1.1.1	↑	↑	↑	↑	→	↑	→	↑	↑	→	↑
Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions	3.1.1.2	↑	↑	↑	↑	→	→	→	→	→	→	→
Characteristics of living systems that enable education and training	3.1.2.2	→	↑	↑	↑	↑	→	→	→	→	→	→
Characteristics of living systems that enable aesthetic experiences	3.1.2.4	→	↑	↑	→	→	→	→	→	↑	↑	↑

Impact: ↑ – stimulating; → – no relevant; ↓ – weakening.

Markiewicz 2005). The creation of such elements of spatial development was justified by the need for education in the field of ecology (Ptaszyk 1995).

The educational potential of the area was strengthened by the creation of educational boards that made it easier to conduct classes for the pupils and students. A demand for the creation of didactic paths within the limits of the study site was raised in many studies (Ptaszyk 1995, Borysiak, Markiewicz 2005, Abramowicz 2018). The didactic paths were designed along walking alleys. Particular boards show the history and wildlife of the Szachty area (Abramowicz 2018).

The impact of recreational and educational-enhancing investments on the potential to provide most of the analysed regulating services was assessed as no relevant. The infrastructure has straightened up unorganised foot and bicycle traffic. It led it at a distance from the most ecologically valuable areas, especially from the wetlands and the sites of legally protected species of plants such as *Centarium erythraea*, *Epipactis helleborine*, *Hedera helix*, *Utricularia vulgaris*, *Nuphar lutea*, *Ononis spinosa*, *Listera ovata* and *Equisetum variegatum* (Michałowska 2005, Wrońska-Pilarek 2016). In this way, a demand of natural capital experts that concerned making the recreational area available for the inhabitants and omitting the most ecologically valuable sites was met (Kaniecki et al. 1995, Ptaszyk 1995, Borysiak, Markiewicz 2005).

However, we assess that increasing the accessibility of the study area as a result of the construction of people-attracting infrastructure weakened the potential of the area for providing regulating service related to maintenance of nursery populations and habitats. It results not only from the transformation of the habitats in the places of the earthworks. It must be emphasised that, for many animals, the Szachty area is attractive when it is inaccessible for people (Ptaszyk 1995, Borysiak, Markiewicz 2005). It refers particularly to the birds of wetlands, such as *Ardea cinerea*, *Cygnus olor*, *Egretta alba* and *Podiceps cristalus* (Michałowska 2005, Wrońska-Pilarek 2016). Before the introduction of the network of pedestrian and cycling paths, the Szachty area, which is wet and boggy in places, made a lot of people hesitant to penetrate it, leaving animals with a suitable place to live and reproduce (Matuszyńska 2001). In addition, in the vicinity of the delimited barbecue area, the animals are scared away by people gathering around the fire.

An action that reduced the negative influence on the habitat services was the creation of vehicle barriers. They have reduced the interference in the habitats by reduction of uncontrolled entry of the vehicles (Urząd Miasta Poznania 2016). It is particularly important because of the proximity of Głogowska Street, running along the northern border of the research area, in which average traffic intensity is 8,200 vehicles a day (Zarząd Dróg Miejskich 2018). A study of Kaniecki et al. (1995) confirmed that species diversity of Szachty area is decreasing with the proximity of Głogowska Street. Also Burchard and Szeląg-Wasielewska (1995) pointed to increased car traffic as a factor that clearly alters the flora and fauna of ecosystems of the Szachty area located in immediate proximity to Głogowska Street. The goal of installation of vehicle barriers was to reduce the mechanical pressure, including damaging grasslands, as well as the acoustic pressure on the sensitive species associated with aquatic ecosystems (Urząd Miasta Poznania 2016).

The investments related to the remediation of ponds and renovation of culverts between them were aimed at the improvement of the water quality (Zarząd Zieleni Miejskiej 2014b), supporting regulating services of water bodies. The waters of the Szachty ponds are strongly eutrophic and very prone to algal bloom, what is driven by pollutants introduced from the outside (Biegała 2014) as well as high internal loads (Zarząd Zieleni Miejskiej 2014b); at the same time, as a result of their location, morphometric conditions and development of the catchment area, the water reservoirs of the study area have very limited self-purification and biological regeneration capabilities (Gogołek et al. 1995). The remediation of the ponds was the precondition of the prevention of degradation of the reservoirs and maintaining their biological diversity (Kaniecki et al. 1995). Providing patency to the whole system of the ponds was also essential for the restoration of the part of the lost acreage of riparian habitats. The flora of these habitats, such as *Angelica sylvestris*, *Equisetum palustre*, *Festuca pratensis*, *Polygonum bistorta* and *Vicia cracca*, is a nutritional base for the rich fauna of invertebrates, including those who are eaten by

breeding avifauna of the Szachty area (Borysiak, Markiewicz 2005). In addition, we assigned a positive impact on the microclimate regulating service to the work. According to Zwierzchowska (2017), water bodies, besides forests, belong to areas with a priority cooling effect potential within Poznań. As the urban heat island is a common occurrence in Poznań (Półrolniczak et al. 2017), stable freshwater ecosystems allow the users of the study site to enjoy distinctly cooler and more humid air than that found in the city centre. The study of Majkowska et al. (2017) showed that the average annual temperature differences between the Szachty area and the city centre are as high as 11°C.

We assessed that the improvement of the state of the reservoirs and arrangement of their shores strengthened CES related to aesthetic values, as well as active and passive interactions, which is indicated by the results of a survey study conducted amongst the users of the study site (Stępniewska, Abramowicz 2016). The educational potential of the study area has also increased; this is related to the fact that the reclaimed water bodies are the subject of two educational paths, which run within the study site.

Tree branch trimming and tree cutting were assessed by us as not relevant for the habitat service because of the location and scope of those works. They were conducted along pedestrian and cycling paths, and they consisted of the elimination of dead branches in the case of 198 trees as well as the cutting down of 16 additional trees. The works were aimed at providing a free and save passage to the users of the alleys. We have also assessed the impact of surface sealing resulting from the construction of cycling paths on the hydrological cycle as not relevant. In the case of Poznań, disturbances of the water flow related to the sealing of the surface are mainly noted in the city centre (Mizgajski et al. 2015). The study site is located peripherally in relation to densely built-up areas. The introduction of 2.8 km of asphalt paths resulted in the loss of the ability to capture rainwater within an area of 0.7 ha, that is, approximately 1% of the hitherto permeable part of the Szachty area. Processes that occur outside of the area have a more significant impact on the water relation of the study site; these include

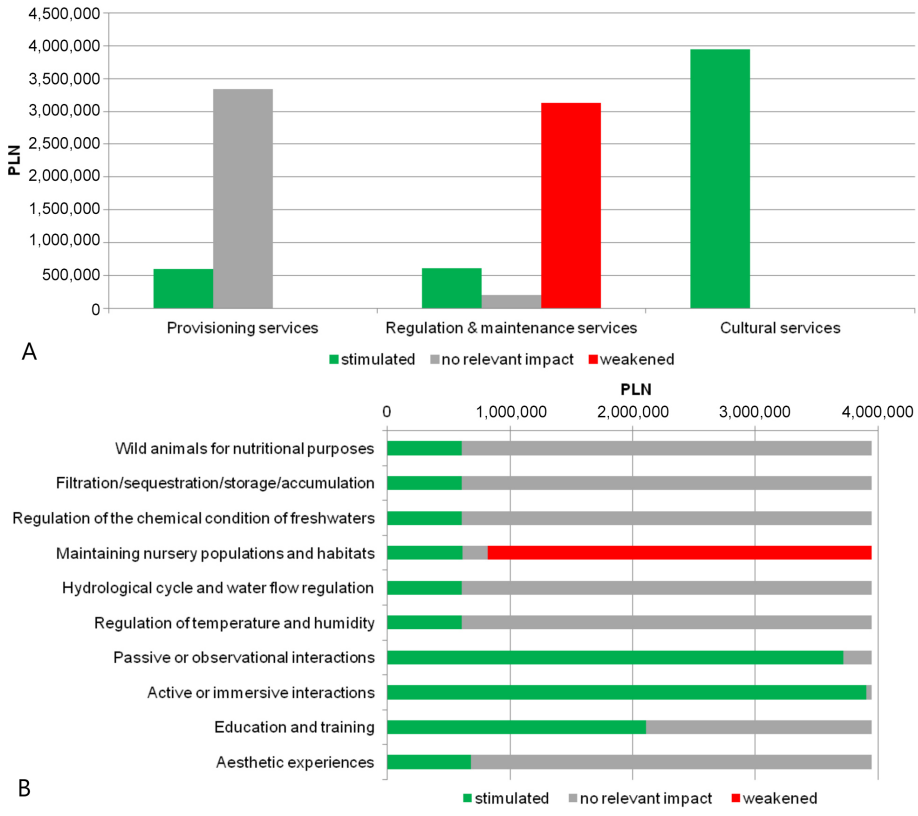

Fig. 3. Affected ecosystem services by sections (A) and classes (B) of the Common International Classification of Ecosystem Services (Haines-Young, Potschin 2018).

changes in the land use in the upper course of the Junikowski Stream, related to the expansion of residential and commercial development (Zacharczuk 1992, Bogucki, Staniewska-Zątek 1996, Matuszewska 2001, Biegała 2014).

The works related to maintenance of cleanliness and removal of storm damages strengthened the capabilities of physical use, as well as aesthetic values, of the study site. Many studies confirmed the importance of the ensuring of accessibility, cleanliness and safety to maintain urban green areas attractive as recreation places (Sutkowska 2006, Czekiel-Świtalska 2010, Bertram, Rehdanz 2015).

Figure 3 summarises incurred expenditure according to their impact on the individual section and classes of ES. The obtained results show that the expenditure stimulated CES the most; they were supported by all actions with the exception of the creation of the vehicle barriers. Amongst CES, the highest stimulating costs were connected with the activities promoting health, recuperation and enjoyment through passive or active interactions (more than 90% of overall expenditures). With reference to regulating ES, the investments worth PLN 0.6 million had a stimulating impact; this figure comprised mainly expenditure on the remediation of ponds and renovations of culverts. The latter actions resulted also in the stimulation of provisioning ES related to non-commercial fishing.

The weakening impact of expenditure concerned regulating ES related to maintaining nursery populations and habitats. Such impact may be attributed to the investments worth PLN 3.1 million that included the construction of recreational infrastructure (paths, vantage points and barbecue area).

Discussion

Current structure and level of ES of the Szachty area have been shaped by sequential influence of several factors: the exploitation of ceramic raw materials that led to transformation of postglacial relief and hydrological conditions to their present form, natural succession after the discontinuation of mining activities that imparted significant ecological values to the area, noticing and protection of these values by granting legal protection and then growing interest in making the study site recreationally available for urban citizens.

The results of our research showed that public policy concerning the Szachty area is focused on the creation of infrastructure supporting CES. According to another study (Abramowicz, Stępniewska 2016), these ES are most often recognised by the citizens; during field survey amongst visitors of the study site, the respondents identified four CES, compared with two provisioning ES and only one regulating ES. Such a perception of the benefits provided by the Szachty area affects the assessment of the actions made by the public authorities. Users of the study site highly valued the introduction of small architecture such as benches, waste bins, signposts and paths. They attached less importance to the actions enhancing regulating ES, such as remediation of ponds and renovation of culverts between them.

Social demand for making GI recreationally available and policy response expressed in the introduction of recreational facilities is reported for the cities both in Poland (e.g. Bernaciak, Mudrak 2014, Stępniewska, Sobczak 2017, Długoński 2018, Fisher et al. 2018) and around the world (e.g. Larson et al. 2016, Hegetschweiler et al. 2017, Wang, Liu 2017, Fisher et al. 2018). At the same time, enhancing of recreational opportunities must be reconciled with the preservation of the potential of the ecosystems for the provision of other ES that are necessary for maintaining the stability of urban social–ecological systems (Grunewald, Bastian 2017). The interactions between CES and remaining ES are diversified locally, depending on the ecological role of a particular piece of GI in the whole urban system, as well as on the forms and intensity of recreational usage (Giedych, Maksymiuk 2017). In case of the Szachty area, a possibility of introducing some recreational facilities is backed by the opinions of natural capital experts (Kaniecki et al. 1995, Ptaszyk 1995, Borysiak, Markiewicz 2005). However, we have already noticed the negative impact of the public investments on habitat regulating service; introduced infrastructure alters the habitats and contributes to scaring way animals (Abramowicz 2016, Rada Osiedla Świerczewo 2018, Rada Osiedla Fabianowo-Kotowo 2018).

Further changes in the structure and level of ES provided by the Szachty area will be driven

by administrative decisions concerning the directions of its spatial development. Recently, the interest in the study site is growing amongst private investors, who see the potential of the area for water recreation. Undoubtedly, organising the recreational use of the Szachty area through the creation of new infrastructure is necessary. For example, the problem noticed by Borysiak and Markiewicz (2005) is the lack of small infrastructure for recreational fishing. Unorganised fishing causes the destruction of biocenoses of littoral through trampling and littering and contributes to eutrophication of waters (as a result of using ground baits). However, the creation of new pedestrian and bicycle paths, resulting in the increased access to the ecologically valuable areas, should be considered with prudence. With reference to making clay pits available for people swimming there, Kaniecki et al. (1995) emphasised that the decisions should be made carefully and individually for the particular water body. In addition, Florkiewicz et al. (2015) highlighted that the varved clays from the Junikowski Stream Valley are soft and compressible and thus present significant difficulties during design and construction of infrastructure.

In Poland, the largest influence on spatial changes is exerted by planning arrangements at the local level (Stępniewska et al. 2018). The tools that can be used for shaping the ES are the study of conditions and directions of spatial development and local master plans. The local master plans are acts of local law and establish conditions of land development, including the principles of protection of nature and landscape and limitation of their use (*Ustawa – Prawo ochrony przyrody* 2001). In 2018, because of the growing interest in the investing in the Szachty area, local government initiated the procedure of passing a local master plan that includes its area. The project of local master plan (*Miejska Pracownia Urbanistyczna* 2018) assumes, amongst others, protection of landscape values through maintenance of existing land cover and land use, protection of surface waters and their natural plant communities, a ban on the investments that may significantly affect the environment, protection of existing trees and in the event of collision with planned infrastructure or development, the requirement of replanting them or planting the new ones.

We strongly agree that it is urgent to make planning decisions that would organise the direction of further land development of Szachty area and determine conditions for executed investments – public and private. These actions should create a space that will address not only ecological priorities but also user demands (Buchel, Frantzeskaki 2015). However, in our opinion, the local master plan should include regulations directly concerning the protection of biological diversity. They would constitute a premise for the creation of, proposed by the experts and the local community, nature conservation area in the form of the ecological site (Kaniecki et al. 1995, Ptaszyk et al. 2002, Borysiak, Markiewicz 2005, Wrońska-Pilarek 2016, Rada Osiedla Świerczewo 2018). In the Polish legal system, the creation of an ecological site corresponds to protection of the service concerning maintaining nursery populations and habitats (*Nature Conservation Act* 2004, Mizgajski et al. 2015); this service, as we assessed, is the most affected by the public infrastructure introduced in the Szachty area and should be specially protected in the case of an execution of further investments.

Conclusions

The study showed that financial policy concerning the development of urban GI is a vital factor driving the delivery of ES. The decisions on public expenditure should ensure continuous provision of all ES that are key for the maintenance of liveability and resilience of urban social–ecological systems. This includes, in particular, tying the local needs with the protection of subregional ecological connectivity, because the study site links the inner urban green areas and the natural surroundings of the city (Zwierzchowska et al. 2018). The fact that the investments aimed primarily at recreational infrastructure significantly affect the ES balance may not be surprising for natural capital experts. However, full and long-term effects of the decisions on land development can be barely visible and incomprehensible for the citizens and decision-makers, especially when they concern areas of high natural values. In such cases, scientific support can help to understand the synergies and trade-offs resulting from the financial

policy, laying the grounds for a more effective ES management.

We are aware of the methodological limitations resulting from the lack of systematic ecosystem monitoring data related to the study area. Nonetheless, in authors' opinion, the obtained results may support more complex and high-quality dialogue concerning the development of urban GI. It refers particularly to the decisions related to balancing the interests of various stakeholders, such as binding citizens' preferences and expectations for enhancing of CES with the protection of regulating ES. Showing the impact of financial decisions on the structure and level of ES may give arguments strengthening the position of nature in the process of social participation whilst making decisions. It is possible by showing the connection between the expenditure on the protection of regulating ES and protection of essential biophysical underpinning of CES delivery. Moreover, presenting the benefits to urban planning from the monitoring of changes in ES during a social and political debate can also justify the need to bear the costs of ecosystem monitoring.

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