Małgorzata PIĘTA-KANURSKA

DEVELOPMENT OF GREEN INFRASTRUCTURE AS A TREND IN CLIMATE TRANSFORMATION - CHALLENGES FOR POLISH CITIES

Małgorzata **PIĘTA-KANURSKA** (ORCID: 0000-0002-8790-2503) – *Wroclaw University of Economics and Business, Department of Ecological Economics*

Correspondence address:
Komandorska Street 118/120, 53-345 Wroclaw, Poland
e-mail: malgorzata.pieta-kanurska@ue.wroc.pl

ABSTRACT: The aim of this paper is to characterize the shaping of green infrastructure for the 12 largest Polish cities in 2005-2021. The research was performed using the data from the Central Statistical Office of Poland (GUS). The outline of the research supports the conclusion that large Polish cities should make changes to increase the area of functional green spaces. In line with global and European trends, investments in the development of green infrastructure should be a priority in the development strategies of Polish cities. The development of functional green spaces should make them more biophilic according to the good practices of the greenest cities in Europe and the world.

KEYWORDS: green infrastructure, functional green space, biophilic city

Introduction

The spaces we inhabit shape our lives. The ways in which they are arranged have a profound effect on our compliance with safety regulations, encouraging us to shop or engage in social interactions and discouraging us from littering. The space is like a hidden director who reaches into our subconscious and affects the decisions we make and even the time we need to solve problems (Bernheimer, 2019). Greenery is a special component of every space. The environment we spend our time in affects our health, well-being and emotions. It can boost our energy, affect our pain levels and blood pressure, accelerate recovery and regeneration, slow down ageing processes or reduce our susceptibility to lifestyle diseases. The size, type, quality, and accessibility of green spaces have a significant effect on the quality of life of individuals and entire communities.

The role of green spaces is particularly significant in urban areas (Prokopska & Martyka, 2017). The city space is largely anthropogenic and devoid of natural features. Buildings, the roads between them, car parks and other paved areas form the cityscape, which is often referred to as the so-called grey space. If the spatial and natural structure is unbalanced, i.e., if there is too much grey infrastructure relative to green spaces, such a condition is referred to as "concreteosis". This phenomenon is the reason many Polish cities are grey, and it contributes to the low quality of life of their residents (Mencwel, 2020).

Cities, due to the increase in population combined with the limited area and resources (e.g., water, energy), should be very careful when arranging every part of their area, paying particular attention to green spaces. The shaping of modern natural and urban structures is a trend that can be observed in many cities in Europe and in the world as a response to the challenges resulting from the unavoidable climate crisis (Geneletti & Zardo, 2016; WMO, 2020).

The increasing frequency of extreme weather phenomena causes many problems to the cities and their residents. High temperatures are recorded increasingly often, contributing to the formation of so-called urban heat islands (UHI), i.e., places where the temperature of paved areas on hot days can be as high as 60°C during the summer. UHI is also documented as rising air temperatures in cities compared to air temperatures in their countryside. Staying in such areas, which are usually located in the city centers, is dangerous to people's health and safety. The UHI might be seen as a worldwide problem that endangers the functioning and habitability of cities and urban ecosystems (Jabbar et al., 2023).

Another problem is severe and sudden rainfalls, which cause pluvial flooding – it occurs when the natural underground drainage system cannot drain rainfall away quickly enough, causing the water table to rise above the ground surface (Graf & Kałużna, 2020; MacDonald et al., 2012).

Whether it is mitigating flood risk, improving access to clean water or treating urban water effluents, managing water is a top priority for all cities in the

DOI: 10.34659/eis.2023.87.4.562

world (Man Hamel & Tan, 2022). The response to these issues is the development of so-called green infrastructure. In most modern cities, there is an increasing share of vegetated areas and green spaces, and natural processes and ecosystem services are being used to manage energy and water in order to mitigate the consequences of climate change (Victoria State Government, 2017; Arcadis, 2022).

Aim of the paper and research methods

The research problem discussed in this paper has been formulated as follows: How does the functional green space develop in large Polish cities from 2005 to 2021?

The additional aim of this paper is also to investigate the significance of green infrastructure in the context of the mitigation of climate change consequences in the greenest cities in Europe and the world and formulate recommendations for the development of green infrastructure in Polish cities. To achieve the primary aim, the following research questions have been formulated:

1. Where is research into green infrastructure being done?
2. How do we understand and define green infrastructure in cities?
3. What are the functions of green infrastructure components?
4. How does functional green infrastructure develop in Polish cities?
5. What are the examples of good practices concerning green infrastructure?
6. What recommendations can be formulated for Polish cities?

The research was performed using the desk research method, which includes an analysis of scientific papers regarding green infrastructure, particularly with respect to its existing definitions and functions in the city's good practices regarding green infrastructure in cities. Also, based on the data from the Central Statistical Office of Poland (GUS), the shaping of green infrastructure has been analysed for the 12 largest cities in 2005-2021. Then, selected green infrastructure solutions in cities that occupy the leading positions in the strategic documents (Rożałowska, 2020; ARUP, 2023), and the solutions they use can serve as examples of good practices in the investigated area. Finally, suitable recommendations were prepared regarding the development of green infrastructure for Polish cities.

Literature review

The review of research papers indexed in the Web of Science database regarding green infrastructure between 2002 and 2019 shows that the highest number of such papers have been prepared in the USA (747 publications), making up 34.05% of all papers. The second place is taken by China, with 231 publications, which makes up approx. 10.53% of the whole. The third place, with only a slightly smaller number of publications, is occupied by the United Kingdom

DOI: 10.34659/eis.2023.87.4.562

(225, 10.26%). Further countries include Italy (160, 7.29%), Australia (153, 6.79%) and Germany (141, 6.43%). The shares of other countries, i.e., Sweden (100), Canada (92), the Netherlands (89), Spain (79) and other countries (177), are smaller than 5% in each case. Also, considering the total number of publications collected in the WOS database over a longer period of time, i.e., between 1995 and 2019, it can be seen that the number of publications has been growing steadily and significantly. In 1995, there were just two such publications, and in 2019, there were 594. The six most important institutions with respect to the highest number of publications include the following: US Environmental Protection Agency (EPA), Swedish University of Agricultural Science, UFZ Helmholtz Centre Environmental Research, University of Hong Kong, Chinese Academy of Sciences and Drexel University US. Also, there has been a rapid increase in the number of publications in recent years at Drexel University US, Swedish University of Science and Technology Agriculture and Wageningen University and Research in the Netherlands (Ying et al., 2021).

The data cited above indicate the growing significance of research into the shaping and development of green infrastructure over the last 25 years. Also, this interest in green infrastructure is global. The direct reason for the growing popularity of research in this field is the increasing risk of a global climate crisis, contributing to the need to plan the sustainable development of urban areas.

"Green infrastructure" is a term that has been used in social and economic practice since the middle of the 1980s. However, it became particularly important in planning processes in 1994 when it was used in a report on the land protection strategy prepared for the governor of Florida. The report indicated that systems of natural areas were equally important parts of the infrastructure. This was an innovative approach because it had been customary to only plan the so-called grey infrastructure. The report's initiative to plan, protect and restore balance to systems of natural areas, i.e., so-called green infrastructure, enabled the decision-makers to recognise its significance in the processes of strategic spatial planning (Fireshock, 2010).

Over the years, the term "green infrastructure" has evolved and come to be defined in various ways (Monteiro et al., 2020). Green infrastructure refers to strategically planned and managed networks of natural land, landscapes and other open spaces that protect the values and functions of the ecosystem and provide a wide range of benefits to human populations and wild nature (Benedict & McMahon, 2006). These benefits include, in particular, fresh air and water. The green infrastructure used in this context forms the ecological framework for environmental, social and economic health and is required to sustain life (Sinnett et al., 2015).

According to the United States Environmental Protection Agency, green infrastructure is a term used to describe different products, technologies and practices that use natural or engineering systems imitating natural processes to

DOI: 10.34659/eis.2023.87.4.562

improve the overall quality of the environment and provide public services (USEPA, 2011).

When green infrastructure is defined in the context of urban areas, it is described as the natural environment within cities, towns and villages and in areas between them. Urban green spaces include parks, nature reserves, sports fields, coastal areas, such as stream and river banks, public gardens, streetside trees, green walls and roofs, alleys and cemeteries. They also include private green spaces, which include private backyards, public areas of buildings and campuses of institutions and companies. Such green spaces vary in terms of size, vegetation cover, species richness, environmental quality and proximity to public transport, buildings and services. They form a system of open spaces, waterways, gardens, forests, green corridors, streetside trees and open village areas that bring many social, economic and environmental benefits to local communities (Burgess et al., 1988). Green infrastructure includes all environmental resources, which is why the approach that provides for shaping the cityscape using green infrastructure also contributes to the sustainable management of resources (Davies et al., 2006).

Green infrastructure has a wide range of important functions (see Table 1). It is planned and used to mitigate the consequences of climate change (O'Donnell et al., 2021). Green space can filter air, remove pollution, attenuate noise, reduce temperature, infiltrate stormwater and replenish groundwater (Ghofrani et al., 2017). For instance, trees in urban areas can reduce air pollution by absorbing certain air pollutants from the atmosphere (Nowak et al., 2006). Green spaces and urban forests can also reduce temperature, providing shade and cooling the area to reduce the risk of heat-related diseases for city residents (Wolch et al., 2014).

Table 1. Benefits and costs of green infrastructure for the city

Benefits	Costs
• improving the attractiveness of the city for residents and tourists, cultural value, • improving the quality of life and health of the residents, • increasing biodiversity, • food production, • sustainable development of the city through the reduction of greenhouse gases, • more efficient management of water and energy, • reduction of high temperatures, i.e., mitigation of the urban heat island effect; cooling effect, • reduction of carbon footprint, • noise attenuation.	• urban greening may, paradoxically, have negative effects similar to the effects of gentrification: increase of real estate prices and living costs, resulting in the resettlement of poorer groups of residents, • unknown effects of environmental engineering.

Source: author's work based on Burgess et al. (1988); Brown and Mijic (2020); Garcia-Lamarca et al. (2021); Fors et al. (2015).

DOI: 10.34659/eis.2023.87.4.562

Green infrastructure is the cornerstone of the concept of a biophilic city, based on the shaping and development of ecosystem services, i.e., benefits for the city provided by the environment. The range of benefits obtained from the environment is very wide: from providing the city residents with basic goods (air, water, resources) through responding to cultural needs to regulating and ensuring high-quality living conditions for the residents (Zwierzchowska & Mizgajski, 2019). These benefits support the environmental integrity of the cities and can help combat many urban problems (Wolch et al., 2014). This range shows the elementary nature of the dependence of urban communities on the good condition of the environment.

Green spaces in large Polish cities

Thus, it is a good idea to analyze functional green infrastructure in the 12 largest Polish cities in 2005-2021. Figure 1 shows the percentage of green spaces in the total area of the investigated cities.

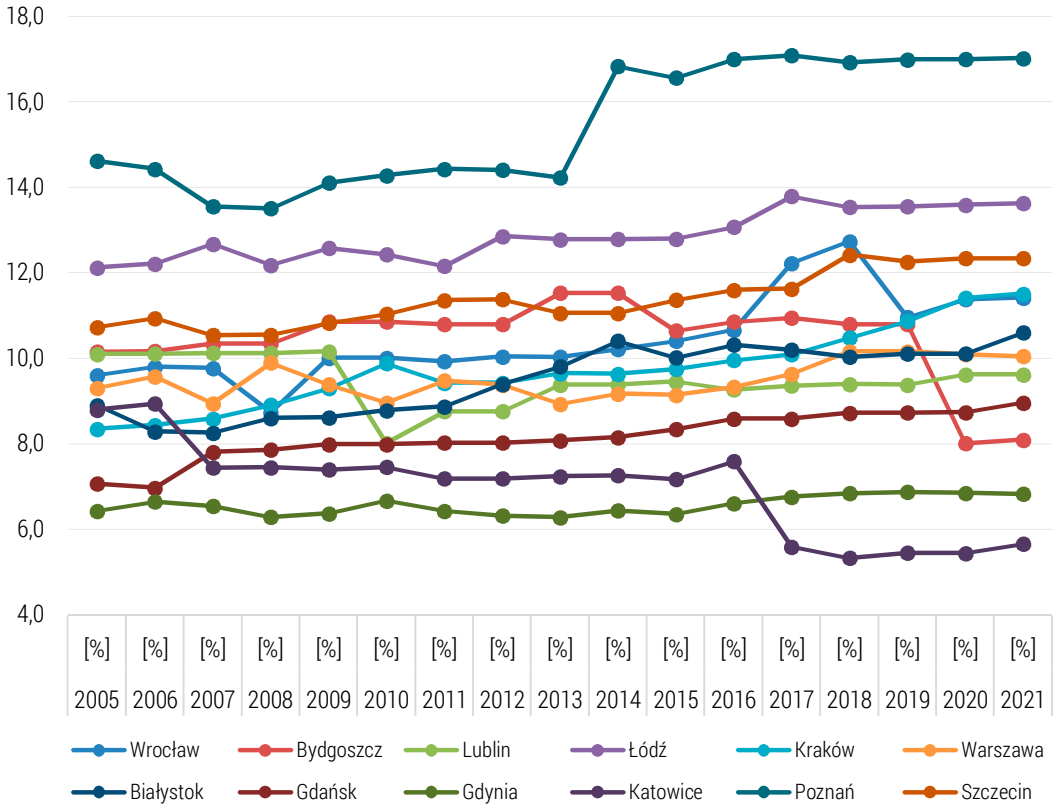

Figure 1. Percentage of green spaces in the total area for the 12 largest Polish cities

Source: author's work based on GUS (2023).

DOI: 10.34659/eis.2023.87.4.562

It should be noted that the percentage of green spaces in the total area of the city is the highest for Białystok, amounting to 17%. Łódź has ranked second, with a share of almost 14%, and the third place is taken by Szczecin (12.34%). Generally, the percentage of green spaces in the total area of the individual cities in the analysed period shows a fairly constant tendency. However, in Katowice and Bydgoszcz, the share of green spaces in the total area has decreased in the last dozen years. This is not a positive trend.

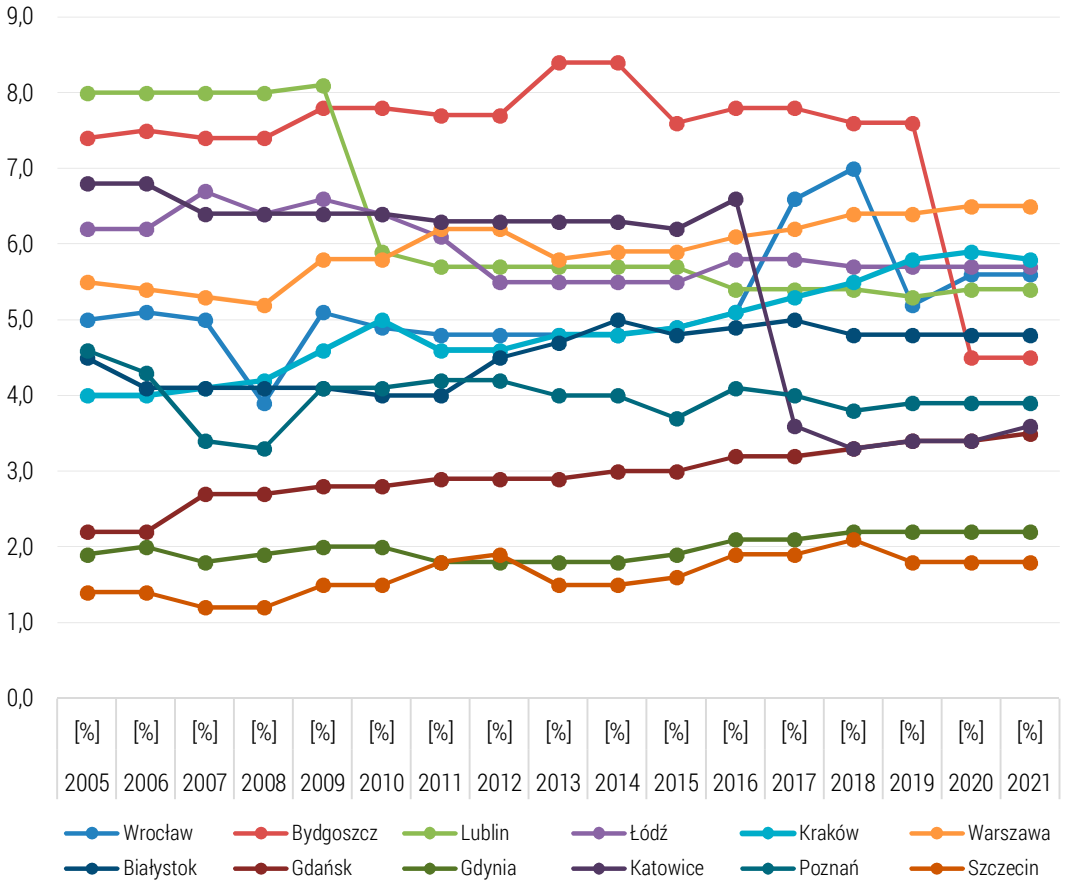

Figure 2. Percentage of parks, vegetated areas and residential green spaces in total area for the 12 largest Polish cities

Source: author's work based on GUS (2023).

Also, green spaces are defined by the Central Statistical Office of Poland as "landscaped ground with service infrastructure and functionally related buildings, covered with vegetation and located within city limits". The green spaces defined in this way also include so-called grey infrastructure. Thus, if we con-

DOI: 10.34659/eis.2023.87.4.562

sider only the green areas of large Polish cities (excluding the functionally related buildings) in the form of parks, vegetated areas and residential green spaces, the percentage of green spaces in the total area is even smaller and does not exceed 7% in the case of the "greenest" city, i.e., in this case, Warsaw (cf. Figure 2).

The situation for the 12 investigated cities is different. In turn, if we consider the forest cover ratio, it is understood as the percentage of forest area to the total area of the city. This ratio is the highest for Gdynia, Katowice and Bydgoszcz (cf. Figure 3).

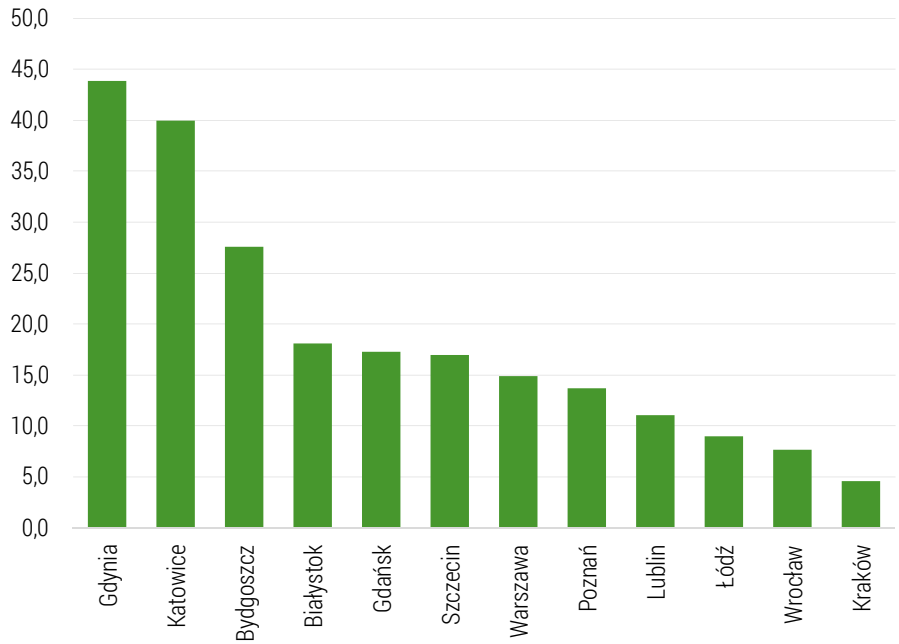

Figure 3. The ratio of forest cover to the total area for the 12 largest Polish cities [%]
Source: author's work based on GUS (2023).

When the forests are considered in the analyses of green spaces, the greenest of large Polish cities will include Gdynia, Katowice and Bydgoszcz, and the total ratio of green space to the area of the city reach 50% (cf. Figure 4).

In comparison with the greenest European cities, the 50% ratio of green spaces to the total area of the city is a fairly good result. Unfortunately, as indicated by the analysis above, this ratio is driven by the urban forests, which are usually located on the outskirts of cities, while the city centres or residential estates do not have a sufficient share of green spaces. These analyses confirm the phenomenon of concreteosis in large Polish cities. The reasons for this can be traced to the way the urban areas have been planned so far. The history of the development of architecture and urban planning reflects the process of the for-

DOI: 10.34659/eis.2023.87.4.562

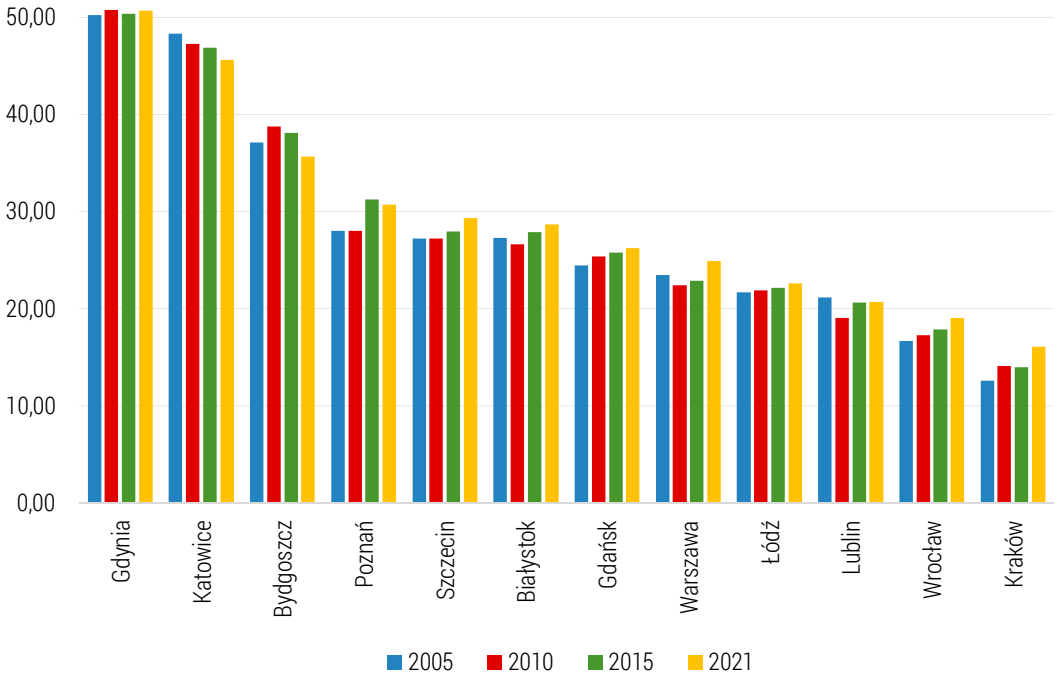

Figure 4. The total ratio of green spaces and forests to the total area for the 12 largest Polish cities [%]
Source: author's work based on GUS (2023).

mation of an artificial environment through the isolation, elimination or neutralisation of phenomena adverse to mankind, but now sustainable urban planning is needed (Agudelo-Vera et al., 2011).

Examples of good practices concerning green infrastructure

Presently, in modern cities, water is increasingly often retained on green roofs and in rain gardens (Burszta-Adamiak & Walter, 2020). This marks an important change in the philosophy and design of urban infrastructure. Grey infrastructure should remain in close symbiosis with green infrastructure. Isolation, the elimination of phenomena potentially unfavourable to people, is replaced with new solutions which "understand" that nature is an important and necessary part of the urban ecosystem.

Auckland in New Zealand is an example of a city that looks for inspiration in nature to find solutions to challenges connected with the climate, such as the management of severe rainfall (Boyle, 2014). It is recognised as the most "spongy" among cities such as London, Bombay, Nairobi, New York, Shanghai and Singapore. It was found to be the best at absorbing torrential rains. In Auckland, half of

DOI: 10.34659/eis.2023.87.4.562

the investigated area consists of green and blue infrastructure, which is why it is capable of absorbing severe rainfall (Arup, 2023). Examples of infrastructure that performs this function include the green roof of the Civic Centre, Waitakere, Auckland. It has received the prestigious Award of Excellence for Sustainability. It is a flat garden with an area of 500 m^2 planted with 10 types of native plants. The substrate uses special, very lightweight materials (clay balls, irrigation mat) to help retain water. Its functions includehalving water runoff during storms, cleaning normal runoff, providing food and habitat for native insects and birds and increasing biodiversity, e.g., by creating living conditions for lizards.

Another example of good practices is the so-called small retention, which is a proposition to solve the problem of groundwater flooding, which is a common issue in cities. Intensive rainfall often leads to local damage, hindering the life of city residents. When rainfall is severe, the sewer system cannot receive large amounts of water, and the storm drains are blocked by rubbish, resulting in groundwater flooding. This is caused by concreteosis, i.e., the sealing of surfaces such as roads, footpaths, squares and roofs, from where stormwater is discharged into the sewer system. The problem can be solved by water retention in every possible area – including small retention in the form of lawns, small ponds, depressions, small green roofs and others. In the urban lawns in Copenhagen, there are so-called soakaways, which increase the retention capacity of the lawn. A soakaway is a large stormwater tank buried in the ground to collect water and use it to irrigate the soil.

The examples above are only designed to illustrate the changes in the ways of thinking about the design of infrastructure in cities. There are many more solutions relating to green infrastructure. Depending on the type of solutions used in the field of green infrastructure, the cities obtain different benefits (Table 2).

Table 2. Examples of green infrastructure in cities – benefits and challenges

Type	Benefits	Challenges
Living roofs (green roofs, gardens on roofs)	• extended life of the roof thanks to protection against UV radiation and the elements, • delayed and reduced stormwater runoff, • improved thermal performance of the roof, • creating habitats for birds and insects, • absorbing carbon dioxide and reducing greenhouse gases, • improving acoustic performance thanks to noise reduction, • improved aesthetics depending on the type of plants, • additional living and recreational space for the city residents.	• initial development cost is high, • potentially inferior visual quality in dry periods depending on the intensity of watering and type of plants, • need for watering in some installations.
City parks, city forests	• improving the welfare of people by providing space for recreation and exercise, • maintaining biodiversity, • providing ecosystem services.	• costs of management and maintenance may be high.

DOI: 10.34659/eis.2023.87.4.562

Type	Benefits	Challenges
Green transport: green streets, green alleys, permeable footpaths and green transport	• permeable pavements offer a solution that slightly reduces the peak volume and retains some of the stormwater during rainfall, • delaying stormwater runoff and removing pollutants from the water, • permeable pavement can also help replenish the catchment because water is retained instead of being discharged with pipes to the outlets (rivers), where it causes problems due to the increased temperature, pollution, sedimentation, etc., • replacing the means of transport with means that are easier on the environment, such as walking and driving a bicycle, can have many health and environmental benefits.	• lower permeability and design considerations, • one of the challenges is to select the appropriate placement to prevent groundwater contamination, • planting vegetation in the streets should also include the reinforcement of road and railroad shoulders with multiple functions (biodiversity, management of stormwater) to achieve multiple benefits.
Living walls (green walls)	• reducing the energy needed to cool the building, studies from Singapore showed that complete coverage with vegetation resulted in a 74% reduction of the required cooling energy, • green walls can mitigate the urban heat island effect and provide insulation if they are correctly designed, • they can provide space for food production and attract wild animals.	• the challenge to the success of this form of green infrastructure are the climate conditions characteristic of the specific city.
Rain gardens and dykes covered with vegetation – bioswales, pretzels planted with grass	• improvement of the street landscape and management of stormwater runoff, • reducing the total pollution content, • retaining stormwater, reducing peak flows and replenishing the catchment, • bioswales, similarly to rain gardens, can reduce peak flow and runoff and filter off some types of pollutants.	• considering the warming potential, the ponds can result in the spreading of pests such as mosquitoes, contributing to the spreading of the diseases they transmit in the region.

Source: author's work based on Boyle et al. (2014); Iwaszuk et al. (2019); Sherer (2006).

These examples confirm the global trend in the strategic planning of city development into the biophilic city, where various nature-based solutions are used that combine green and grey infrastructure (Nowakowska & Przygodzki, 2016).

DOI: 10.34659/eis.2023.87.4.562

Conclusions

The research supports the conclusion that large Polish cities should make changes to increase the area of functional green spaces. Examples of green infrastructure solutions show that green infrastructure contributes to the resilience of the city in many ways. It should be emphasised that the latest concepts of city development indicate a departure from the purely economic aspect of city development towards biophilic cities, which are more resistant to climate change. The following recommendations can be formulated based on the conducted research:

1. Green infrastructure systems should be developed according toglobal and European trends in the strategic planning of city development (Legutko-Kobus, 2017), and there are various nature-based solutions that can be used.
2. Investments in the development of green infrastructure should be a priority in the development strategies.
3. Examples of good practices should be sought in cities in Europe and the world and adapted to the social, spatial requirements, and environmental requirements of Polish cities.
4. More extensive research should be conducted regarding the concept of the biophilic city, and new, innovative solutions should be sought to imitate nature.

The conducted research proves that the topic is very important to the sustainable development of Polish cities, which is why there is a need for further work in this regard.

References

Agudelo-Vera, C. M., Mels, A. R., Keesman, K. J., & Rijnaarts, H. H. M. (2011). Resource management as a key factor for sustainable urban planning. Journal of Environmental Management, 92(10), 2295-2303. https://doi.org/10.1016/j.jenvman.2011.05.016

Arcadis. (2022). *The Arcadis Sustainable Cities Index 2022.* https://www.arcadis.com/en/knowledge-hub/perspectives/global/sustainable-cities-index?utm_source=google&utm_medium=Search_ad&utm_campaign=Sci22&gclid=Cj0KCQiAkMGcBhCSARIsAIW6d0BqHLZrN3ARfcgpbsB-qULnwcYRa75O7ubQHM3Ls4YFkSe_5Fh03B0aAgRwEALw_wcB

ARUP. (2023). *Global Sponge Cities Snapshot.* https://www.arup.com/perspectives/publications/research/section/global-sponge-cities-snapshot

Benedict, M. A., & McMahon, E. T. (2006). *Green Infrastructure: Linking Landscapes and Communities.* Washington, D.C.: Island Press.

Bernheimer, L. (2019). *The Shaping of Us.* Texas: Trinity University Press.

Boyle, C., Gamage, G. B., Burns, B., Fassman-Beck, E., Knight-Leninhan, S., Schwendenmann, L., & Thresher, W. (2014). *Greening cities a review of green infrastructure.* New Zealand: University of Auckland. https://cdn.auckland.ac.nz/assets/creative/schools-programmes-centres/transforming%20cities/Greening_Cities_Report.pdf

DOI: 10.34659/eis.2023.87.4.562

Brown, K., & Mijic, A. (2020). Integrating green and blue spaces into our cities: Making it happen. Grantham Institute Briefing paper, 30, 1-8. https://www.imperial.ac.uk/media/imperial-college/grantham-institute/public/publications/briefing-papers/Integrating-green-and-blue-spaces-into-our-cities---Making-it-happen-.pdf

Burgess, J., Harrison, C. M., & Limb, M. (1988). People, Parks and the Urban Green: A Study of Popular Meanings and Values for Open Spaces in the City. Urban Studies, 25(6), 455-473. https://doi.org/10.1080/00420988820080631

Burszta-Adamiak, E., & Walter, E. (2020). *Green roofs and walls as a solutions supporting urban green infrastructure*. Wrocław: Wydawnictwo UWP.

Davies, C., MacFarlane, R., McGloin, C., & Roe, M. (2006). *Green infrastructure planning guide*, p. 45.

http://www.scribd.com/doc/ 33007993/Green-Infrastructure-Planning-Guide

Firehock, K. (2010). *A Short History of the Term Green Infrastructure and Selected Literature.* https://gicinc.org/wp-content/uploads/GI-History.pdf

Fors, H., Molin, J. F., Murphy, M. A., & Konijnendijk van den Bosch, C. (2015). User participation in urban green spaces – For the people or the parks? Urban Forestry & Urban Greening, 14(3), 722-734. https://doi.org/10.1016/j.ufug.2015.05.007

Garcia-Lamarca, M., Anguelovski, I., Cole, H., Connolly, J. J. T., Argüelles, L., Baró, F., Loveless, S., Pérez del Pulgar Frowein, C., & Shokry, G. (2021). Urban green boosterism and city affordability: For whom is the 'branded' green city? Urban Studies, 58(1), 90-112. https://doi.org/10.1177/0042098019885330

Geneletti, D., & Zardo, L. (2016). Ecosystem-based adaptation in cities: An analysis of European urban climate adaptation plans. Land Use Policy, 50, 38-47. https://doi.org/10.1016/j.landusepol.2015.09.003

Ghofrani, Z., Sposito, V., & Faggian, R. (2017). A Comprehensive Review of Blue-Green Infrastructure Concepts. International Journal of Environment and Sustainability, 6(1), 15-36.

Grădinaru, S. R., & Hersperger, A. M. (2019). Green infrastructure in strategic spatial plans: Evidence from European urban regions. Urban Forestry & Urban Greening, 40, 17-28. https://doi.org/10.1016/j.ufug.2018.04.018

Graf, R., & Kałużna, J. (2020). Zarządzanie wodą opadową w mieście w aspekcie minimalizacji ryzyka podtopień i powodzi typu „flashflood" (na przykładzie Kalisza). In D. Wrzesiński, R. Graf, A. Perz & K. Plewa (Eds.), *Zmiany Obiegu Wody. Współczesne Problemy i kierunki badań* (pp. 171-191). Poznań: Bogucki Wydawnictwo Naukowe. https://www.researchgate.net/profile/RenataGraf/publication/344390010 (in Polish).

GUS. (2023). *Local Data Bank.* https://stat.gov.pl/ (in Polish).

Iwaszuk, E., Rudik, G., Duin, L., Mederake, L., Davis, M., & Naumann, S. I. W. (2019). *Błękitno-zielona infrastruktura dla łagodzenia zmian klimatu w miastach*. Warszawa: Fundacja Sendzimira. (in Polish).

Jabbar, H. K., Hamoodi, M. N., & Al-Hameedawi, A. N. (2023). Urban heat islands: a review of contributing factors, effects and data. *Proceedings of the 3rd International Conference on Smart Cities and Sustainable Planning,* 1129, 012038. https://doi.org/10.1088/1755-1315/1129/1/012038

Kapetas, L., & Fenner, R. (2020). Integrating blue-green and grey infrastructure through an adaptation pathways approach to surface water flooding. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 378(2168). https://doi.org/10.1098/rsta.2019.0204

Legutko-Kobus, P. (2017). Adaptacja do zmian klimatu jako wyzwanie polityki rozwoju miast w kontekście krajowym i europejskim. Komitet Przestrzennego Zagospodarowania Kraju Polskiej Akademii Nauk, 268, 83-97. (in Polish).

MacDonald, D., Dixon, A., Newell, A., & Hallaways, A. (2012). Groundwater flooding within an urbanised flood plain. Journal of Flood Risk Management, 5(1), 68-80. https://doi.org/10.1111/j.1753-318X.2011.01127.x

Man Hamel, P., & Tan, L. (2022). Blue–Green Infrastructure for Flood and Water Quality Management in Southeast Asia: Evidence and Knowledge Gaps. Environmental Management, 69(4), 699-718. https://doi.org/10.1007/s00267-021-01467-w

Manley, W., & Price, S. (2017). Green Infrastructure. In S. Huston (Ed.), *Smart Urban Regeneration: Visions, Institutions and Mechanisms for Real Estate* (pp. 40-53). London: Routledge. https://doi.org/10.4324/9781315677521-3

Mencwel, J. (2020). *Betonoza*. Warszawa: Wydawnictwo Krytyki Politycznej. (in Polish).

Monteiro, R., Ferreira, J. C., & Antunes, P. (2020). Green infrastructure planning principles: An integrated literature review. Land, 9(12), 1-19. https://doi.org/10.3390/land9120525

Nowak, D.J., Hoehn, R.E.I., Crane, D.E., Stevens, J.C., & Walton, J.T. (2006). *Assessing Urban Forest Effects and Values*. Washington, D.C.'s Urban Forest. USDA Forest Service, Northern Research Station.

Nowakowska, A., & Przygodzki, Z. (2016). Zintegrowane metody i narzędzia zarządzania miastem. In Z. Przygodzki (Ed.), *EkoMiasto#Zarządzanie. Zrównoważony, inteligentny i partycypacyjny rozwój miasta* (pp. 109-138). Łódź: Wydawnictwo Uniwersytetu Łódzkiego. https://doi.org/10.18778/7969-721-2.06 (in Polish).

O'Donnell, E. C., Netusil, N. R., Chan, F. K. S., Dolman, N. J., & Gosling, S. N. (2021). International perceptions of urban blue-green infrastructure: A comparison across four cities. Water, 13(4), 544. https://doi.org/10.3390/w13040544

Prokopska, A., & Martyka, A. (2017). Miasto jako organizm przyjazny człowiekowi Aleksandra. Budownictwo i Architektura, 16(1), 165-174. https://doi.org/10.24358/Bud-Arch_17_161_14 (in Polish).

Rożałowska, B. (2020). The functioning of smart city in the context of global city rankings. Scientific Papers of Silesian University of Technology: Organization and Management Series, (146), 413-425. https://doi.org/10.29119/1641-3466.2020.146.29

Sherer, P. (2006). *The Benefits of Parks: Why America Needs More City Parks and Open Space.* San Francisco: The Trust for Public Land.

Sinnett, D., Smith, N., & Burgess, S. (2015). *Handbook on Green Infrastructure: Planning, design and implementation*. Cheltenham: Edward Elgar Publishing. https://doi.org/10.4337/9781783474004

Stanley, B., Stark, B., Johnston, K., & Smith, M. (2012). Urban open spaces in historical perspective: A transdisciplinary typology and analysis. Urban Geography, 32(8), 1089-1117. https://doi.org/10.2747/0272-3638.33.8.1089

USEPA. (2011). *Exposure Factors Handbook: 2011 Edition.* Washington: U.S. Environmental Protection Agency. https://www.nrc.gov/docs/ML1400/ML14007A666.pdf

Victoria State Government. (2017). *Planning a Green-Blue City.* https://www.water.vic.gov.au/__data/assets/pdf_file/0030/673248/Planning-a-green-blue-city-2017.pdf

WMO. (2020). *WMO Statement on the Status of the Global Climate in 2019*. https://library.wmo.int/doc_num.php?explnum_id=10211

Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough'. Landscape and Urban Planning, 125, 234-244. https://doi.org/10.1016/j.landurbplan.2014.01.017

DOI: 10.34659/eis.2023.87.4.562

Ying, J., Zhang, X., Zhang, Y., & Bilan, S. (2022). Green infrastructure: systematic literature review. Economic Research-Ekonomska Istrazivanja, 35(1), 343-366. https://doi.org/10.1080/1331677X.2021.1893202

Zwierzchowska, I., & Mizgajski, A. (2019). Potencjał zielonej infrastruktury w dużych polskich miastach do świadczenia usług ekosystemowych. Rozwój Regionalny i Polityka Regionalna, (47), 21-36. https://doi.org/10.14746/rrpr.2019.47.03 (in Polish).

DOI: 10.34659/eis.2023.87.4.562

Małgorzata PIĘTA-KANURSKA

ROZWÓJ ZIELONEJ INFRASTRUKTURY – WYZWANIA DLA POLSKICH MIAST

STRESZCZENIE: Celem artykułu jest charakterystyka kształtowania się zielonej infrastruktury dla 12 największych polskich miast w latach 2005-2021. Do badania wykorzystano dane Głównego Urzędu Statystycznego (GUS). Na podstawie przeprowadzonych badań należy stwierdzić, że duże polskie miasta powinny dokonać zmian w celu zwiększenia powierzchni funkcjonalnych terenów zielonych. Inwestycje w rozwój zielonej infrastruktury powinny stanowić priorytet w strategiach rozwoju polskich miast, a w konsekwencji uczynić je bardziej biofilnymi, co jest zgodne z trendami i dobrymi praktykami najbardziej zielonych miast w Europie i na świecie.

SŁOWA KLUCZOWE: zielona infrastruktura, funkcjonalne tereny zielone, miasto biofilne

DOI: 10.34659/eis.2023.87.4.562