

Climate change adaptation activities planning and implementation in large cities: results of research carried out in Poland and selected European cities

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Abstract

Continuous climate change forces cities to take actions to prevent risks and adapt urban spaces to new conditions. The experience of many European cities in recent years shows that actions adapting urban space to climate change have become an important part of local policy. The subject of the article is the adaptation activities planned and implemented for climate change in urban spaces. The purpose of this article is to classify and identify adaptation activities carried out in large cities. The authors analyzed data from 44 Polish cities and placed them in the context of leading adaptation activities carried out in selected European cities. The purpose of the detailed research is to compare the number and type of activities planned and implemented on the scale of individual Polish cities, indicating dominant and minority activities. The authors conclude that with the passage of time, climate change adaptation activities will have an increasing impact on shaping the landscape of European cities, including those of Poland. Their number will gradually increase, as will the awareness of the city authorities and the activity of local communities. The types of activity will also change and, with them the quality of urban spaces and the quality of life of residents. The authors also conclude that further research will need to conduct quantitative and qualitative studies in the context of the effectiveness of the adaptation process in urban spaces, resulting from the evaluation and monitoring of both systematically updated planning and strategic documents and implemented spatial programs and interventions.

Keywords Adaptation to climate change \cdot Adaptation activities \cdot Urban resilience \cdot Urban spaces

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1 Introduction

Climate change is continuing with increasing intensity. Ongoing and imminent changes are determining new directions and strategic goals for urban policy and pointing to the need to shape urban spaces taking into account the challenges posed by potential hazards (European Commission 2021). The destruction caused by heavy rains, prolonged heat, strong winds, seasonal storms, urban heat waves, or frost waves leads to flooding, river floods, urban floods; affects urban areas, urban infrastructure, and green areas; and deteriorates living standards. These are phenomena that will worsen and their effects will intensify (IPCC 2018, 2020). The projections of change over the next 10–30 years (EU Adaptation Strategy 2021) have made climate change adaptation an important issue that affects the present and determines the future of urban areas. In recent years, European cities that pursue development policies aimed at increasing the resilience of urban spaces to the risks of climate change have begun to move increasingly from the planning phase to the process of implementing adaptation activities. Solutions used in practice that respond to identified climate risks measurably affect cities' adaptation to climate change (Rosenzweig et al. 2018). Part of this process is to shape and develop the urban structure in a sustainable way, taking into account the contemporary challenges of civilization.

The subject of the article is the adaptation activities planned and implemented for climate change in urban spaces. The purpose of this article is to classify and identify spatial adaptation activities carried out in large cities. The authors analyzed data from 44 Polish cities and placed them in the context of leading adaptation activities carried out in selected European cities. The purpose of the detailed research is to compare the number and type of activities planned and implemented on the scale of individual Polish cities, indicating dominant and minority activities. Such selected research objectives allowed the authors to determine the number of adaptation activities, analyze their distribution in relation to urban climate-sensitive zones and areas, and determine which activities cities plan the most/lowest and which ones they implement. The results of the study showed in which direction Polish cities are moving in relation to other European cities, how they implement the adopted strategic goals, increase the resilience of urbanized areas, and what the impact of adaptation activities undertaken on the urban space and living conditions of the residents is. The article is structured as follows: presentation of the state of the research, introduction of the research methods, outline of the European context, case study of Polish cities, analysis of the collected data, discussion of conclusions, and summary of the research.

1.1 State of research

The issue of adapting urban space to climate change is part of many studies conducted in research centers, institutes, and universities.

Research that presents ways to shape the built and natural environments, increase their resilience, and adapt cities to current or expected climate conditions and their impacts, the authors have prioritized in setting development directions and strategic objectives for sustainable urban areas (Solecki et al. 2018). Various scientific disciplines related to climate, including architecture and urban planning, spatial management, environmental engineering, energy, sociology, management, biology, geography, and many others, are dealing with these issues. Researchers work in interdisciplinary, often international research teams. Prominent among the research fields are issues related to water and wastewater management (Koop and

Van Leeuwen 2017), environmental biotechnology (Aerni et al. 2015), closed-loop economy (Romero-Perdomo et al. 2022), renewable energy sources (Gernaat et al. 2021), energy management (Knodt and Schoenefeld 2020), innovative technologies (Nguyen and Davidson 2017), revitalization of degraded areas (Gorgon 2017), shaping the indoor environment (Vardoulakis et al. 2015), intelligent buildings (Gunasingh et al. 2017), education, and environmental awareness (Jorgenson et al. 2019). The activities of architects and urban planners focus on cities, urban spaces and facilities, and the relationship between climate and urban areas, the natural environment, and people (Burchard-Dziubinska 2016; Egerer et al. 2021). Scientists, who study the future of cities in the context of climate change, new challenges, and human needs (Moriarty and Honnery 2014), are involved in identifying sources of hazards (Füssel et al. 2017), assessing the vulnerability of cities (Kumar 2021), the response of urban communities to climate change (Hunter et al. 2020), and conducting research on the impact of buildings (De Wilde and Coley 2012), the urban heat island (Yenneti et al. 2017), or the application of blue-green infrastructure (Molla 2015; Ahern 2007; Fudała 2021). In published studies, the authors devote a great deal of attention to the analysis of solutions based on natural capital (Gill et al. 2007; Frantzeskaki et al. 2017), particularly the resulting economic benefits for cities (Saraev 2012). They also consider the interactions mitigation and adaptation activities in cities (Grafakos et al. 2020). The experience of European cities allows one to compare data, draw conclusions, and make more conscious urban policies that effectively strengthen the resilience of cities. The literature compares urban adaptation processes at different scales and levels (Heidrich et al. 2016; Aguiar et al. 2018; Deetjen et al. 2018; Reckien et al. 2018; Olazabal and Gopegui 2021; Otto et al. 2021). Research is also warranted to test and compare the effectiveness of decisions made, experiments conducted, and investments made to adapt to climate change in cities around the world (Broto and Bulkeley 2013; Araos et al. 2016; Shi et al. 2015; Preston et al. 2011). Some of the research aims to identify indicators to ensure the systematization and standardization of measures for monitoring and evaluating the progress and effectiveness of the adaptation process in cities (Ford and Berrang-Ford 2016). Researchers point to resilience indicators (Cai et al. 2018) and assessment tools that allow municipalities to assess the level of risk, vulnerability, adaptation, and/ or resilience and use to inform future adaptation activities, e.g., the City Resilience Index, the Urban Adaptation Support Tool, or the UKCIP Adaptation Wizard (Metroeconomica 2004).

In Poland, research related to the preparation of Urban Adaptation Plans (UAPs) for 44 large cities is particularly relevant (Adaptation Manual for Cities 2014). These studies became the starting point for conducting detailed analyses in this article.

1.2 Description of the method

The research method includes the selection of cities surveyed, the definition of spatial scopes and their components, and the collection and analysis of data that the authors used to identify planned and implemented adaptation activities. The authors conducted detailed research on 44 large Polish cities whose residents make up 30% of the country's total population. The selection of cities was based on the following criteria:

 Participation of cities in the project of the Ministry of Environment Development of Urban Adaptation Plans for cities with more than 100,000 inhabitants in Poland, implemented in 2017–2019 (Climate change adaptation 2018). The project was financed by the European Union with funds from the Cohesion Fund and the state budget. It was initiated by the Polish Ministry of Environment and was carried out by the following: The Environment Protection Institute– National Research Institute, The Institute for Ecology of Industrial Areas, The Institute of Meteorology and Water Management–National Research Institute, and ARCADIS Poland. This is the first time in Europe that leading players in the environmental sector have taken systemic activities to strengthen the resilience of large cities to climate risks on such a scale. It is also the first time in Poland that local government authorities, together with a group of experts, have coherently identified the risks of cities associated with climate change, identified the areas most vulnerable to change, and identified adaptation activities to reduce the adverse consequences of these changes;

- Adoption by cities of Urban Adaptation Plans (UAPs)—planning and strategic documents, limiting the adverse consequences of climate risks in cities, defining priority undertakings and tasks, setting the directions of adaptation activities along with the time of their implementation and estimated costs, and shaping local policies on adaptation to climate change, with an implementation period until 2030;
- Size of cities: large cities were selected for the study—of the 44 cities surveyed, during the period of preparation of the UAPs, 37 had a population of more than 100,000, three cities had a population of 90,000 to 100,000, and the population of four cities was less than 90,000.

Finally, the authors studied the following Polish cities: Bialystok, Bielsko-Biala, Bydgoszcz, Bytom, Chorzow, Czeladz, Czestochowa, Dabrowa Gornicza, Elblag, Gdansk, Gdynia, Gliwice, Gorzow Wielkopolski, Grudziadz, Jaworzno, Kalisz, Katowice, Kielce, Krakow, Legnica, Lublin, Lodz, Myslowice, Olsztyn, Opole, Plock, Poznan, Radom, Ruda Slaska, Rybnik, Rzeszow, Siemianowice Slaskie, Slupsk, Sopot, Sosnowiec, Szczecin, Tarnow, Torun, Tychy, Walbrzych, Wloclawek, Wroclaw, Zabrze, and Zielona Gora. These cities differ from each other in terms of geographic location, degree of economic development, urban structure, and local conditions. What they have in common is vulnerability to climate risks and planning adaptation activities that are optimal for identified risks (Urban Adaptation Plans 2019).

Taking into account both the key sectors of climate change mitigation (urban infrastructure, built environment, transportation, carbon sequestration, and urban form) identified by Broto and Bulkeley (2013), as well as the most vulnerable sectors of cities (public health, transportation, water management, energy, biodiversity, land use, high-intensity areas, tourism, cultural heritage) identified in 44 UAPs, and also the variety of scopes of adaptation activities applied in Polish UAPs (Climate change adaptation 2018), the authors limited the adaptation activities studied to technical, spatial investment activities that allow urban spaces to adapt to climate change relatively quickly.

The research methods chosen by the authors are critical analysis of sources and case studies involved in identifying criteria for selecting planned and implemented adaptation activities that strengthen the resilience of urban spaces and their adaptation to anticipated climate change. Among these criteria, there were (1) time criteria (time/ period of implementation, achievement of effects)—the study covered the years from 2014 to early 2022. This period was due to the implementation of projects submitted, among others, to the *Operational Program Infrastructure and Environment 2014–2020*, the timing of the Urban Adaptation Plans for 44 Polish cities: 2017–2019 and the period of gradual implementation of adaptation activities resulting from the plans, allowing the authors to analyze them from 2014 to early 2022. Data for the research were collected by first-year and second-year students of the Department of Urban and Spatial Planning, Department of Architecture, Silesian University of Technology in 2020/2021;

(2) accessibility criteria (digital availability of data and source materials)-data for the study were collected through a review of key literature, planning documents and legal acts, as well as internet searches. In the surveyed cities, sources of information on planned adaptation activities, in addition to the UAPs, include other local planning and strategic documents, such as urban development strategies, studies of land use conditions and directions, or urban revitalization programs. Among the sources of information attesting to the activities implemented, there are data from Operational Program Infrastructure and Environment 2014–2020, websites of the Ministry of Climate and Environment, municipal offices, civic budgets of individual cities (especially the so-called green budgets profiled toward the implementation of public tasks in the field of ecology and environmental protection), environmental institutes and foundations, urban greenery boards, information portals, articles and scientific items, as well as cartographic and photographic materials. The results obtained may be subject to errors due to the lack of access to all data in each city and limitations due to the number of student hours. In addition, many adaptation activities may not be reported on the Internet or may be inaccessible to standard search engines; and (3) spatial criteria (types of spatial interventions and their distribution)—the authors focused exclusively on technical/ investment activities that adapt urban spaces to climate change-tangible activities of an architectural, urban planning, infrastructural, and environmental nature, the effects of which residents can notice in the city landscape. Included in this group are spatial interventions that shape urban structure, urban development, and green infrastructure and increase the resilience and attractiveness of public spaces.

The authors divided the studied adaptation activities into five spatial scopes. They include different types of technical/investment adaptation activities, which are part of the open catalog of planned adaptation activities specified in the methodology for preparing UAPs projects (Methodology 2017), and correspond to specific adaptation activities included in the 44 analyzed UAPs and other formal and non-formal adaptation activities initiated by city authorities, organizations, foundations, and citizen groups in Polish cities. The authors related the following groups of interventions to the spatial scopes studied:

- A) sustainable management of water resources,
- B) sustainable management of green spaces,
- C) transportation infrastructure,
- D) sustainable urban development, and
- E) microinterventions/urban acupuncture.

We then separated the most representative groups of activities in each spatial scope. Thus:

1) in terms of sustainable management of water resources, we analyzed activities related to the following:

- renaturalization and regulation of rivers,
- revitalization of rivers, reservoirs, and waterside areas,
- large and small retention,
- infrastructural system activities, and
- flood protection;

2) in terms of sustainable management of green areas, we analyzed activities related to the following:

- revitalization of landscaped green areas,
- introduction/development of new green areas/recreational areas,
- revitalization of degraded natural areas, and
- protection of naturally valuable areas/floodplains;

3) in terms of transportation infrastructure, we analyzed activities related to the following:

- new forms of mobility,
- activities of the infrastructure system/adjustment of public transportation,
- · revitalization of post-transportation areas,
- greening of transportation areas and facilities, and
- bicycle/pedestrian infrastructure;

4) in terms of sustainable urban development, we analyzed activities related to the following:

- revitalization of degraded areas/facilities,
- development of public spaces,
- adaptation of building structures,
- unsealing of paved surfaces, and
- aeration systems;

5) in terms of micro-interventions, which are small actions in space often called urban acupuncture, we analyzed activities related to the introduction of the following:

- pocket parks,
- rain gardens,
- community gardens,
- green walls/green roofs,
- green streets/woonerfs, and
- green courtyards.

Activities that could not be categorized in this way were assigned by the authors in each scope to a group they called the "other."

For the activities categorized in this way, the authors used comparative quantitative analysis to determine the number of studies planned and implemented in each city and to draw conclusions about their distribution, dominance, or shortcomings.

The developed database should not be considered complete, but should provide an indicative preview of the spatial adaptation activities planned and implemented in large Polish cities during the specified time period.

The model for adaptation activities planned and implemented in large Polish cities become the selected European cities. These include Copenhagen, London, Paris, Berlin, and Barcelona. The authors selected these cities based on their experience in conducting the adaptation process, the selection of planning, strategic and implementation tools, and the results visible in urban spaces. These examples are sources of good practice in strategic planning and implementation of adaptation activities. The authors surveyed the selected cities with the intention of giving a more general indication of the directions in particular spatial scopes, rather than a detailed identification of all adaptation activities.

2 Research results

2.1 Adaptation of urban space to climate change in selected European cities

Many cities, following the guidelines of the European Union's climate and energy policy, are implementing activities related to adapting cities and urban areas to climate change. These activities are based on documents, initiatives, projects, and plans developed at various levels of government or conclusions from climate conferences and conventions and international forums (Geneletti and Zardo 2016). The most important of these include the following: White paper—adapting to climate change: toward a European framework for action, COM 2009, Delivering the European Green Deal, New Leipzig Charter, Territorial Agenda 2030, EU Adaptation Strategy 2021, and many others have set goals and directions for transforming cities, shaping urban space, and building a climate-resilient society. With time, the local planning and strategic documents adopted by cities raised the issue of adaptation to climate change and began to gradually implement it. Currently implemented adaptation activities are increasingly visible in the landscape of European cities, changing their image and improving the quality of life and safety of residents (Pancewicz 2022a, b). Characteristic examples of European cities that are recognized as sources of good practice in strategic planning and adaptation activities that significantly affect architecture are the following: Copenhagen, London, Paris, Barcelona, or Berlin.

Copenhagen is a city where many of the measures to adapt urban spaces to climate change, and in particular the implementation, prioritizing urban nature, can be considered as a model (Pancewicz 2022a). In 2011, the city government enacted its first climate change adaptation plan. Currently, the city has numerous documents that establish the city's development policy, guiding Copenhagen toward a sustainable and resilient city. These include, among others, *Copenhagen Climate Adaptation Plan 2011, Copenhagen City Cloudburst Plan 2012, Urban Nature in Copenhagen Strategy 2015–2025, CPH2025 Climate Plan—A Green, Smart, and Carbon Neutral City 2012, and Copenhagen Solutions for Sustainable Cities 2014. Among adaptation activities are those dealing with the issue of water management, both in the context of water scarcity and surplus.*

The city has emphasized systemic activities, for example, reconstruction of sewerage systems, use of permeable pavement, and construction of local retention reservoirs (Engberg 2018). Several adaptation activities include introducing blue-green infrastructure solutions into urban spaces and improving transportation. These activities, with the support of educational programs, raise awareness among residents.

In London, the most important local documents on the city's adaptation to climate change include the *London Environment Strategy 2018*, *SuDS in London—a guide 2016*, the *Climate Action Strategy 2020–2027*, and *The London Plan. The Spatial Development Strategy for Greater London 2021*. All the projects presented in these documents are focused on ecology and environmental benefits. The main directions of the planned activities emphasize water resource management and zero-emission transportation. The city's main problem is the inadequate regulation of rivers, the ponding of rainwater on vast paved areas, and the death of green spaces, so the city has focused primarily on introducing solutions based on natural capital to prevent flooding in the city (Mazur-Belzyt 2021).

Barcelona's 2021 *Climate Emergency Action Plan 2030* has set a target of reducing CO2 emissions by 45% and achieving carbon neutrality. Priority tasks include achieving zero energy poverty, maintaining water and energy supplies, and adapting building facilities to climate change. The city is struggling with extreme temperatures, water scarcity, rising sea

levels, and shrinking beaches (Villalbí and Ventayol 2016). Adaptation efforts are focused on improving the quality of life of residents, especially those most vulnerable to the effects of climate change. According to the *Barcelona Green Infrastructure and Biodiversity Plan* 2020 and the *Barcelona Nature Plan* 2030, the city focusses on sustainable management of greenery and water when implementing activities. A special role is played by maintaining the natural elements of the urban structure, introducing new green areas and elements in urban areas, and shaping the public space and the transportation system using the bluegreen infrastructure.

Berlin implemented Adapting to the Impacts of Climate Change in Berlin–AFOK in 2016. The city has seen a significant increase in temperature, an increase in annual average precipitation, and the frequency of heavy rains. The occurrence of heat islands is also a problem. Proposals for urban quarter model layouts with protective greenery and shading elements, the use of temporary parking spaces as rainwater storage, and the increase of green spaces that spot reduce ground temperature are prominent among activities to make urban spaces more attractive and adaptable to climate change. Despite the high density and intensity, 44% of the city is green and recreational land, which is why the provisions of the Action Program Berlin Urban Green 2030 developed for the city link the city's development with greenery development. As a result, the implementation of adaptation activities involves creating links between existing protected areas, protecting and restoring valuable habitats, building new squares and parks in the urban fabric, and introducing solutions based on natural capital (Thierfelder and Kabisch 2016).

Paris, back in 2007, enacted its first climate action plan, thus becoming a pioneering city in the fight against global warming. Updated in 2018, the *Paris Climate Action Plan 2018* focused on carbon offset and the use of renewable energy. The goal of Paris is to achieve carbon neutrality by building urban solar power plants, developing a wastewater energy recovery system, replacing lighting systems and supplementing them with motion sensors and shading structures, and eliminating diesel-powered public transport. Improving quality of life and strengthening resilience in urban spaces have become an important part of adaptation efforts. The adaptation activities, which were written down in the *Paris Resilience Strategy 2018* and gradually implemented, have become visible in the city's landscape, mostly through projects related to adapting public spaces to climate change and increasing the proportion of natural areas in the city (Romo 2015).

The adaptation activities in selected European cities, classified into five spatial scopes, showed in a simplified way the strategic directions of the urban climate change adaptation policy carried out on a local scale. The detailed and spatial scopes, or the leading types of adaptation activities undertaken in selected European cities specified by the authors of the paper, have become a reference point for research in Polish cities.

2.2 Climate change adaptation activities planned and implemented in Polish cities

The formation of Poland's climate change-sensitive urban spatial policy began on a large scale in 2013 (Pancewicz 2021). In that year, the Council of Ministers adopted the *Strategic Adaptation Plan for Sectors and Areas Vulnerable to Climate Change to 2020 with an Outlook to 2030* developed by the Ministry of Environment, which identifies priority directions for adaptation activities required for implementation in different areas and spatial scales. This document became the basis for a project organized and co-financed by the Ministry of Environment and implemented in 2017–2019 (Climate change adaptation 2018). The project resulted in the development of UAPs in 44 of the largest Polish cities

(Urban Adaptation Plans 2019). The team that developed these documents aimed to reduce or mitigate the effects of the most serious climate change that affect vulnerable urban areas. The organizational, technical, and informational-educational activities planned in the documents, with an implementation period until 2030, cities are gradually implementing in urban spaces. At present, more than 1173 activities have been implemented on the Polish territory, a significant part of which are those resulting from the UAP implementation. This number will increase when more Polish cities with a population above 20,000 will be obliged, according to the *Draft Law on Amendments to Certain Laws to Strengthen the Climate Dimension of Urban Policy of 2021*, to develop the UAPs.

Local authorities address planned and implemented adaptation activities to specific urban areas. In this way, they reflect the actual problems and needs of a given city. Their essence is diversity, complementarity, and interdependence, resulting in increased resilience to the city. In the research undertaken, the authors focused exclusively on spatial activities that allow short-term effects to be observed in urban spaces. These activities, in addition to strengthening the resilience of the city, affect the shape of urban structure, urban development, public spaces, green areas, and infrastructure.

2.3 The main directions of adaptation activities

Among the planned and implemented adaptation activities studied, the authors identified five scopes concerning sustainable urban development, water resource management, green space management, and transportation infrastructure, as well as microscale activities, or so-called urban acupuncture.

Within the framework of a study on sustainable water resource management (Fig. 1), the authors considered activities related to river restoration and regulation, revitalization of waterside areas, large- and small-scale retention, infrastructure, and flood protection. An analysis of the spatial distribution of this group of activities in individual cities highlighted its concentration near major watercourses and reservoirs. Among cities with UAPs, 231 actions from the above scope were planned, while 248 were implemented. A significant predominance of planned actions can be observed in the field of large and small retention (73). The predominant number of activities implemented is related to the revitalization of rivers, reservoirs, and waterside areas (53). Cities that stand out in terms of the number of



Fig. 1 Distribution of adaptation activities in 44 polish cities. A Implemented activities. B Planned activities. Author: W. Anczykowska



Fig. 2 Distribution of adaptation activities in the sustainable management of water resources. A Implemented activities. B Planned activities. Author: W. Anczykowska



Fig. 3 Distribution of adaptation activities in the sustainable management of green spaces. A implemented activities. B Planned activities. Author: W. Anczykowska

sustainable water resource management activities are Rzeszow (6 planned and 24 implemented) and Katowice (15 planned and 14 implemented).

Studies of sustainable management of green areas (Fig. 2) included revitalization of landscaped green areas, introduction/development of new green areas/recreation areas, revitalization of degraded areas into natural areas, and protection of valuable natural areas/floodplains. Analysis shows that adaptation activities in this area are mainly located in urban centers, as well as near reservoirs and waterways, and forests and park areas. In this regard, 209 activities were planned and 249 were implemented. The overwhelming number of planned activities (84) introduce or develop new green and recreational areas. The largest number of projects (94) are implemented in the field of green and revitalization of landscaped areas. In terms of the number of activities, one can distinguish Szczecin (13 planned and 9 implemented), Rzeszów (12 planned and 6 implemented), Sosnowiec (3 planned and 15 implemented).

The transportation infrastructure activities (Fig. 3) that the authors examined in the context of introducing new forms of mobility, infrastructural system activities, revitalizing post-transportation areas, adapting public transportation, bicycle, and pedestrian infrastructure, are mainly accumulated in the city centers, where participation and access to transportation are much greater than in the suburbs. The scope refers to 241 planned and 208 implemented activities. Among them, planned activities in the field of infrastructure



Fig. 4 Distribution of adaptation activities in the transportation infrastructure. A Implemented activities. B Planned activities. Author: W. Anczykowska



Fig. 5 Distribution of adaptation activities in the sustainable urban development. A Implemented activities. B Planned activities. Author: W. Anczykowska

system and matching of public transportation (93) and activities related to bicycle and pedestrian infrastructure (68) were dominated. The city that stands out from others in terms of the implementation and planning of activities in the field of transportation infrastructure is Wroclaw (12 planned and 14 implemented).

Adaptation activities in the field of sustainable urban development (Fig. 4), such as revitalization of degraded areas and facilities, development of public spaces, adaptation of building structures to climate change, and unsealing of paved surfaces and systemic activities related to the ventilation system of urban spaces, covered mainly the city centers. In the cities analyzed, 222 adaptation activities were planned and 197 were implemented. Among the planned activities, the revitalization of the areas/objects degraded was the dominant factor (85). The implemented activities were dominated by the adaptation of the building facilities to climate change (75). The leading cities in terms of the number of actions are Gorzow Wielkopolski (21 planned and 3 implemented) and Gdynia (8 planned and 12 implemented).

The activities analyzed in the field of microintervention/urban acupuncture (Fig. 5) introduce pocket parks, rain gardens, community gardens, green walls, rooftops, streets/ woonerfs, and courtyards into urban space, as in other scopes, are mostly concentrated in city centers. However, their characteristic feature is spatial dispersion. The analyses show that 137 activities have been planned since 2014, while 288 have been implemented, with

pocket parks being the most popular activity in cities (38 activities planned and 55 implemented). The largest number of activities in the above range can be attributed to Lodz (2 planned and 43 implemented). Subsequent cities perform at least twice as well.

3 Discussion of results

The adopted research method allowed the authors to make a comparative analysis of planned and implemented climate change adaptation activities carried out at the scale of 44 large Polish cities.

Quantitative data acquired on adaptation activities during the period 2014–2021 in analyzed Polish cities determine the relationship that occurs between planned and implemented activities. Comparison of the total number of activities planned on the scale of all Polish cities (1057) with the number of activities implemented (1173) shows the complementarity of planned activities with the degree of their implementation. The significant number of activities implemented is due not only to the implementation of activities enshrined in planning and strategic documents but also to the implementation of municipal projects and initiatives that involved the ability and skill to obtain and use European, national funds, or municipal budgets. The results of the research obtained also made it possible to determine the number of adaptation activities in each scope and to compare cities among themselves (Table 1).

The number of all activities planned in each scope is between 137 and 248. Differences are due, among other things, to the individual conditions and characteristics of each city, the degree of development, and the specific risks and difficulties they face (Fig. 6).

Research shows that the highest number of planned adaptation activities are in the field of sustainable water resource management (248). In particular, small and large retention activities dominate (73). The least amount of planned activities is in the field of microinterventions (137). In particular scopes, some types of planned activities are sporadic, for example, the establishment of green backyards (19).

In the cities analyzed, the number of activities implemented ranges from 197 to 288, with the highest number in the field of microinterventions (288). Of these, activities related to the establishment of pocket parks dominate (55). The least implemented activities were those in the field of sustainable urban development (197). In most scopes, some activities are hardly or minimally implemented, such as the revitalization of post-transportation areas (3). The reasons for this, in addition to local conditions and the lack of appropriate tools, may be due to the way urban development policies are carried out or the timing of subsequent activities.

The authors compared individual adaptation activities implemented in Polish cities with those implemented in selected European cities, making it possible to see similarities and differences and to identify leading directions of activities:

- in the field of sustainable water resource management, both in Poland and in the analyzed European cities, the largest number of activities implemented is related to the revitalization of rivers, reservoirs, and waterfront areas;
- among the activities related to the management of green areas in Poland, the largest number of activities implemented is related to the revitalization of green areas, while among European cities, activities related to the protection of environmentally valuable areas dominate;

Participant Participant		sustainable management of water resources		sustainable management of green spaces		transportation infrastructure		sustainable urban development		micro- interventions/ urban acupunture		шns	
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Table 1 Implemented and planned adaptation activities in 44 Polish cities. Author: W. Anczykowska



Fig. 6 Distribution of adaptation activities in the microinterventions/urban acupuncture. A Implemented activities. B Planned activities. Author: W. Anczykowska

- among the activities of the transportation infrastructure in Poland, the largest number of activities are implemented in the field of bicycle and pedestrian infrastructure, while the activities related to new forms of mobility dominate in the analyzed European cities;
- in terms of sustainable urban development, in Poland, most activities have been implemented in the field of adapting buildings to climate change, and in European cities, the development of public spaces;
- in the scope of microinterventions/urban acupuncture, in Poland, activities related to the establishment of pocket parks dominate, while in European cities, it is the implementation of green roofs and walls;
- the number of planned activities concerning water resources, sustainable urban development, and transportation infrastructure in Polish cities exceeds the number of realized activities, while the opposite situation is in the analyzed European cities, where the number of realized activities is greater than the number of planned ones; and
- in the field of sustainable green space management and microinterventions, the number of activities implemented is higher than planned, both in Polish and foreign cities.

The analysis shows that some Polish cities stand out from others, not only in the number of activities, but also in the complementary approach and even distribution of adaptation activities in all five scopes. Such a state of affairs was influenced, among other things, by factors related to the implementation of programs and plans not directly related to climate change adaptation, but resulting from the possibility of obtaining external funding for activities from regional, national, or EU programs.

An example of a city representing a holistic approach to increasing resilience to climate change is Wrocław. The city is developing infrastructure in all the scopes studied: it is introducing the Wroclaw Tramway Programme 2.0, proposing Park&Ride parking lots, running the *Grow Green* programme to create pocket parks, green streets, and developing new green areas (Climate and Nature 2022). Furthermore, the FoodShift2030 programme (FoodSHIFT2030 2020), which focusses on changing the European food system, is being carried out in the Wroclaw area. The second outstanding city is Gdansk. Due to its location, great emphasis is placed here on sustainable water management activities, including flood protection in the form of drainage pumping stations or retention reservoirs. In the city, green spaces, such as parks and squares, are being revitalized, new flower meadows are being planted, and public spaces are being developed (Green Gdansk – Ecology 2022). Additional programs are also underway, such as the *Gdansk Helps the Bees* programme, under which habitats and homes for insects are being built in urban spaces (Gdansk helps 2017). The city is also emphasizing the interconnection of bicycle and pedestrian paths, as well as the introduction of new routes, especially in the vicinity of reservoirs. In addition to systemic activities, great importance is also given to microinterventions, resulting in the appearance of pocket parks, rain gardens, green walls, or urban farms in urban spaces. Such a multifaceted approach positively influences the resilience of cities in the face of a variety of threats, providing the possibility of their sustainable development and, at the same time, creating a friendly human living environment. It also shows that when pursuing adaptation policies, cities need to redefine their role, not only as a place of maximum concentration of the power and culture of a given human collective (Mumford 1961), but as a resilient space, capable of adapting to change, offering a new quality of life.

Comparative studies have shown that cities play a key role in planning adaptation activities (Broto and Bulkeley 2013). Analyses have shown that Polish cities, when planning adaptation activities, focus most on larger, often systemic architectural, urban, and environmental projects, but implement them most often through point interventions that constitute a kind of urban climate acupuncture, shaping and supporting the quality and resilience of urban spaces and their social, economic, and environmental transformation. This result is largely due to the short period of time since the enactment of the UAPs needed to implement the different types of activities. It is also linked to the fact that the implementation of adaptation activities relies not only on local government initiatives, but also on the involvement of other stakeholders: non-governmental organizations, foundations, community groups, and individuals (Berrang-Ford et al. 2011). This is particularly evident in the predominance of point interventions, which is often initiated by foundations, organizations, and social communities (Hunter et al. 2020).

The results of the study, particularly the lack of coverage in some scopes, suggest that UAPs need to be continually updated, supplementing and refining the offer of adaptation activities and becoming more complementary with other local documents, programs, and non-climate related factors affecting sustainable urban development (Preston et al. 2011). This involves the ability of cities to plan adaptation activities and to organize and manage the entire process. These factors, combined with the criterion of time, affect the number and completeness of activities and provide a basis for the systematic identification, characterization, comparison of adaptation and evaluation of its progress and effectiveness (Ford and Berrang-Ford 2016; Otto et al. 2021).

The research also showed the local nature of adaptation, which became apparent despite the use of a common strategic-planning methodology to develop UAPs for all the 44 cities. This locality of the adaptation process in many cases is analogous to the results obtained in cities where local climate plans are based on different preparation methods and result from different development policies (Reckien et al. 2018). The specific characteristics of each city influence the diversity of approaches to climate change activities, initiatives, and interventions (Ford and Berrang-Ford 2016); the selection of processes and tools that govern them; and the different patterns of adaptation planning (Aguiar et al. 2018). They are the result of individual geographic, economic, and social conditions; city-specific risks; the consistency of tools and measures of local policy making; and the participation of all stakeholders in the process. It should be remembered that in Poland, the results have been limited to the adaptive capacity of a group of large cities with populations above and around 100,000 and belonging to a highly developed country, so the data obtained are not directly comparable with those of cities from developing or low-income countries (Berrang-Ford et al. 2011). However, such a comparison is not excluded when we look at examples of cities where adaptive planning is independent of wealth levels and institutional barriers (Araos et al. 2016).

At the same time, it is important to be aware that a high number of adaptation activities do not equate to a more resilient society. Adaptation activities can be temporary, underadaptive, or have little impact (Ford and Berrang-Ford 2016). In either case, however, adaptation should be an interdisciplinary, multi-step process that includes not only spatial, but also socio-economic and environmental aspects of vulnerability to climate change (Dovers 2009).

4 Conclusions

The research presented here shows that the adaptation activities that are being implemented to climate change have an increasing impact on the shaping of the urban landscape, affecting the quality of urban spaces and the quality of life of residents. Despite the variation in the level of economic and social development and access to financial, institutional, human, and knowledge resources across countries and cities, adaptation activities can be seen as a tool to increase the attractiveness of urban spaces, strengthen natural capital, or create safe conditions for urban living. In conjunction with contemporary development trends and ideas, based on modern pro-environmental and pro-social solutions and efforts to shape sustainable, compact, and resilient cities, they are an important part of ongoing urban policies aimed at reducing or mitigating the effects of climate change risks.

A comparison of the leading directions of adaptation efforts evident in the development policies of European cities, including Poland, shows that awareness of the relationship between climate and the city is growing in local communities. This translates into planning and implementing solutions that are efficient and sustainable and bring maximum benefit to the built and natural environment.

The authors conclude that the number of adaptation activities for adapting urban spaces to climate change will gradually increase over time. Along with new challenges, there will also be new activities that will be planned and written in updated versions of the planning and strategy documents. The proportions of activities in individual scopes will also change, which will result both from the degree of saturation of urban spaces with individual realizations, securing adequate financial resources, overcoming legal barriers, as well as from the increased awareness of city authorities and the activation of local communities to codetermine the future of cities. The effectiveness of the implementation of adaptation activities in Polish cities will depend on the efficient coordination of the various elements of the entire process, on the organization of the structures responsible for their implementation, consistency with the ongoing urban policy, as well as on the development of operational programs and action plans from which individual investments would result.

Research conducted by the authors are as follows:

- provide a basis for further quantitative and qualitative research relating to each type of identified adaptation activities;
- provide a starting point for assessing the results and impacts of the actions/investments/ projects undertaken on urban spaces; and
- can contribute to updating the UAPs for subsequent planning periods, complementing the indicators to achieve the strategic goals.

Future research will allow the authors to monitor changes and identify new relationships that occur between planned adaptation activities and their implementations. They will also allow data to be supplemented with information on cities that have not yet introduced UAPs and implementations that have not yet been completed, as well as on the evaluation and progress of adaptation over time. The research should aim to provide qualitative analyses of the adaptation process, resulting from the evaluation of planning and strategic documents, implemented spatial programs and interventions, and continuously updated quantitative data. Complementary research can provide answers to the question of whether adapting urban spaces to climate change will work or not. They will also allow qualitative assessment with comparison of urban adaptation planning and implementation methods with theoretically derived components of adaptation success and best practices. This evaluation can be done according to different types of criteria: adaptation (effectiveness, reliability, flexibility, synergy), socio-environmental (side effects, acceptability, sustainability), time (implementation time/period, timing of effects), and economic (costs, benefits) (Metroeconomica 2004; Methodology 2017). In order to assess the effectiveness of the different types of adaptation activities and their cost-effectiveness from the point of view of meeting specific social and environmental needs, a multicriteria analysis will be necessary, based on an economic analysis of the costs and benefits of implementing the activities along with their maintenance costs, made in financial, environmental, social, and spatial terms, as well as their feasibility in technical, operational, and legal terms. This approach is in line with the evaluation methodology proposed for the development of UAPs in Poland (Methodology 2017).

In summary, a quantitative and qualitative assessment of the effectiveness of the adaptation process in cities requires time to implement all planned activities, apply appropriate measures and tools, and take a holistic view of the entire process. The research presented by the authors is a starting point for a more systematic study of progress in adaptation to climate change.

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical approval The study did not require ethical approval.

Consent for publication You have our permission to publish the work after due process.

Competing interests The authors declare no competing interests.

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