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How Does Blue Infrastructure Affect the Attractiveness Rating of Residential Areas? Case Study of Olsztyn City, Poland

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Abstract: Blue Infrastructure (BI) is a system of water-based ecological and engineering interactions that provides multiple social and ecosystem benefits in an urbanized environment. The study answers the questions: (1) Can the assessment of the attractiveness of residential areas be influenced by the availability of water reservoirs with a specific functionality? (2) What are the indicators that determine this impact? The research aimed to develop a methodology for the evaluation of residential neighborhood spaces, considering the indicator of the functional value of water bodies and their accessibility. The following research hypothesis, that the recreational and esthetic functions of water bodies along with the accompanying infrastructure are the most attractive features that hold the greatest significance in evaluating residential areas close to them, was verified. Cartographic and field inventory studies were conducted to prove this. An inventory form was applied along with social research using a geo-survey to determine the ranking of individual water bodies. As part of the test of the developed method, all water bodies in the city of Olsztyn (northern Poland) were evaluated. The test revealed that the indicators related to the functional value of water bodies and their accessibility influence the assessment of the residential neighborhoods' attractiveness. Therefore, they should be considered in the assessment of cities containing both natural and anthropogenic water bodies.

Keywords: housing estates; residential neighborhood; water bodies; water reservoirs

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1. Introduction

Blue Infrastructure (BI) is a complex concept. It refers to a system of water-based ecological and engineering interactions that provides various social and ecosystem benefits in an urban environment. The development of BI in cities is currently a significant research topic for scholars and urban planners, focused on sustainable urban development. Given that water is a scarce and essential resource for life, such research aligns with multiple Sustainable Development Goals (SDGs) [1]. A predominant focus is on devising concepts for sustainable water management under SDG 6 (Ensure availability and sustainable management of water and sanitation for all) [2]. Issues concerning Sustainable Drainage Systems, which involve infiltration, drainage, and water storage to provide benefits like improved water quality, wildlife habitats, and societal amenities, are actively explored [3,4].

From a climate change perspective (SDG 13—Take urgent action to combat climate change and its impacts), particularly recent global warming trends, studies have emerged to determine the impact of BI on reducing the urban heat island effect, common in urban areas [5]. It has been proven that green spaces, surface waters, and other elements of BI can help lower temperatures and create a more pleasant thermal environment in cities [6,7]. Other studies in this field focus on assessing the influence of BI on the air quality in urban areas. Green areas and water features reduce air pollution by capturing dust, and absorbing carbon dioxide and other harmful substances [8,9].

However, the topic of BI encompasses more than research related to systems, ecosystem services, and sustainable water management solutions aimed at managing stormwater, minimizing flooding [10–12], and improving surface water quality. It also includes studies on the evaluation of urban landscapes and their esthetic and functional value arising from the presence or absence of BI, as well as public awareness regarding water use and participation in development projects. Consequently, under SDG 3 (Ensure healthy lives and promote well-being for all at all ages), research examines the impact of green areas, parks, ponds, and other BI elements on the mental health and well-being of urban residents. Numerous studies have shown that access to nature, in the form of green spaces and water elements, contributes to stress reduction, improved well-being, and overall quality of life [13,14]. This was particularly evident from research conducted during the COVID-19 lockdowns [15,16]. Furthermore, with regard to SDG 4 (Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all), the level of residents' awareness and knowledge regarding BI and its benefits has been assessed. This includes analyzing the effectiveness of information and educational campaigns on blue solutions and their impact on acceptance and community engagement [17,18].

Under SDG 11 (Make cities and human settlements inclusive, safe, resilient, and sustainable), emphasis is placed on scientific research regarding residents' access to BI in cities. These studies aim to identify inequalities due to cultural preferences, mobility needs [19,20], or exclusions based on race [21] and develop strategies that ensure equitable access to blue solutions' benefits for all city residents [22]. Finally, concerning SDG 17 (Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development), research focuses on community participation in planning, designing, and implementing BI projects. Local community involvement, knowledge, and engagement are crucial for the success of BI projects [23]. However, despite a number of studies considering the accessibility of BI in cities (described in more detail in Section 2) and their importance for the well-being of residents, there are no studies in the available literature that examine what type of BI functionality is most desired by residents and thus influences the attractiveness of housing neighborhoods. This is an important and necessary issue from the point of view of urban planning and resident-friendly spatial management that takes into account the needs and preferences of the residents.

Considering the current knowledge about BI and its developmental benefits, the following questions arise. (1) Can the assessment of the attractiveness of residential areas be influenced by the availability of water reservoirs with a specific functionality? (2) What are the indicators that determine this impact? Answering these questions will expand understanding, provide methods, and offer useful tools for assessing the functional and landscape attractiveness of residential neighborhoods in the context of SDG 11.

In the subject literature, six primary functions of water bodies are distinguished: ecological, recreational [24], educational, social, economic, and esthetic [25]. The topology of this classification can be applied to both natural and anthropogenic water bodies. The study aims to develop a methodology for the evaluation of residential neighborhood spaces, considering the indicator of the functional value of water bodies and their accessibility. This is an issue that will highlight the significance of BI functionality within a city context in evaluating the attractiveness of residential neighborhoods/units. It has been demonstrated that specific functionality is a determining factor in shaping urban spaces [26].

Inventory mapping and field studies were conducted to prove this hypothesis. An inventory form was applied, along with social surveys using a geo-questionnaire to determine the ranking of all water bodies. The city of Olsztyn, located in the Warmia-Mazury region of Poland and commonly known as the 'Land of a Thousand Lakes,' was chosen as the test area. The city is characterized by the presence of irregularly distributed water bodies of different sizes numbering more than 160. Such a BI-rich city is an appropriate research example to show qualitative differences and their impact on neighboring residential areas.

The study fills an existing research gap in the field of planning residential neighborhoods and managing public space. The proposed approach is based on introducing methods that enable the implementation of smart geographic information systems (GISs) technologies (geo-survey) and the automation of analytical processes evaluating open public spaces. The proposed innovative approach complements studies related to urban quality of life by incorporating new indicators of accessibility to water bodies with specific functionality. The use of diagnostic tools like the geo-survey, which supports resident-friendly land management, is a new approach and highlights the importance of public opinion in the assessment of public spaces. As demonstrated by test studies, some indicators have a greater influence on the assessment of residential neighborhoods' attractiveness. Therefore, they should be considered in evaluating cities with natural and anthropogenic water bodies. The developed method is straightforward, innovative, and versatile, making it applicable for use by urban planners, real estate agents, and property appraisers to assess the attractiveness of residential neighborhoods.

2. Literature Overview—Diagnosis of Urban Design and Water Management

Previous evaluations of entire cities or specific districts included an indicator of the average share of green spaces within estates [27] or accessibility/distance to recreational areas with constructed water bodies, regardless of their size or functionality [28]. Diagnostics and evaluations of water reservoirs in cities are carried out using various methodological approaches, including taking into account the elements of ecosystem services [29,30] or laboratory criteria for water purity [31,32]. There are also methods that determine various approaches, such as esthetics and landscape shaping, recreation and tourism, biodiversity, climate use, water retention, and flood management. However, some authors omit several functions of water bodies in their methodologies. Li et al. [33] conducted a study on the ecological health and inhabitants of river corridors in Zhengzhou, China, using 26 indicators (mainly ecological, economic, and geographical) assessed through a five-point Likert scale in expert surveys. The indicators included charge cards, width of the border, water transparency, and eutrophication status. However, they used an expert interview without taking into account the actual needs and preferences of the residents. Kimic and Ostrysz [34] analyzed various green and BI solutions in terms of their value in shaping the public space of urban transport, identifying 19 different Blue-Green Infrastructure services based on territorial, functional, service, and social aspects. Langie et al. [35] identified data on the availability of water facilities in the public space of large cities, considering factors such as communication, composition, infrastructure, use, and esthetics. Bacchin et al. [36] focused on BI responsible for spatial and performance modeling of stormwater systems, integrating catastrophic and blue performance. Their research in the city of Porto Alegre utilized water, ArcGIS, and EPA SWMM platforms to analyze the spatial environment, identify flood-prone areas, and model the performance of stormwater drainage infrastructure at various spatial scales—macro, meso, and micro. This method integrates the theory of landscape ecology with practical applications for stormwater management.

Over the past five years, ISO 37,120 norms [37] have also been employed for assessing the urban quality of life, where supporting indicators take into account the aspect of accessibility to BI and include: 13.1 square meters of public indoor recreation space per capita and 13.2 square meters of public outdoor recreation space per capita (supporting indicator). The primary indicators in this norm are: 21.1% of the city population with potable water supply service, 21.2% of the city population with sustainable access to an improved water source, 21.3% of the population with access to improved sanitation, and 21.4 total domestic water consumption per capita (liters/day). However, there is a lack of an approach to evaluating the attractiveness of residential neighborhoods that considers the accessibility indicator for BI, marked by various distinct functions that such water bodies can serve despite the increase in popularity of BI plans and investments in recent years [38]. There is growing evidence of potential environmental, social, and health benefits [39]. Blue and green infrastructure elements combine and have a multifunctional impact on urban space [40]. This definition covers a wide range of issues and solutions. Moreover, green infrastructure and BI cannot be assigned to one profession [41]. Views on the topic also change depending on the discipline [40]. Authors often point out that blue (water) and green (nature, squares, and parks) infrastructure serve to protect against floods, droughts, and other effects of climate change and undoubtedly contribute to maintaining environmental balance and security in the city [42]. Therefore, BI functionalities are manifold. It is important to determine which of them are the most important and have the strongest impact on the assessment of the attractiveness of the public open space residential areas, taking into account the needs and preferences of the residents, which is part of a resident-friendly approach to spatial management. In this light, the following research hypothesis was verified: the recreational and esthetic function of a water body and the accompanying amenities are the most attractive features, which hold significant importance in evaluating residential neighborhoods.

3. Materials and Methods

3.1. Study Area

Olsztyn is a city located in the northeastern part of Poland (Figure 1). It serves as the capital of the historical region of Warmia and Mazury, holds the status of a provincial capital, and is a constituent of the Green Lungs of Poland region. According to the statistical data on 31 December 2022 [43], the city (with an area of 88 km^2) is home to a population exceeding 168,000 individuals, resulting in a population density of over 1904 people per square kilometer. According to cadaster data [44], land under water accounts for a high proportion of land use in the city (Table 1).

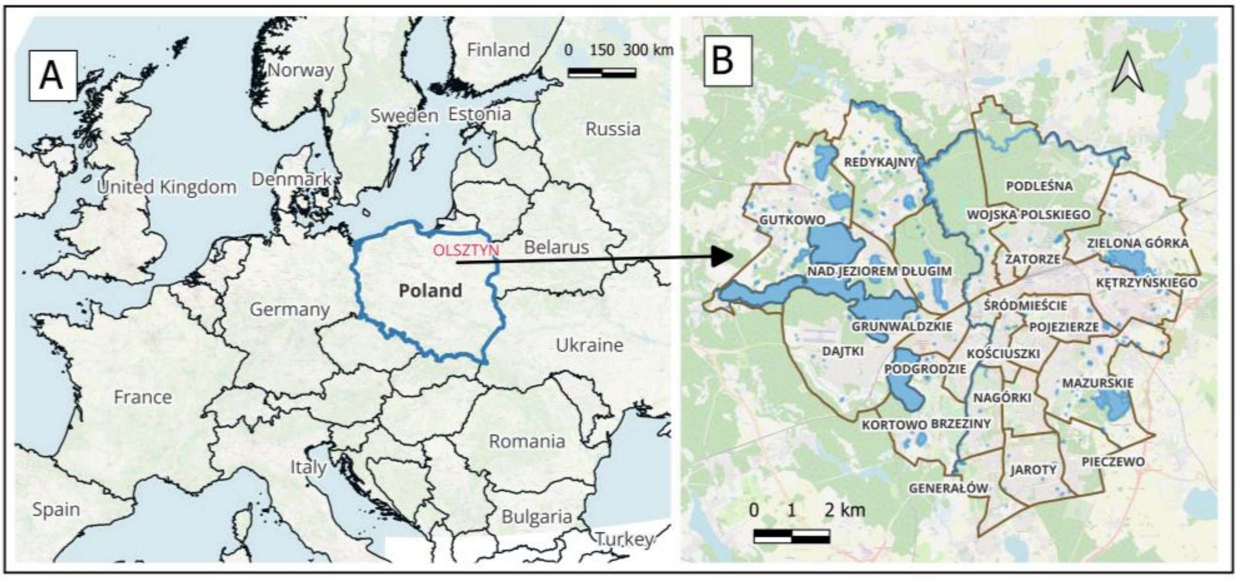


Figure 1. Study area—(**A**) Poland's location in Europe, (**B**) Olsztyn city location.

Table 1. Land use structure in the city of Olsztyn at the end of 2022.

Type of Land Use	Area (ha)	Coverage (%)
agricultural areas	2119	25.8
wooded and shrub land	2013	23.0
residential areas	996	23.0
industrial and storage areas	1199	6.3
parks and green areas	479	2.0
general urban services areas (including railways)	1166	9.2
lands under water	852	10.7
city area (Total)	8824	100.0

At the end of September 2023, the lowest unemployment rate was among men, and it was only slightly higher for women. During that period, the unemployment rate stood at 2.0%, well below the national average of 5.1%. This indicates the robust economic development of the city area. Consequently, the economic factor does not negatively affect the development of urban spaces or limit residents' preferences for spending their leisure time due to financial constraints.

Olsztyn was chosen as the research site due to its rich BI. The city is renowned for its profusion of water reservoirs, including lakes, rivers, and ponds, which collectively form scenic landscapes and stand as vital recreational spots for both residents and tourists. The city's BI comprises 15 lakes, including 13 with an area over 1 ha, 2 rivers, and an additional 150 water reservoirs, such as ponds and retention basins. The total area of lakes in Olsztyn is about 720 ha (8.15% of the town's area). Their distribution is uneven in favor of the western part, where the lakes cover 40% of the town's area (8% in the eastern part) [45].

Flash floods occur sporadically in Olsztyn, covering only a small part of the city. Therefore, BI is not perceived as a threat to the city but rather as a source of many benefits [46].

These diverse water features offer a spectrum of activities and leisure opportunities. Residents and visitors have the chance to enjoy beaches, bathing areas, as well as walking and cycling paths lining the lakeshores. Water-based sports like sailing, canoeing, and fishing are immensely popular. Moreover, the city boasts marinas tailored to boats and yachts, enabling the exploration of the lakes. Water equipment rental services are available for those who wish to engage in water activities but do not possess their own equipment. The abundant BI of Olsztyn attracts both its everyday residents, who utilize these areas regularly, and tourists who come to revel in the city's charm. The diverse water spaces and the attractions lining them constitute a significant aspect of the urban landscape, contributing to the residents' quality of life and providing distinctive experiences for those visiting the city.

The Olsztyn Municipality Office actively implements city planning and development to create an attractive place to live, work, and stimulate economic development. The city invests funds in the development of road, transport, and communication infrastructure. By striving to improve the condition of roads, establish new public transport connections, and modernize transportation, accessibility to all facilities in the city is enhanced. Traveling by public transport is facilitated by the new bus and tram fleet, contributing to improved road safety. Road investments implemented in 2023 in the city of Olsztyn [47] demonstrate continuous improvement in the condition of road infrastructure:

i. Construction of ul. Towarowa—from the intersection of Towarowa Street and Leonharda Street to the Wschód Junction (S51);
ii. Reconstruction of Partyzantów Street;
iii. Reconstruction of Pieniężnego Street along with the St. Jacob's Bridge;
iv. Transfer junction at the railway/bus station;
v. Extension of provincial road No. 598—Płoskiego/Witosa/Bukowskiego/Jaroty (S51);
vi. Construction of a tram line from Pieczewo to the city center;
vii. Construction of a new Olsztyn Główny railway station.

Olsztyn strives to attract investments and develop the local economy. Favorable conditions for entrepreneurship are created by providing investment areas, supporting the development of strategic sectors, and offering various forms of assistance and relief for entrepreneurs. Through economic investments, the city aims to create new jobs and strengthen sustainable economic development [48]. Simultaneously, the city is investing in recreational infrastructure to encourage people to relax in BI, exemplified by new bicycle routes along the Łyna River—Łynostrada section 1–3, the reconstruction of St. Jacob's Bridge connecting Podzamcze Park and Central Park, the construction of retention reservoirs in the eastern and southeast parts of the city, including the reservoir at Bukowskiego Street, the modernization of urban plantations with spaces for relaxation along the Łyna River, and the construction of a modern eco-heating plant on Bublewicza Street [49]. These efforts aim to improve air quality and encourage people to spend time outdoors even during the colder months.

The environmental policy of the city of Olsztyn is focused on shaping a 'green city' [46]. According to the Environmental Protection Programme for the City of Olsztyn by 2024, with an outlook to 2030, Olsztyn initiated its pro-environmental efforts with the development of sewage management [46]. The construction of sewage collectors and the modernization of the Municipal Sewage Treatment Plant were pivotal in protecting the beautiful Olsztyn lakes. Subsequent pro-environmental investments within the city focus on the development of low-emission public transportation. In 2011, following consultations, a decision was made to construct the first tramline. Currently, the city is implementing another project, 'Development of Public Transport in Olsztyn—Rail Traction,' which includes the construction of additional tramlines. This initiative aims to reduce vehicle emissions and encourage residents to use public transportation. Olsztyn is committed to renewable energy sources, investing in photovoltaics on both public buildings and a photovoltaic farm. The city also utilizes grants for the thermal modernization of public buildings, particularly schools. It is replacing coal-fired boiler rooms with more environmentally friendly heat sources.

The city has modernized one of its municipal boiler houses in Kortowo by installing a BIO boiler, powered by forest wood chips. The city is constructing a new combined heat and power plant. It will be fueled by the combustible fraction of municipal waste, along with a peak-load boiler (gas and oil) with a capacity of about 70 MW. The construction of the Waste Disposal Facility has been completed and put into operation.

The city is taking action such as preserving natural water retention in watersheds, maintaining small-scale water retention, and building retention reservoirs. These measures help to manage rainfall and reduce flood risk.

Efforts related to the revitalization of public spaces, tree planting, the creation of 'green yards' and 'rain gardens' aim to enhance the quality of life for residents and incorporate more ecological elements into the city. The city maintains green areas, establishes ecological land uses, designates natural monuments, and shapes the species and age structure of forest stands. The authorities of the city of Olsztyn encourage residents to plan revitalization investments by submitting space development projects under the participatory budget. Residents want to modernize the space around water reservoirs. Many applications have received approval for funding (Table 2).

As can be seen from the table above, the local community is involved in the revitalization of the sites at reservoirs, which relate to almost all the identified functionalities except for the economic function. This shows that the sites at reservoirs are realistically used by the residents and they want to use them in an even more efficient way.

The city conducts informational and educational campaigns promoting pro-environmental behaviors. Olsztyn strives to prevent soil erosion through the use of sustainable vegetative cover and appropriate agrotechnical practices that protect soil from erosion. Ongoing and planned pro-ecological activities are carried out throughout the urban space of Olsztyn and hence do not affect the quality of the space above individual water bodies. Therefore, the test object of the developed methodology is a representative one. Due to the fact that all residential neighborhoods have equal access to the water supply and sewage infrastructure, these BI indicators were not significant in the test.

Table 2. Citizens' budget projects submitted by residents in the last period since 2021.

Name of Civic Budget Project	Type of Project	Location	Funding (EUR)	Project Description	Strengthening Functional Qualities
'Green Me' Slightly larger pocket park. Pond of rethinking.	neighborhood project	Jaroty housing estate	92,112	Creation of a Pocket Park around the Thinking Pond—Adaptation and Modernization of a green area of public space.	esthetic function, recreational function
Redevelopment of the skatepark on the city beach	municipal project	On Ukiel Lake	184,224	Extension of the skatepark on the city beach in Olsztyn. Adding another part of the skatepark to the existing one to enlarge the riding area with new obstacles.	recreational function
'Concerts in Jakubowo Park—Culture in the Park'	neighborhood project	Wojska Polskiego housing estate	11,514	The refurbished stage at the pond, which includes an electrical box, and offers a great opportunity to use the venue for concerts with local and invited artists to bring the community together.	social function
Dances in Jakubowo Park—Culture in the Park	neighborhood project	Wojska Polskiego housing estate	11,514	The refurbished stage, which has an electrical box next to it, provides ample opportunity to use the venue for a number of social gatherings with local dance music artists to organize dances.	social function
Save Długie Lake 3	neighborhood project	on Długie Lake	27,634	The object of the task is to clean Lake Długie of excessive biomass of submerged vegetation and mats of filamentous algae. The ecological, esthetic, and recreational qualities will be improved.	ecological function, esthetic function, recreational function
ŁYNOSTRADA GROVE—construction of a footpath in Podgrodzie	neighborhood project	Podgrodzie housing estate	56,516	The area along Korczaka Street is a site with the potential for a small park. Meadows along the water channel, a dog run, and fruit trees have been designed—the aim is to create a new green spot on the city map.	esthetic function, recreational function, social function

Source: own study based on [50].

3.2. Research Framework

The conducted empirical research encompassed both qualitative and quantitative methods, the sequence and scope of which are presented in the diagram below (Figure 2). The developed method for assessing the attractiveness of residential neighborhoods is based on the classification of water bodies, which constitute the BI network, their accessibility, and their location. Geospatial analysis using Geographic Information System (GIS) tools was employed to assess residential neighborhoods in the city. The method assumes an optimal distance of 500 m to a water body, acceptable across various age groups of the respondents. This distance is one that seniors can comfortably cover on foot [28,51].

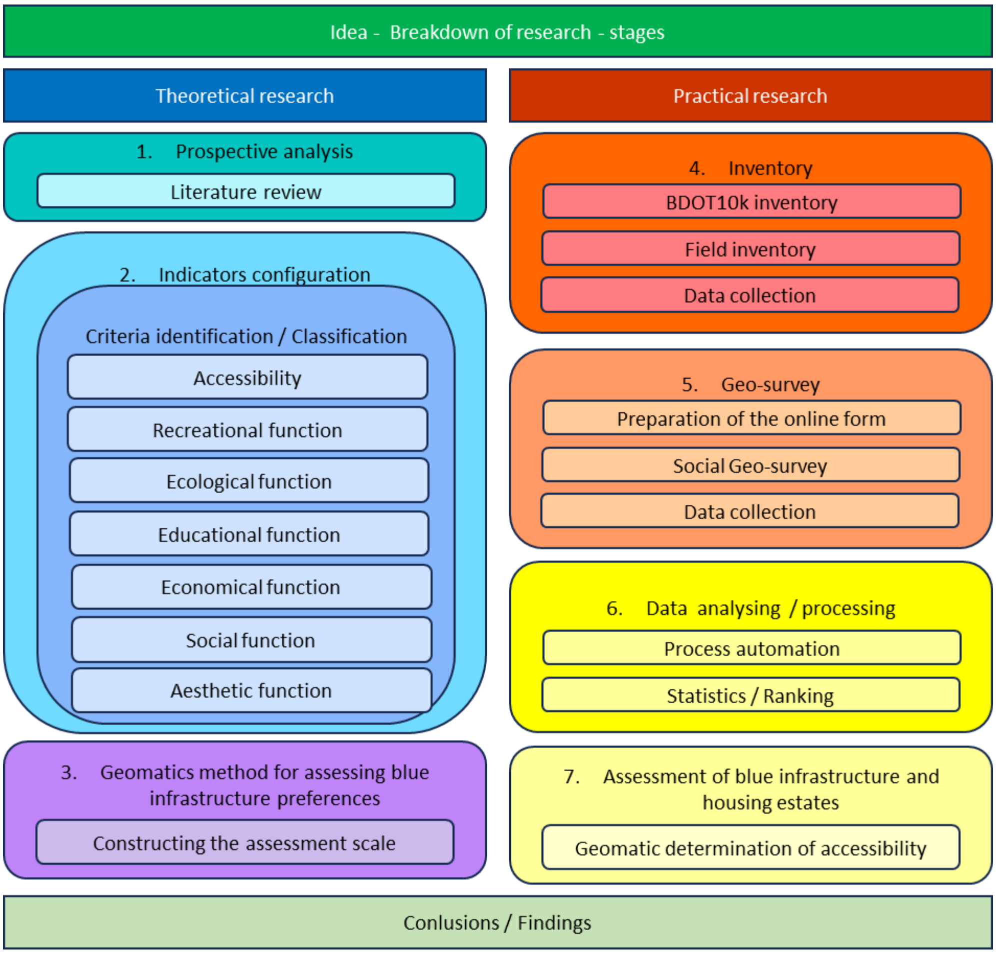


Figure 2. Research framework for the present study.

The classification of water bodies was established based on their functionality, determined after a two-stage inventory. The presence of a specific function was marked with points ranging from 0.5 to 2. Using quartiles, the water bodies were divided into four classes of functional quality. The obtained values were verified based on the results of a survey. Validation is an essential stage of this assessment process.

Ultimately, for the assessment of residential neighborhoods' attractiveness, the most prominent and multifunctional water bodies from the top quartile, with the highest practical significance in the city, were considered. Ultimately, the percentage of a neighborhood's area within the buffer of a significant water body determines its level of attractiveness.

3.3. Geo-Questionnaire Design

The conducted geo-survey formed both a cognitive and validation aspect of the research. Consequently, the survey geo-questionnaire was meticulously crafted to extract information regarding the water bodies' most desired functionalities as per residents, in addition to exploring the possibilities and methods of their utilization. The preferences and expectations of residents were investigated concerning the utility and development of these reservoirs. The developed geo-questionnaire is a versatile tool that can be employed for survey research in cities of various sizes and among different social groups. The geo-questionnaire was created using the ArcGIS Survey123 tool, enabling participants to accurately geolocate their favorite water bodies while simultaneously completing the geo-questionnaire (Figure 3). This facilitated the efficient, convenient, and effective collection of spatially related data. The tool used is one of the new GIS technologies aimed at collecting public opinion needed for resident-friendly land management.

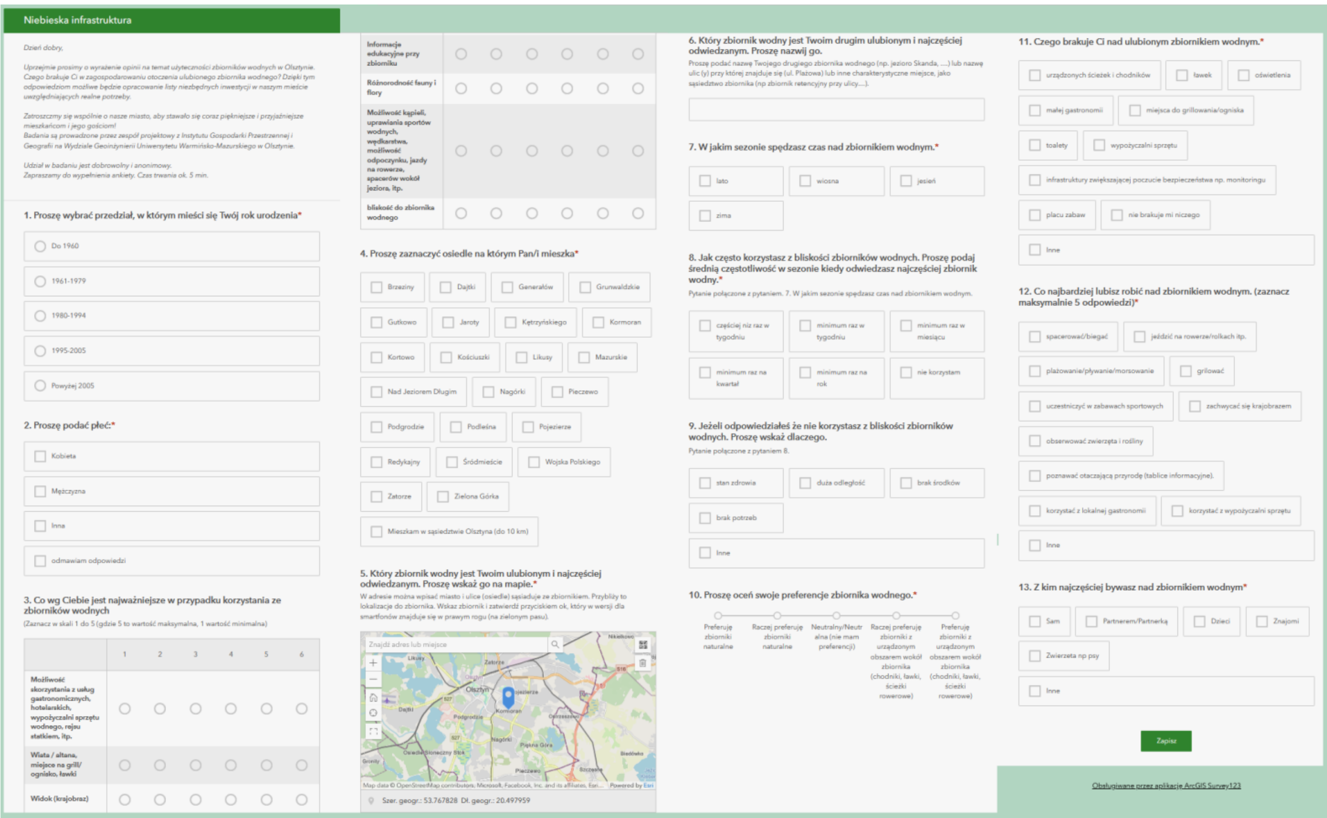


Figure 3. View of the design of the electronic geo-survey form in ArcGIS Survey123. * obligatory.

The survey results were analyzed using contingency tables to investigate the relationships between categorical variables. Sample analyses included examining associations between the respondents' age, gender, and preferences regarding the functionalities of water areas, as well as their choice of preferred types of water reservoirs. The general formula for the chi-squared statistic to assess the independence between two variables is presented below:

$$\chi^2 = \frac{\left(O_{ij} - E_{ij}\right)^2}{E_{ij}}$$

where

O_{ij}—represents the observed number of cases in a given cell,

E_{ij}—represents the expected number of cases in a given cell, and the sum encompasses all the cells of the contingency table. This analysis allows for the identification of significant relationships between the investigated variables.

When applying this test, it is important to note that the input data must be presented in the form of an empirical distribution, representing the value of observations. This test is recommended only when the expected number in each cell is greater than 5. Additionally, the observations should be conducted independently. The application of this significance test necessitated a modification in the encoding of age groups for the respondents, whereby they were categorized into three groups (1980–2005; 1961–1979; over 1960).

The geo-survey in the Polish language was conducted using a computerized version during the period of June–July 2023. Adult residents were invited to participate in the geo-survey via social media by posting a link to the research on local housing estate groups corresponding to 23 administrative units (districts) of the city of Olsztyn. The methodological assumptions, according to the calculations of the representative sampling generator with a fraction size of 0.5 and a maximum error of 3%, assumed that the random sample should consist of 1059 respondents out of 139,440 people over 18 years of age. It was important that the sampling included residents from each of the 23 housing estates, where the least populated housing estates should consist of at least 25 people in accordance with the calculation of a distribution proportional to the number of adult residents.

The geo-questionnaire as a ready-made tool provided by ArcGIS Survey 123 software allowed for the construction of 13 questions, mostly single-choice closed questions, which were divided into several categories. Due to the fact that this tool is not used enough in social geography research, the authors decided to describe its capabilities using the example of the questions developed in this study. Therefore, with the tool only being developed in Polish, each question is briefly described. The first three questions aimed to characterize the respondents, known as metric questions. However, these questions did not violate the principles of anonymity and the voluntary nature of the study. In the first question, the respondents were asked to select their age group. The responses encompassed different age groups, from individuals born before 1960 to those born up to 2005. Age ranges were tailored to generational groups. Different generations prefer different activities and rest differently in contact with nature [52]. Generally, different generations have different leisure preferences [53]. In the second question, the respondents were asked to provide their gender, selecting options such as 'Female,' 'Male,' 'Other,' or the possibility of declining an answer. The respondents indicated the residential neighborhood they inhabit in the third question. The next question pertained to the functions and utility of water bodies.

Then, the respondents rated their selected functionalities of water bodies using a 6-level scale, where 1 indicated the lowest value and 6 the highest value. The functions of water bodies were indirectly described, referring to various activities possible within the water body space, such as the possibility of using catering services, accommodation services, water equipment rental, or organizing boat trips (f1); the presence of shelters/pavilions, places for grilling/bonfires, and benches (f2); landscape significance (f3); accessibility of educational information nearby the water body (f4); diversity of fauna and flora (f5); opportunities for swimming, water sports, fishing, relaxation, cycling, and walking around the lake, etc. (f6), as well as accessibility to water bodies (f7). The question aimed to understand the importance that the respondents (residents) attach to the various functions of water reservoirs and which of these functions are the most important or attractive to them. This will help to identify which services and attractions offered by water areas are important to different groups of people. The results of this study can assist in allocating resources for the development and improvement of waterfront areas, as well as in planning tourism infrastructure. Additionally, the study can help to identify areas requiring protection or restoration and promote nature conservation.

Water bodies attract residents and tourists [24] due to their esthetics while simultaneously constituting a source of income and wealth for the communities in their surroundings [54,55]. Recreation in natural environments, both direct (e.g., swimming, boating, windsurfing) and indirect (as a focal point of picnics, walks, or other nature-related activities), can improve human health through physical activity [56,57]. Although water clarity and color may not be critical to aquatic recreation, the appearance of water influences its esthetics and potential to attract recreational users and tourists [58].

Questions 6 and 7 related to the favorite and most frequently visited water bodies (the two most visited). The respondents marked their favorite water bodies on the map.

Question 8 was about the preferred season (time of year) for spending time at the water body. It allows an understanding of which seasons are the most popular among users of these spaces. The next question asked the respondents to evaluate how often they visit these places during the season. They had the following answers to choose from: 'at least once a week,' 'once a month,' 'once a quarter,' 'once a year,' or 'I do not use them.' Question 9 targeted individuals who do not use water bodies and aimed to understand the reasons for not using them. The available response options included health condition, distance, lack of financial means, lack of interest, or other. Question 10 aimed to examine the respondents' preferences regarding the type of water body that best suits their expectations. The respondents had five options to choose from: 'I prefer natural water bodies,' 'I rather prefer natural water bodies,' 'Neutral (no preference),' 'I rather prefer water bodies with a defined area around them,' and 'I prefer water bodies with a defined area around them.' This question is important for several reasons. Firstly, it helps in understanding which types of water areas are more desirable to the community. Based on this information, development plans and water infrastructure can be adjusted to meet user expectations. If society strongly prefers natural areas, it may suggest a need to protect and preserve these spaces. When choosing areas for infrastructure development, decision makers may consider investing in the enhancement of such natural spaces.

The 11th question examined users' needs. It identified the missing elements of infrastructure and services near water bodies. In this question, the respondents indicated up to five most important options among landscaped paths and sidewalks, benches, lighting, small catering, places for grilling/bonfires, toilets, equipment rental, playgrounds, security-enhancing infrastructure such as monitoring, and others. The penultimate question aimed to investigate the respondents' preferred activities while spending time at water bodies. The respondents had the opportunity to select up to five answers from the following list: walking/jogging, cycling/rollerblading, sunbathing/swimming/diving, grilling, participating in sports games, admiring the landscape, observing animals and plants, learning about the surrounding nature (informational signs), using the equipment rental, enjoying the local cuisine, and others. This question helps in understanding which activities are most popular among the respondents when visiting water bodies. This allows for adjusting the recreational offerings around these water bodies. Thanks to this, it is possible to better adapt investments, spatial planning, and environmental protection policies to the real needs of communities and tourists. The final question determined whom the respondents most often spend time with at water bodies. There was an option to select one or several answers from the set: alone, with a partner, with children, with friends, with pets, and others.

3.4. Blue Infrastructure Inventory

The identification of the functional types of water bodies in urban areas was performed based on the conducted literature analysis using the keywords: water body function; lake/river function; BI function. They were classified into 6 functional groups: recreational, ecological, educational, economic, social, esthetic [59,60]. The inventory form is presented in a tabular format, where the presence of specific features is marked with numerical values. The individual columns of the form encompasses:

i. Water body number;
ii. Information on whether the area is private;
iii. Water body accessibility, understood as the possibility of physical access to the water/shore of the water body, unrelated to ownership (0 points—no access; 1 point—partial access; 2 points—full access). Reservoir accessibility was also assessed based on the 'density of roads, paths, cycling paths' [59], as well as 'the accessibility of shores,' 'the accessibility and size of the water surface,' and 'the seasonal stability of the water surface' [61].
iv. Recreational function (0 points—absent; 0.5 points—water body with potential for recreational use, offering space for public use; 1 point—partially realized recreational function outside the water body—at least one activity such as fishing, cycling,

rollerblading, sunbathing, etc.; 1 point—partially realized recreational function within the water body—at least one activity such as swimming, use of water equipment such as kayaks, sailboats, boats; 2 points—full recreational function both outside and within the water body). The assessment of recreational activities related to water bodies was conducted by L'Ecuyer-Sauvageau et al. [62] who, following Savard (2005), listed all activities, swimming, and none. Moreover, the recreational function was assessed in terms of the 'variety in landscapes with (potential) recreational uses' [27]. In other studies [59], the recreational function of reservoirs concerned the definition of the 'number of areas for recreation' (assessed as high, medium, low). Subsequent research [61] focused on identifying the following elements: 'beaches; cultural programme; equipment for team games; water and land (hiking, skiing, walking, and horse riding); tourist trails, nature trails; sailing; permanent and temporary bathing beaches; diving; canoeing; powerboating; fishing.' In addition, the recreational function understood as 'preventive healthcare; well-being, leisure and hobby' was analyzed by Józefowicz et al. [63];

v. Ecological function (0 points—degraded water body; 1 point—undegraded water body, not requiring restoration). Similar research was performed by L'Ecuyer-Sauvageau et al. [62], who quoted Savard (2005), assessing the visual aspect of the water body as water clarity (opaque, troubled, clear water). They also rated water bodies based on ecological health as bad, intermediate, or good [26]. The cited studies also analyzed odor—the smell from the water body, such as: garbage, cut grass, none. However, our research did not take into account odor because if there was no access to a given reservoir, the assessment was based on available map data. A similar scale, but increased by cultural value near the shore, was proposed by Rzętała [61]. The ecological function was also analyzed in terms of biodiversity protection and regulation [63];

vi. Educational function (0 points—absent; 1 point—educational paths or informational boards about the fauna and flora in the vicinity of the water body and its surroundings). The recreational function was also utilized by Józefowicz et al. [63].

vii. Economic function (0 points—absent; 1 point—business establishments within 100–200 m from the water body—gastronomy, water equipment rental, accommodations, recreation and sports; 1 point—commercial or public transport and communication services: ferries, water trams). This approach aligns with the research methodology of L'Ecuyer-Sauvageau et al. [62], who, following Savard (2005), considered the annual increase in municipal tax to gauge economic contribution. Subsequent studies [61] extended the evaluation to include specific elements like 'commercial and catering services, i.e., shops, restaurants' and 'accommodation facilities, i.e., private lodgings campsites, hostels, B&Bs, hotels, and motels.' The economic function was further examined concerning the presence of investment and industrial elements [63];

viii. Social function (0 points—absent; 1 point—publicly accessible spaces for social integration—at least one of the elements such as camping areas, places for bonfires, grills, shelters, benches). Pena et al. [59] analyzed social preferences for 'different ecosystems and landscapes for recreation.' They used the European Nature Information System (EUNIS) [64] and e-mail-in photo-questionnaires. In the case of the research that is the subject of this paper, it was not possible to use EUNIS, because its data concerning water reservoirs for the Warmia and Mazury Voivodeship, where Olsztyn is located, are too general and do not include information about most of the city's reservoirs. Social function was also the subject of analysis by Józefowicz et al. [63];

ix. Esthetic function (0 points—neglected water body without significant viewing points or with minimal ones, possibly polluted; 1 point—water body with moderate viewing points not emphasizing the beauty of the landscape; 2 points—water body with high esthetic value resulting from open view, cleanliness and neatness, mostly evoking positive emotions, pleasant experiences, and admiration in the observer). The esthetic function was assessed by considering two important factors: open view [65,66] and cleanliness and well-kept surroundings [67]. Esthetic information, such as the attractiveness of landscape features, was evaluated as 'Enjoyment of scenery (e.g., scenic roads, housing)' [29]. Esthetic value was also assessed by evaluating 'water quality' and 'esthetic values of the vicinity' [61].

The classification of water reservoirs on the scale of individual functionalities was based on identifying the presence of at least one option without examining the intensity of a specific phenomenon to accelerate the inventory process toward automation.

The inventory was planned and carried out in two stages:

1. Inventory on a map with the use of the topographic objects database (BDOT10k), which consisted of determining the coverage of individual water bodies (flowing, standing) and utilizing high-resolution orthophoto maps provided by the Main Office of Geodesy (Figure 4);
2. Field inventory consisted of visual assessment and photographic documentation. It was a necessary step to verify the current accuracy of available cartographic documentation.

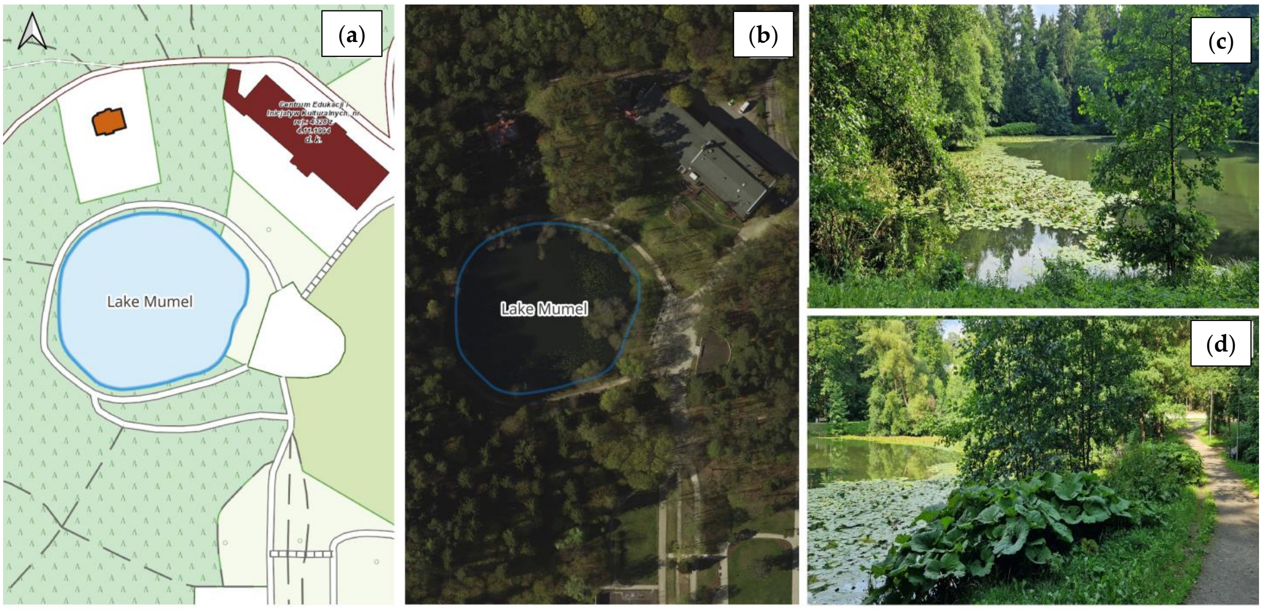


Figure 4. Data sources in the process of water bodies' inventory—(**a**) database of topographic objects—BDOT10k, (**b**) high-resolution orthophoto map, and (**c**,**d**) photographs by M. Gross.

All water bodies located within the boundaries of the city of Olsztyn were selected for the inventory. A significant challenge during fieldwork proved to be access to many water bodies, because some of them were privately owned and thus enclosed by fences, preventing access to the shoreline, precise characterization, and assessment of the water body. In numerous cases, these enclosures were not identified on maps, and it was only during the on-site visits that the lack of accessibility to the water bodies was discovered. Therefore, this stage proved to be essential.

3.5. A Process of Geo-Analysis

In the methodological assumptions for the geospatial analysis process (based on literature), it was established that the more functions that a water body fulfills, the higher the value of a water body and the surrounding areas. Therefore, the higher the cumulative score a particular water body received during the inventory process, the greater its significance within the city's landscape. The point value assigned to a specific function obtained during the inventory was the subject of a weighting based on the respondent's feedback. The method of calculating weights, as presented, was based on assigning weight to each water body function proportionally to its median rating in relation to the sum of all median ratings. This is a normalization method that expresses the contribution of each function as a percentage of the total sum of ratings and is expressed by the formula:

$$W_{f_i} = \frac{M_{f_i}}{\sum_{i=1}^{n} M_{f_i}} * 100$$

W_{f_i}—weight for function f_i
M_{f_i}—median rating for function f_i
n—number of functions

Below there is a description of the research steps that were conducted within the framework of assessing the attractiveness of residential neighborhoods. The first step involved evaluating the water bodies and then selecting those with the highest scores. Subsequently, 500 m buffers were created around the selected water bodies using the Multi-Ring Buffer plugin in QGIS software 3.28.3-Firenze to determine the areas influenced by these water bodies. The vector layer 'OT_PTWP,' representing flowing and standing surface waters as well as marine waters, was used for this purpose. This layer was derived from BDOT10k (Base of Topographic Objects) data available on the national Geoportal [68].

The next stage was to evaluate the percentage of areas covered by the buffers within the total area of residential neighborhoods. To achieve this, geoprocessing tools available in QGIS software such as 'Clip' and 'Intersection' were utilized, along with tools for manipulating geometry to break down complex multipart objects into individual, single-part elements. A shapefile layer containing the boundaries of residential neighborhoods, provided by the city of Olsztyn [69] was also used. The entire analysis was carried out using QGIS version 3.28.3-Firenze, utilizing geospatial analytical functions to visually define the influence zones of water bodies on the spatial distribution of residential neighborhoods.

Water bodies were classified to a specific function. The examples of classification are presented in Figure 5.

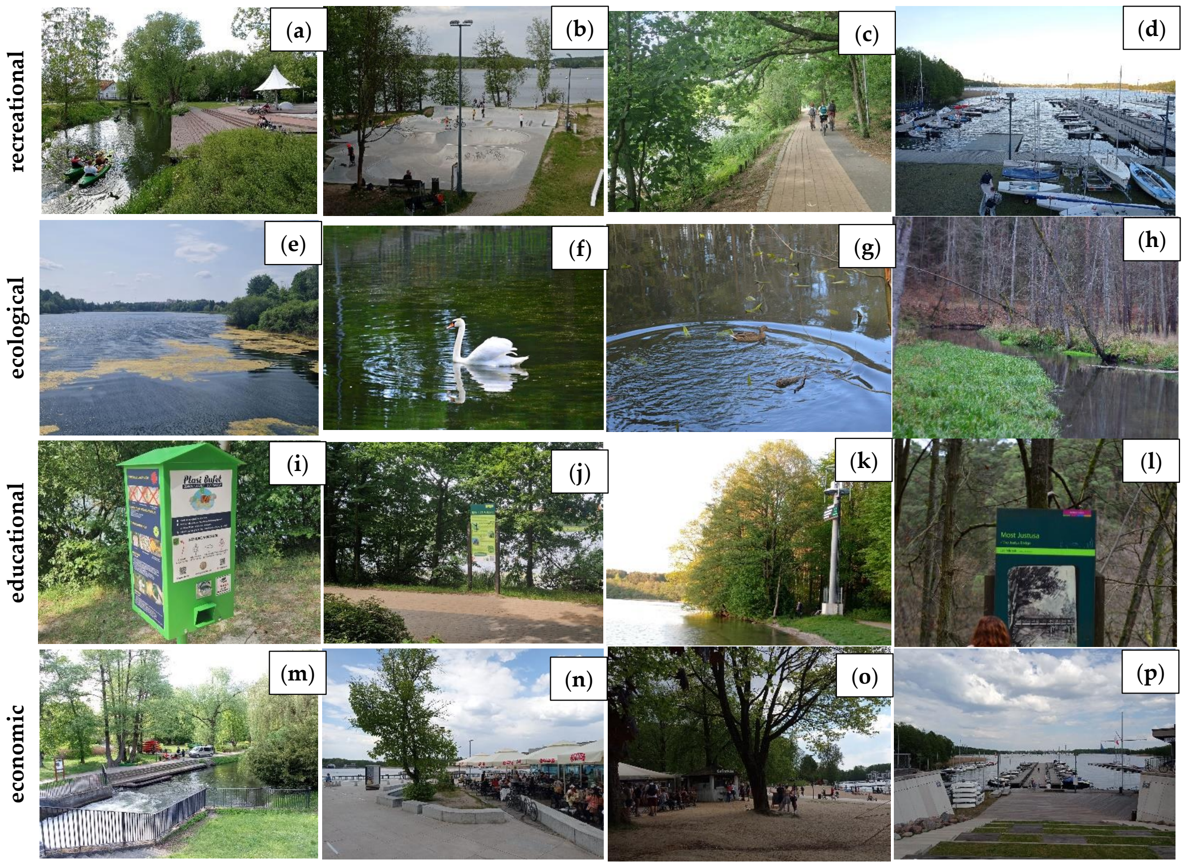


Figure 5. *Cont.*

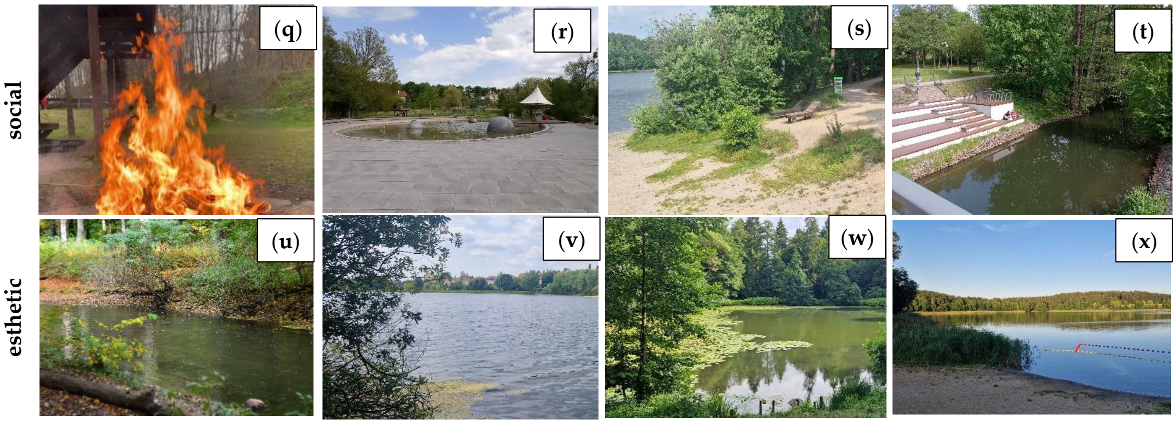


Figure 5. Examples of classification of water bodies for a specific function—recreational: (**a**) Łyna River, (**b**) Ukiel Lake, (**c**) Długie Lake, (**d**) Ukiel Lake, ecological: (**e**) Długie Lake, (**f**) Water body no. 25, (**g**) Mummel Lake, (**h**) Łyna River, educational: (**i**) Długie Lake, (**j**) Długie Lake, (**k**) Ukiel Lake, (**l**) Łyna River, economic: (**m**) Łyna River, (**n**) Ukiel Lake, (**o**) Ukiel Lake, (**p**) Ukiel Lake, social: (**q**) Łyna River, (**r**) Łyna River, (**s**) Długie Lake, (**t**) Łyna River, esthetic: (**u**) Łyna River, (**v**) Długie Lake, (**w**) Mummel Lake, (**x**) Żbik Lake. Source: photographs by M. Gross & A. Dawidowicz.

4. Results

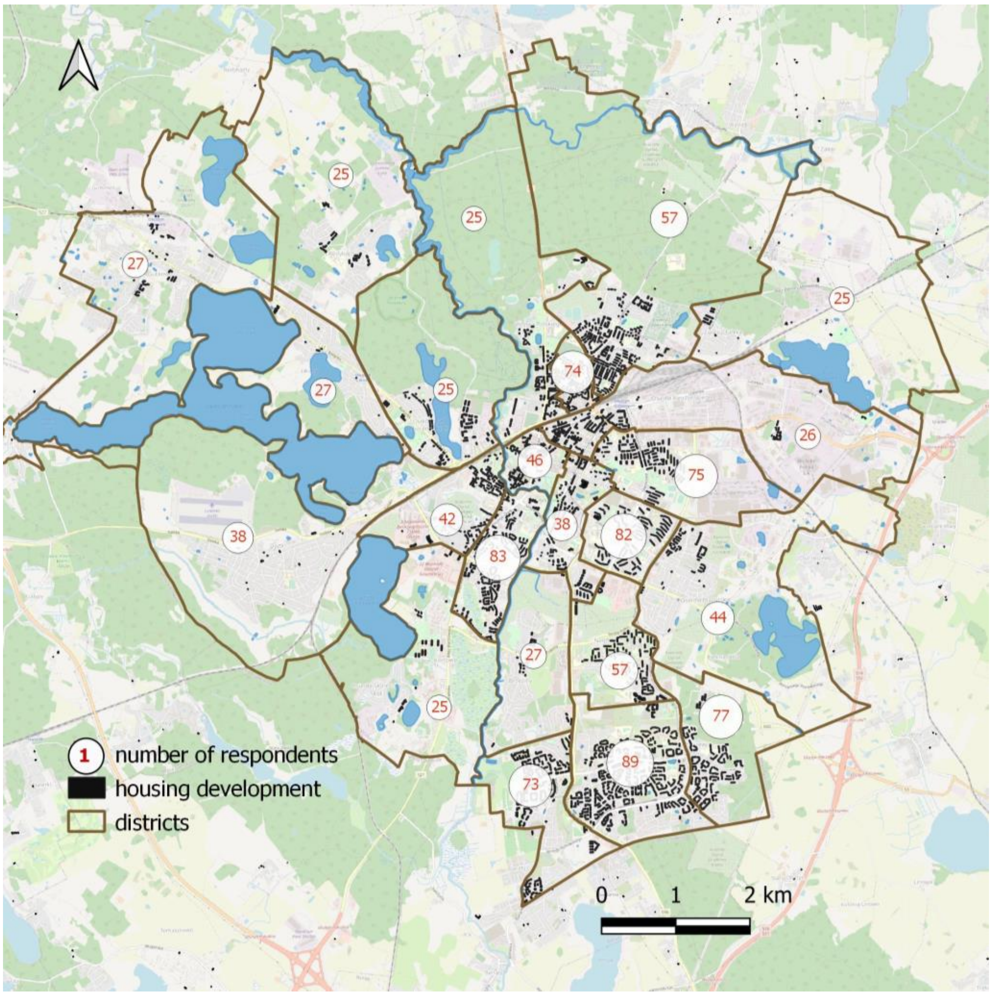
4.1. Geo-Survey Results

A total of 1107 adult residents of Olsztyn and its surroundings representing various age groups participated in the study. Several key strategies were adopted to minimize the bias in these studies. Firstly, the selection of respondents for the study was random, minimizing the risk of bias. Secondly, adult respondents over 18 years of age were divided into different age groups, considering generation characteristics and the type of housing estate, thus taking into account the diverse perspectives of the respondents.

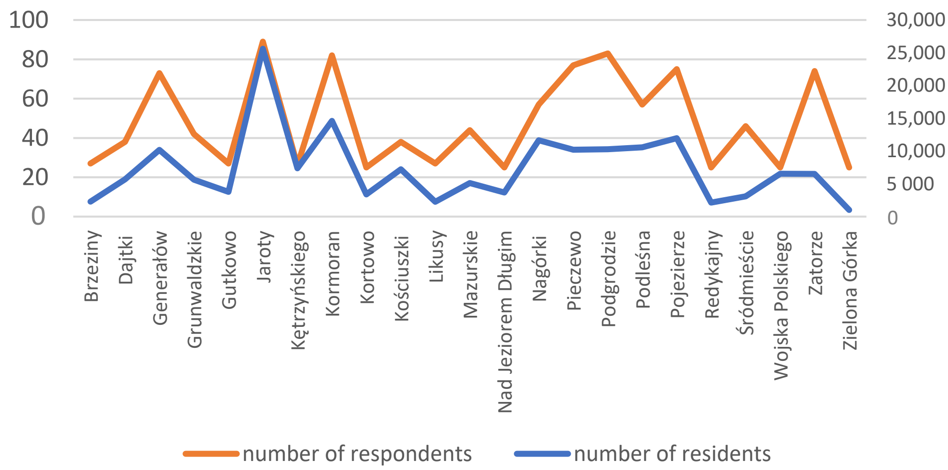
The largest group consisted of those born between 1961 and 1979—individuals of working age, accounting for 40.38% of the respondents. The next sizable group included individuals born between 1980 and 1994, representing 36.67% of the respondents (30 year olds). The group of individuals born before 1960 (senior group) represented 17.34% of the respondents, while a small percentage of those born between 1995 and 2005 (5.78%) took part in the survey. Such a small percentage of the respondents aged 18–29 could indicate low social engagement or a highly dynamic lifestyle that hinders involvement in local community affairs.

Slightly more women participated in the survey, comprising 61.52% female and 38.48% male respondents. Residents from all parts of the city, including all neighborhoods, took part in the survey. To ensure the representativeness of the results, the authors assumed that the distribution of the respondents should be proportional to the number of adult residents in the estates. After collecting the surveys, we conducted a data quality control procedure, resulting in the removal of 11 incomplete or incorrect surveys to maintain the integrity and effectiveness of the data. Among these, five surveys lacked information about the respondents' favorite water bodies, and six surveys lacked answers to three or more questions.

The figure below (Figure 6) shows the spatial distribution of the respondents, which closely resembles the distribution of the city's population. It is worth noting that the highest participation rates were observed in the districts of Podgrodzie, Jaroty, and Kormoran, characterized by a predominance of multi-family buildings and a population exceeding 10,000. On the other hand, the lowest response rates were recorded in single-family housing estates such as Kortowo, Nad Jeziorem Długie, Wojska Polskiego, and Zielona Górka.



(**a**)



(**b**)

Figure 6. Image depicting the distribution of respondents across individual housing estates in Olsztyn—(**a**) visualization on a map, (**b**) distribution adjustment diagram.

People asked about what they value most being around water bodies rated the opportunity to engage in diverse activities (e.g., swimming, water sports, fishing, relaxation, cycling, and walking around the lake (f6)), scenic views (f3), and convenient location (f7) the highest (6 points). They valued the availability of catering services, accommodations, water equipment rental, boat trips (f1), and the diversity of fauna and flora (f5) at a moderate level (rating of 4). In contrast, the smaller amenities like shelters/pavilions, places for grilling/bonfires, benches,(f2) and educational information (f4) nearby the water body were rated the lowest (3 points) (Table 3).

Table 3. Evaluation of respondents' activity preferences describing the functions of water reservoirs.

Functions of Water Reservoirs	**Average Value of the Function**	**Median**	**Minimum (Obtained)**	**Maximum (Obtained)**	**Standard Deviation**
f1-economic (possibility of using catering services, accommodations) services, water equipment rental)	3.68	3	1	6	1.49
f2—social (presence of shelters/pavilions, places for grilling/bonfires, and benches)	3.3	3	1	6	1.59
f3—esthetic (landscape significance)	5.29	6	3	6	1.08
f4—educational (educational information nearby the water body)	2.86	3	1	6	1.57
f5—ecological (diversity of fauna and flora)	3.94	4	1	6	1.7
f6—recreational (opportunities for swimming, water sports, fishing, relaxation, cycling, and walking around the lake, etc.)	5.31	6	2	6	1.17
f7—accessibility to water bodies	5.03	6	3	6	1.22

The analysis of individual age groups revealed different preferences. The youngest study participants rated the highest for f6—opportunities for swimming, water sports, fishing, relaxation, cycling, and walking around the lake (5.6 points) and f3—importance of the landscape (6 points), while f4—education (only 1.8 points) and f5—diversity of fauna and flora (2 points) were rated the lowest (Figure 7). Residents born during 1980–1994 appreciated f7—accessibility to water areas (5.4 points) and f5—diversity of fauna and flora (4.4 points) the most. In turn, f2—the presence of roofs/pavilions, barbecue areas, and benches (3.0 points) was least appreciated by people born during 1961–1979, who rated the remaining activities at an average level. Seniors rated the highest for feature f1—the possibility of using catering services, accommodations, and renting water equipment (4.3 points) and f4—educational information in the water area (3.2 points). Drawing a picture of these results, it can be seen that differences in preferences are significant depending on age group, suggesting the need to adapt the offer of water areas to the different expectations and preferences of individual social groups.

Pearson's chi-squared tests (χ^2) revealed statistically significant associations between the ratings of facilities related to the accessibility of catering services, accommodations, and water equipment rental (referred to as f1) and the age groups of the respondents (χ^2 = 69.20, p = 0.000). These preferences (f1) varied across different age groups among women (χ^2 = 28.53, p = 0.00001). In the age groups 1980–2005 and 1961–1979, the majority of female respondents gave lower ratings (1–2 points).

Similarly, the chi-squared test for the association between variable f2 (presence of pavilions, barbecue areas, and benches) and age groups yielded statistically significant results (χ^2 = 28.50, p = 0.00001). Preferences for f2 also showed differences among women in different age groups (χ^2 = 22.65, p = 0.00015). In the cohort of women born during the years 1980–2005, a preference for lower ratings (1–2 points) dominated, while higher ratings (3–4 points and 5–6 points) were observed among women born during the years 1961–1979 and those born after 1960.

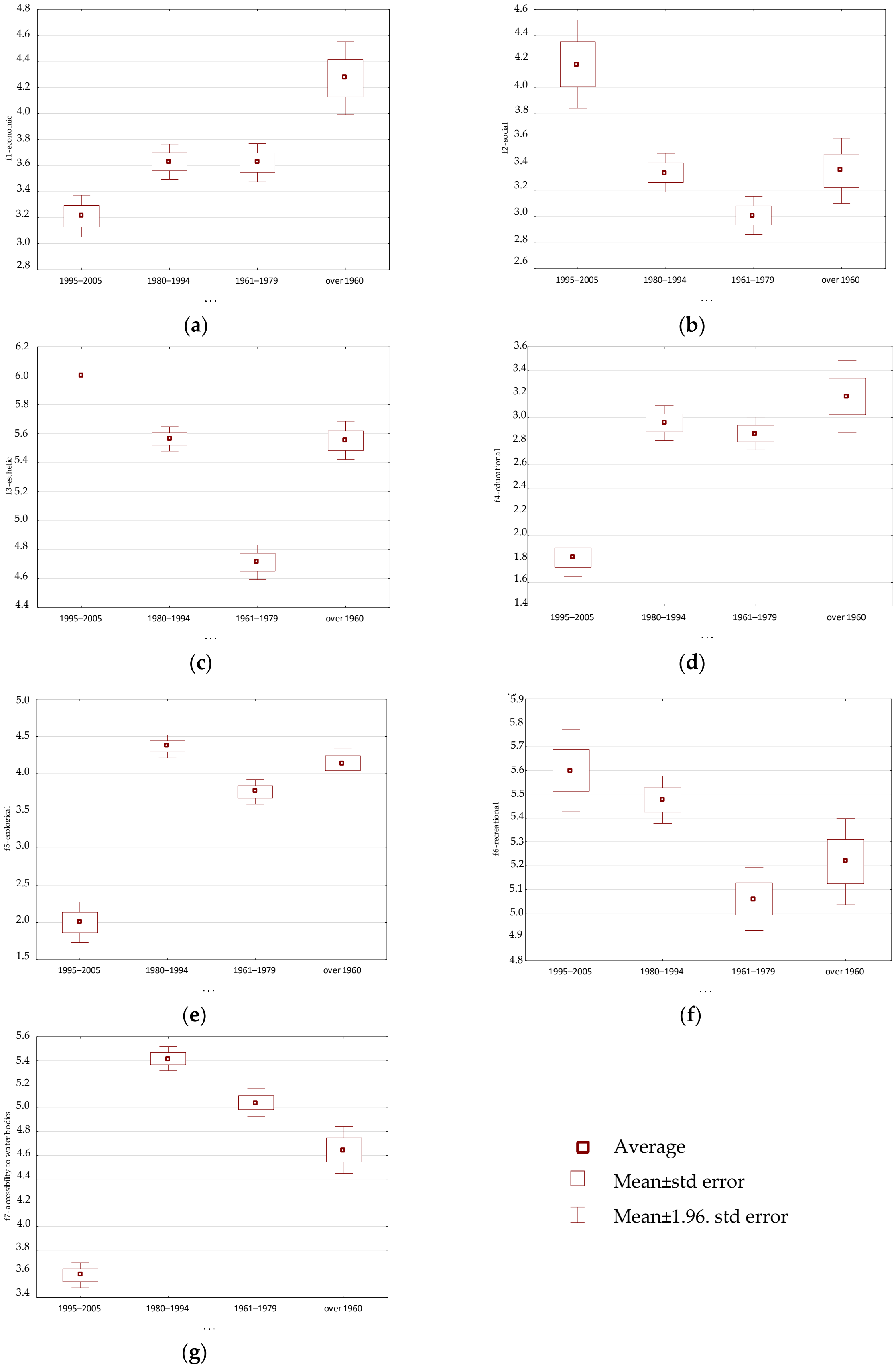


Figure 7. Distributions of preferred functionalities of water reservoirs by respondents according to the age groups—(**a**) economic function, (**b**) social function, (**c**) esthetic function, (**d**) educational function, (**e**) ecological function, (**f**) recreational function, (**g**) accessibility to water bodies.

Statistically significant dependencies were also observed in the analysis of f3—esthetics (landscape significance) among the respondents of different ages and different age groups of men (chi-squared test result: $\chi^2 = 81.20$, $p = 0.000$). In the age group 1961–1979, the majority of men gave ratings at the 3–4 point level, suggesting a moderate or good consideration of the landscape in this age category. Conversely, the highest ratings of 5–6 points among men born during the years 1980–2005 indicated a greater emphasis on landscape esthetics when assessing the functions of water bodies in the younger demographic.

Furthermore, Pearson's chi-squared tests showed statistically significant dependence between ratings of f4—education (educational information at the water reservoir) and age groups of female respondents ($\chi^2 = 61.48$, $p = 0.000$). In the cohort of women born in the years 1961–1979, the majority gave ratings at the 5–6 point level, whereas in the group born after 1960, the highest ratings were at the 3–4 point level.

Pearson's chi-squared tests were statistically significant for the variable f5—ecological (biological diversity) in relation to the respondents' age, and similarly for the variable f6—recreational (swimming, water sports, fishing, leisure, cycling, lake walks, etc.)

Results of the chi-squared test (χ^2) for the relationship between variable f7 (availability of water reservoirs) and age group suggest statistically significant associations ($\chi^2 = 27.35$, $p = 0.000$). In the age group 1980–2005, more individuals rated the availability of water reservoirs at 3–4 points. Conversely, in the age group 1961–1979, a reverse trend occurred, with a higher number of the respondents giving higher ratings (5–6 points). Similarly, in the age group above 1960, the majority of the respondents gave higher ratings for the availability of water reservoirs.

Drawing a picture of these results, it can be seen that differences in preferences are significant depending on age groups, suggesting the need to adapt the offer of water areas to the different expectations and preferences of individual social groups.

The respondents, when answering the question about their two favorite and most frequently visited water bodies, indicated that Lake Ukiel was the most commonly chosen place, receiving 35% of the votes. In second place was Lake Skanda, which received 22% of the responses. Other lakes received lower scores, e.g., Lake Długie—15%, Bartążek—8%, and Kortowskie—7%, as well as artificial retention reservoirs at Pieczewo and the Generałów district with 2% and 3%, respectively. Lake Wadąg, located near the city, also received 2% of the votes (Figure 8).

During the processing of the geo-survey results, imprecise markings on the map were identified and excluded from the analysis (Figure 8). Preferences of residents regarding their favorite primary water body were also determined during the study, broken down by residential neighborhood (Table 4).

Based on this information, it has been determined that despite the distance between the water body and the residential neighborhood, residents are able to overcome distances greater than 500 m [28], facilitated additionally by good public transportation. This is significant information for administrators and event organizers. Due to these additional conditions, residents opt for recreational spots in more distant areas of the city. The following table (Table 5) presents the averaged results of the distances to preferred BI locations.

Summer is the most popular season for spending time at water bodies, according to all the survey participants. Spring and autumn also enjoy significant interest (52% and 42%, respectively), while winter is a less-preferred period for water-related activities (14%). The respondents take advantage of the proximity of water bodies to varying degrees in their preferred seasons: 23.12% of them visit water bodies more than once a week, 48.15% at least once a week, 21.14% at least once a month, and 3.79% at least once a quarter or year (Figure 9).

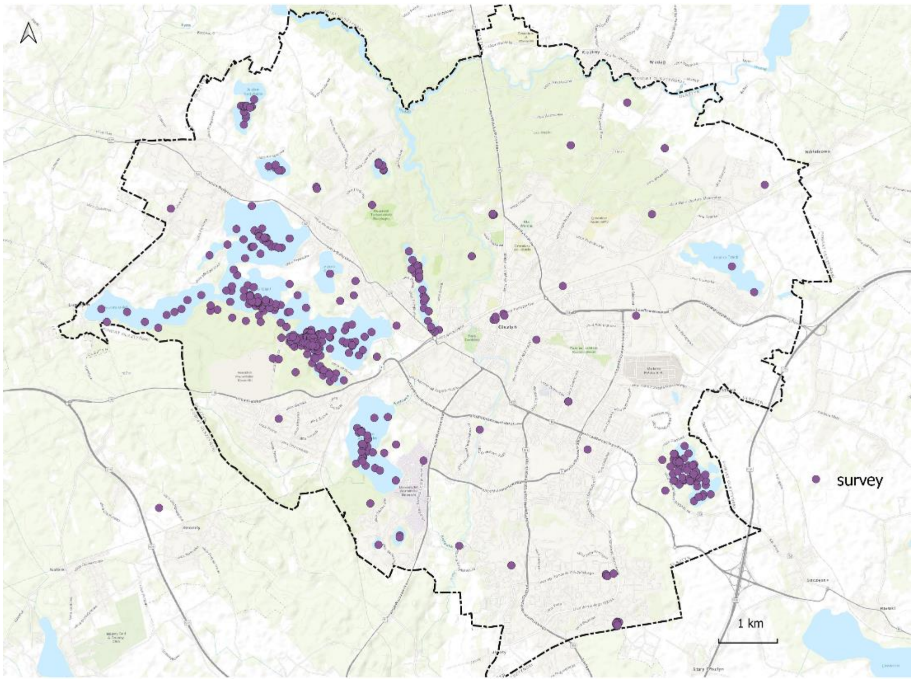


Figure 8. Map of respondents' indications generated with ArcGIS Survey123.

Table 4. Preferences of favorite blue infrastructure among residents of individual residential neighborhoods.

Lake	Residential Neighborhood
Ukiel	15 housing estates, i.e., Dajtki, Gutkowo, Generałów, Jaroty, Pieczewo, Podgrodzie, Redykajny, Śródmieście, Wojska Polskiego, Zatorze
Kortowskie	Generałów, Kortowo, Podgrodzie, Pojezierze
Skanda	10 housing estates, i.e., Generałów, Jaroty, Kormoran, Mazurskie, Pieczywo, Podgrodzie, Pojezierze, Olsztyn's neighborhood, Zatorze
Długie	7 housing estates, i.e., Kortowo, Nad Jeziorem Długim, Podgrodzie, Podleśna, Śródmieście, Wojska Polskiego
Żbik	1 housing estate: Likusy
Wadąg	Residential neighborhoods in the vicinity of Olsztyn
Bartążek	Generałów, Brzeziny

Table 5. Average distance between the indicated primary-choice water body and the centroid of the residential neighborhood in kilometers.

Value	Distance (km)
mean	3.357774
minimal	0.740425
maximal	10.74031
median	3.003056

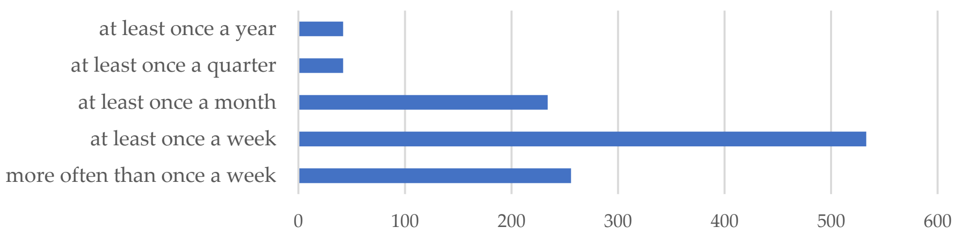


Figure 9. Frequency of water body use.

In the survey, only 44 individuals responded to the question regarding not taking advantage of the proximity to water bodies. Among them, 23 people (52.27%) indicated long distances as the reason, 12 (27.27%) mentioned lack of need, and 9 (20.45%) provided reasons other than those listed in the survey. None of the respondents chose health-related issues or lack of means as a reason for not taking advantage of the proximity to water bodies.

The survey indicates that the majority of the respondents prefer water bodies with developed surroundings (57.63%), while a smaller, but still significant number, choose natural water bodies (30.71%) and a neutral stance was taken by 11.56% of the respondents. In the age groups 1980–2005 and 1961–1979, the majority of the respondents indicated a preference for developed water bodies, while in the group above 1960, a clear majority favored natural water bodies.

The opinions of the survey participants about missing infrastructure and services at their favorite water body revealed that the primary need is access to toilets, as reported by 42.28% of the respondents. On the other hand, 36.49% of the respondents did not notice the lack of any infrastructure. Other needs include small eateries (15.36%), playgrounds (17.25%), benches (13.46%), and equipment rental (13.46%). Infrastructure for increased safety (9.57%), lighting (7.68%), and places for grilling or bonfires (7.68%) were also mentioned as important. Individual respondents also expressed a need for changing rooms, shops, and exercise equipment.

The survey results indicate that 69.20% of the participants prefer to admire the landscape at the water body, while 34.60% observe animals and plants. It is worth noting that often, appreciating the landscape, wildlife, and plants accompanies other water-related activities. These natural landscape elements enrich experiences and add beauty to various activities. Additionally, 28.81% of the respondents prefer using equipment rental. Other activities such as sunbathing, swimming, snorkeling, grilling, and sports are less popular, ranging from 13.60% to 9.57%. Furthermore, 5.78% of the respondents indicated other activities not mentioned in the survey, such as 'quiet relaxation.'

Not all activities are preferred by the respondents in different age groups. Seniors do not participate in sports games, grilling, and cycling/rollerblading (Figure 10). The youngest adults do not prefer participating in sports games, using equipment rental, learning about the surrounding nature (informational signs), and observing animals and plants. However, all residents prefer sunbathing/swimming/diving, admiring the landscape, and walking/jogging (Figure 10). These results align with the preferred activities indicated by the respondents in the various age groups.

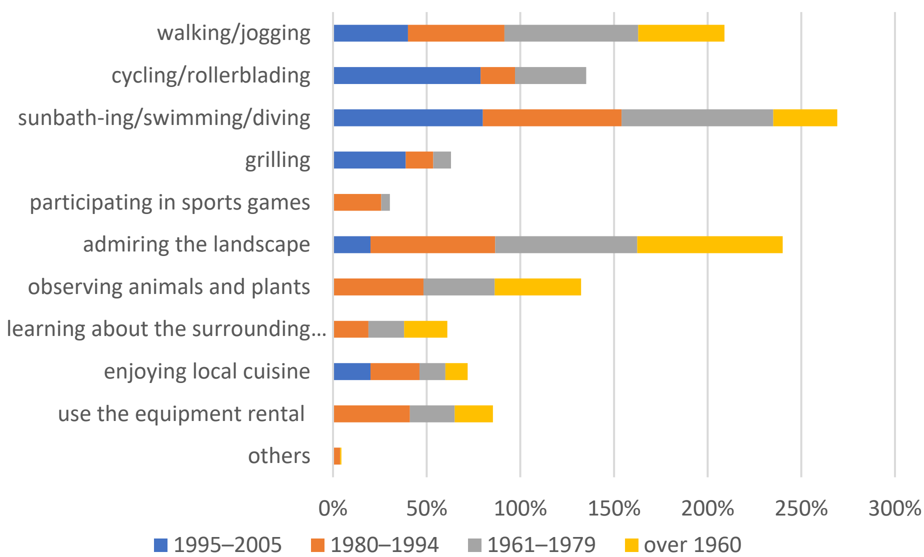


Figure 10. Distributions of activity preferences at water reservoirs: analysis by age group.

These results confirm the relevance of the selection of indicators, as none of them fell below 30% significance in relation to the total number of responses of all age groups. On the other hand, the very low return of indicating other forms of activity at reservoirs shows that the constructed list of indicators is complete.

Most commonly, the respondents spend time at a water body with their children (59.62%) and partners (44.26%). About one-third of the respondents are accompanied by friends (34.59%), 30.80% choose to spend time at a water body alone, and 17.31% bring their dogs along. This result is consistent with the respondents' prioritization of functionality. The respondents preferred to spend time at reservoirs alone or with their close family; hence, the social function appeared to be less important. This is also confirmed by the low score of willingness to participate in sports games. Indeed, during the inventory, it was noted that beach volleyball is only played by young people. Despite the planning of many beach volleyball courts on Lake Ukiel and basketball courts on Lake Kortowski, they tend to be deserted or used by young people or students. This raises another area for research into why working people do not integrate socially and in sports teams.

4.2. Parametric Evaluation of Water Bodies

As a result of inventory work and a geospatial survey, a total of 199 water bodies were identified within the city limits of Olsztyn. While some of the water bodies have their own names, most of them are designated solely by the unique numerical identifier of the land use in the cadaster, such as 286201_1.0096.Bz.1. To facilitate the study, water bodies were sequentially numbered with integers starting from 1 within the city except for lakes, which retained their own names. Following the calculations, a ranked list of water bodies was compiled and categorized into four importance groups according to designated quartiles (Table 6). During the evaluation, only 15% of water bodies were found to be multifunctional and thus particularly valuable.

Table 6. Ranking of water bodies in Olsztyn.

Value Ranges	Number of Water Bodies	Percentage of Total Number of Water Bodies (%)	Name of the Lake	Water Body Number
0–0.170	44	22	-	72, 125, 153, 165, 186, 187, 81, 15, 65, 44, 141, 63, 82, 13, 142, 147, 137, 77, 3, 133, 129, 93, 57, 189, 130, 43, 149, 66, 86, 42, 111, 45, 97, 19, 52, 128, 120, 96, 197, 34, 33, 11, 188
0.171–0.490	39	20	Zgniłek	73, 152, 177, 12, 23, 59, 124, 74, 58, 27, 41, 60, 78, 80, 112, 122, 151, 158, 161, 173, 195, 163, 91, 144, 126, 69, 135, 88, 40, 193, 76, 160, 110, 47, 167, 14, 150, 123, 99, 157, 105, 67, 61, 48, 54, 148
0.491–0.900	86	43	Trackie, Starodworskie, Poligonowe, Żbik	48, 54, 148, 71, 87, 100, 106, 118, 159, 190, 90, 9, 198, 16, 172, 196, 119, 10, 55, 84, 20, 85, 132, 56, 64, 31, 155, 5, 26, 98, 140, 175, 199, 139, 17, 181, 24, 2, 192, 4, 89, 185, 70, 194, 162, 138, 164, 79, 162, 22, 191, 171
0.901–1.530	30	15	Ukiel, Długie, Skanda, Czarne, Redykajny, Łyna, Podkówka, Kortowskie, Sukiel	50, 22, 7, 101, 114, 134, 134, 49, 109, 38, 25, 176, 25, 103, 92, 102, 108, 39

The recreational and esthetic functions are the most valuable in the respondents' opinion and determine their use of water bodies (Table 7). This result confirms the research hypothesis formulated at the beginning. Interestingly, only 11 out of 199 evaluated water bodies possess full recreational functionality. Similarly, only 29 water bodies exhibit high esthetic value. The confirmation of this result is reflected in the number of identified economic and social functions. Only 25 inventoried water bodies have a business environment, and 29 offer facilities conducive to organizing social integration events. This result aligns with the obtained highest quartile of functional value for water bodies in Olsztyn, as shown in Table 7. The obtained results correspond to the city's investment activities and the needs of residents expressed in the geo-survey.

Table 7. Summary of water reservoirs in the city of Olsztyn.

Function	Weight	Characteristic	Number of Water Bodies	% of Water Bodies
Recreational	0.187	lack	128	64.3
		partial outside of the reservoir (fishing, cycling, rollerblading, sunbathing, etc.)	51	25.6
		partial inside the tank (swimming, swimming, the possibility of using water equipment, etc.)	20	10.1
		full (external and internal)	11	5.5
Ecological	0.125	degraded tank	22	11.1
		non-degraded tank	177	88.9
Educational	0.094	lack	185	93.0
		educational paths/information boards	14	7.0
Economic	0.125	lack	174	87.4
		proximity to business (gastronomy, accommodations, water equipment, etc.	25	12.6
Social	0.094	lack	170	85.4
		public places for social integration (fireplace, grill, shed, etc.)	29	14.6
Esthetic	0.187	neglected reservoir	73	36.7
		a reservoir with a small viewing opening that does not sufficiently emphasize the beauty of the landscape	97	48.7
		tank of high esthetic value	29	14.6
Accessibility to the reservoir	0.187	lack	68	34.2
		partial	76	38.2
		full	55	27.6

In light of the information provided earlier, the water bodies that received the highest points in the ranking were chosen for subsequent geospatial analysis to evaluate their impact on the appeal of residential neighborhoods. These selected water bodies are depicted in the chart (Figure 11).

To verify the obtained ranking of water bodies, the achieved results were compared with the results of the respondents' indications regarding their favorite water body from two independent choices. This relationship is presented in the following chart (Figure 12). It can be observed that the higher the ranking of a water body, the more people who prefer it. A particular case is Lake Skanda, which ranks in the middle of the ranking of the most attractive water bodies. However, its location in the eastern part of the city, as one of the few larger water bodies in this area, can make it popular due to the lack of competition. The other top water bodies are likely third- or fourth-place choices. Perhaps this is due to their size and proximity to the lakes of the first and second choices. Certainly, significant investment in environmentally and human-friendly recreation infrastructure, consistent with the adopted environmental development program [46], has a significant impact on the assessment of these reservoirs.

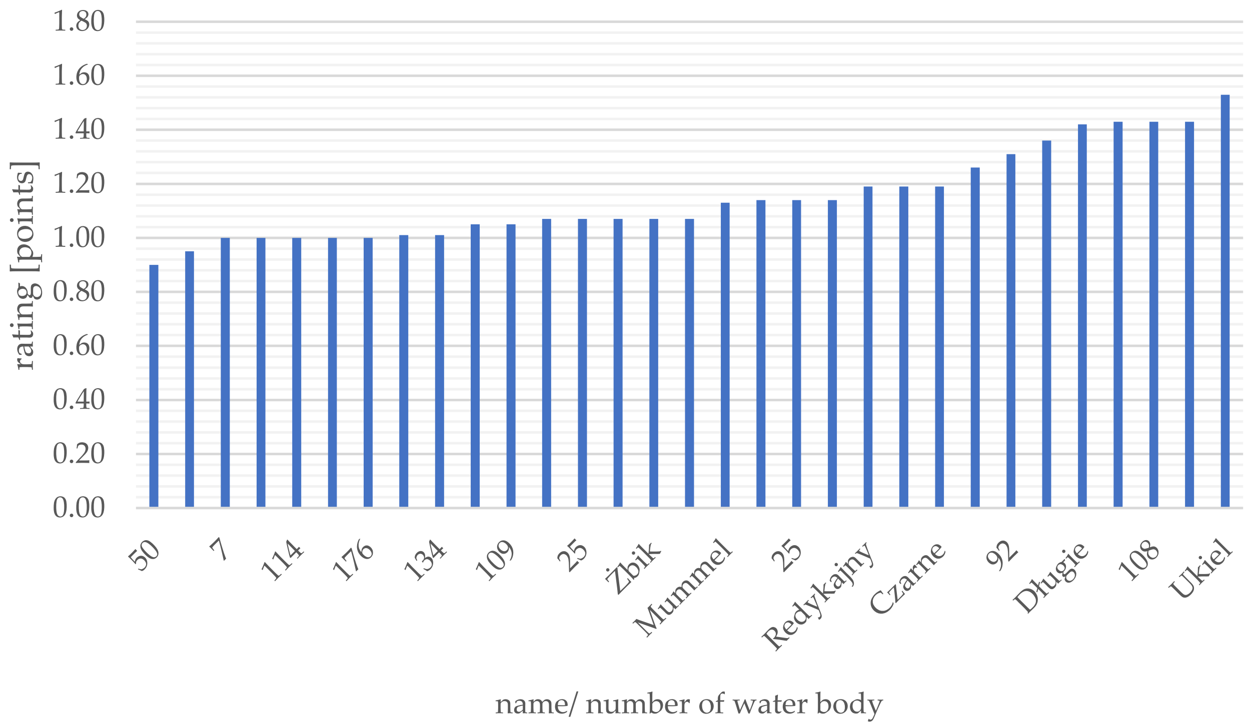


Figure 11. Ranking of the most functionally attractive water reservoirs according to the points obtained.

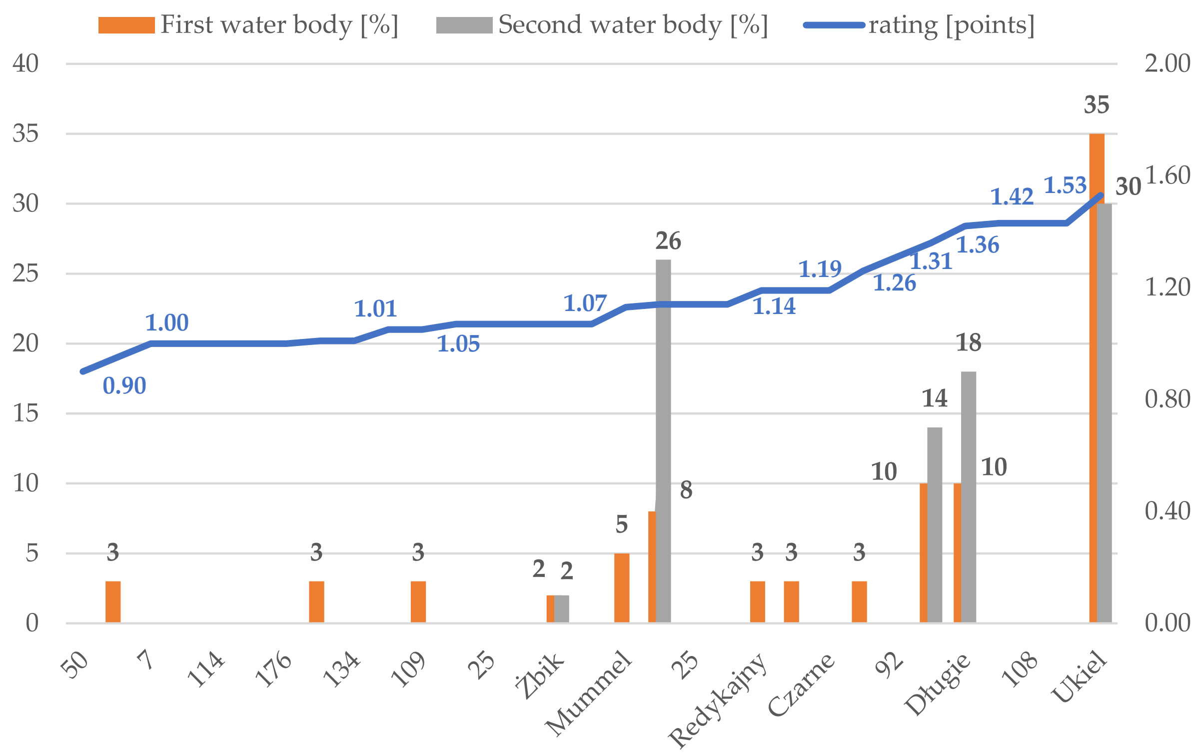


Figure 12. Relationship between the rank of the water body and the choice of the most attractive water body by respondents. Labels: blue color—water body's score, black color—indication of the favorite water body as the first choice, orange color—indication of the favorite water body as the second choice.

Despite selecting only 30 water bodies with the highest functional value for further analysis, as many as 90% of the water bodies exhibit a good ecological condition. These are clean and biologically active water bodies with rich flora and fauna. This is a highly satisfactory result.

4.3. Evaluation of Residential Neighborhoods

Taking into consideration the adopted 500 m distance from the water bodies' shorelines as the optimal walking distance for all age groups in society, a geospatial analysis was conducted to assess the positioning of the most functionally valuable water bodies in relation to the location of residential neighborhoods. The concentration and coverage map (Figure 13) illustrates that water bodies with the highest value are concentrated throughout the western and southern parts of the city.

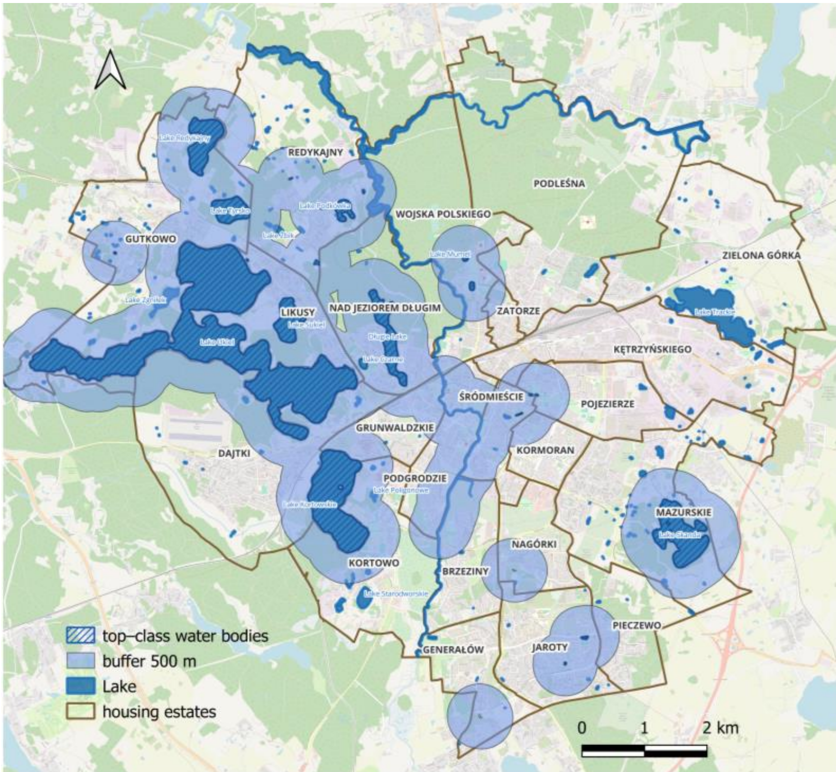


Figure 13. Concentration map and optimal accessibility zones to the most attractive water bodies in Olsztyn.

The layer depicting the administrative boundaries of neighborhoods reveals uneven access to water bodies from different parts of the neighborhoods. Hence, the percentage of the neighborhoods' area contained within the optimal buffer zone of access to these water bodies was examined. According to the adopted methodological assumptions, if 75–100% of a neighborhood's area has access to valuable water bodies within the optimal distance, it is considered highly attractive; 50–74% indicates an attractive location; 25–49% signifies a moderately attractive location, while 0–24% designates an unattractive location. Surface geospatial analyses were performed on neighborhoods based on these criteria. By segmenting the areas, ranking of neighborhoods was obtained and categorized into the four attractiveness groups, as presented in Figure 14.

Among the total of twenty-three residential neighborhoods, four were classified as highly attractive, four as attractive, nine as moderately attractive, and six as unattractive. The obtained indicators should not be the sole determinants of neighborhood attractiveness; however, when compared with land and property prices in different locations, the results confirm the significant influence of BI on property value in residential neighborhoods. Furthermore, neighborhoods situated near water bodies in Olsztyn tend to be older developments. This fact aligns with the attractiveness of these areas as per the theory of urban development [70], which posits that settlement initially occurs in areas close to water. Access to water sources has historically been a crucial factor in shaping urban growth [71].

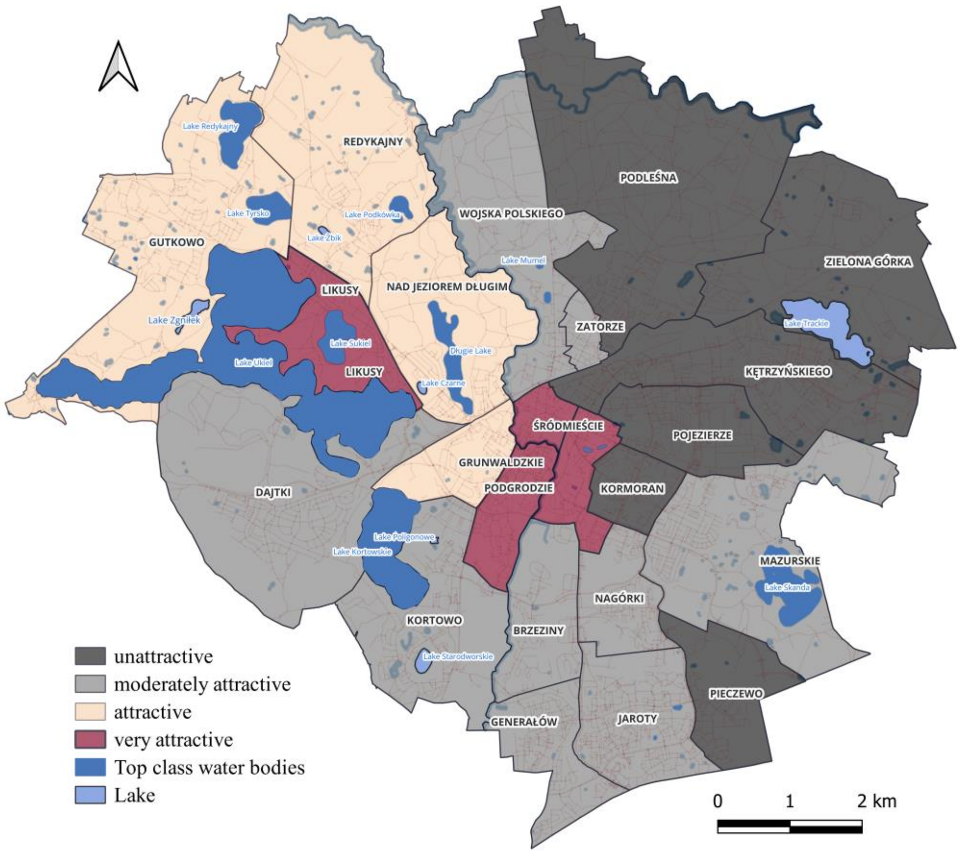


Figure 14. Map of residential neighborhood attractiveness in Olsztyn based on their proximity to the most valuable water bodies.

5. Discussion

The approach proposed in this study for assessing the attractiveness of water reservoirs, based on their functionality and accessibility, aims to support the simplified and automated valorization of housing estates. By supporting resident-friendly land management in the proposed method, residents were included to express their opinions. This is in line with the development direction of 'good governance through public participation' [72,73]. Assigning appropriate weights to individual functions, along with the use of point scaling weighted by the opinions of the respondents, allows for an objective and comprehensive examination of the importance of individual reservoirs in urban space for city residents. This approach aligns with the development directions of friendly urban design and water management [74,75]. The introduction of this method enables the comparison and classification of reservoirs, supporting effective planning and management of water space in urban areas and their surroundings.

The innovative method developed in this study for evaluating the attractiveness of housing estates, considering the proximity of various functions of water reservoirs, such as recreational, ecological, educational, economic, social, and esthetic, introduces a new approach that complements existing solutions. In comparison to other international studies on the assessment of housing estates in terms of BI accessibility [27,28,34], this is a unique approach that takes into account the impact of the BI functionality on the attractiveness of a given housing estate from the point of view of residents' needs. Researchers in Riga (Latvia) highlighted that the external space of housing estates, influenced by various factors, 'should be evaluated and integrated into the design and implementation process of other places' [34].

The results of social research have indicated varying needs among particular age groups and gender, but two functionalities—recreational and esthetic—dominate over others and should be especially considered when assessing the attractiveness of housing estates from the point of view of social needs. The strong correlation between the high ranking of esthetic functionality among the group of youngest adult respondents proved very positive. Their liking for the esthetic qualities of the landscape bodes well for a new generation's care for the environment and its visual appearance. In contrast, the evaluation at the highest level of recreational functionality of older groups of respondents shows a positive social trend that with age comes a desire to be active and move outdoors. This corresponds with the affirmation that a healthy senior is an active senior. Hence, particular care should be taken to enhance the recreational functionality of water bodies to stimulate activity among the elderly. Taking into account these results, the research hypothesis was confirmed that the recreational and esthetic functions of a water body, along with accompanying amenities, are the most attractive features, holding significant importance in evaluating residential neighborhoods. The obtained result is consistent with partial research results determining the impact of recreation and cultural value on the housing sector [76]. Surprisingly, we found that the social function, including feasting and relaxing in groups of friends at water bodies, was not as important to the residents. What is more, it is incomprehensible that many initiatives of the citizens' budget are related to revitalizing selected water bodies for their social use. Additionally, we noticed intensified planning and investment activities of city planners to place more various land-use elements next to reservoirs, such as deckchairs and cascade benches (small amphitheaters nearby reservoirs), e.g., on Ukiel Lake and in Park Centralny along the Łyna River and fountains. They are intended to stimulate the community to integrate and be more willing to spend time with friends in nature. Nevertheless, the results of the geo-survey showed that there is little interest in the social functionality of the development of the area around reservoirs. This may be due to the habit of separation and the need for more top-down initiatives to encourage spending time with family and friends on the water. It is particularly important to ensure the safety of these places, as statistical significance showed that the least interest in social functionality was among young women. This may be due to the anxiety over spending time nearby them in a publicly accessible public space.

All functionalities can be tested using a more extensive list of metrics. The limitation of this study is the adoption of the simplest set of factors to be able to identify them mainly through cartographic inventory, which favors the automation of the evaluation process. Therefore, the number and intensity of functional elements were not examined, but simply their presence. For example, when determining the esthetic value, a set of factors was adopted, limited to the viewing opening and the visual cleanliness and well-maintained condition of the tank. These are objective parameters and easy to identify. In the future, additional factors can be considered, such as Scale, Time, Condition, Sound, Balance, Diversity, Novelty, Shape, and Uniqueness [77], as well as those resulting from the subjective feelings of the local society, such as the dominance of preferred colors [78].

The obtained evaluation results reflect the sustainable development of the areas surrounding water reservoirs. They are consistent with the city's pro-environmental policy and implemented investments. Reservoirs with significant infrastructure for recreation and sports received the highest rank and were rated the best by residents. Determining the residents' preferences regarding their favorite water reservoir of first and second choice confirmed the reliability of the ranking of individual functionalities. Based on the social research conducted, a list of necessary investments in the buffer zones of water reservoirs can be created, which will increase their attractiveness. Planned revitalization may contribute to increasing the attractiveness of other housing estates.

The conducted research highlighted, to a limited extent, the issue of outdated cartographic materials. When initiating a cartographic inventory, it is crucial to verify the validity and accuracy of map images, which might obviate the need for a field inventory in the research. This finding aligns with the outcomes of prior research [79,80]. The analyses of spatial data obtained from social surveys are in line with current trends in big data processing [81].

6. Conclusions

Spatial data geo-analysis derived from the inventory of water bodies in Olsztyn and the conducted geo-survey allowed for the initial assessment of the attractiveness of water bodies and based on that, the evaluation of residential neighborhoods according to the developed methodology. Above all, the research hypothesis was confirmed through the study, indicating that the recreational and esthetic functions of water bodies, along with accompanying infrastructure, are the most attractive features that hold the greatest significance in evaluating BI. Following the inventory, it was found that 40% of water bodies in Olsztyn exhibit recreational functionality, with only 5.5% having full functionality. On the other hand, 63% of water bodies exhibit esthetic functionality, but those with the highest esthetic value make up only 14.6%. These results indicate the need to reinvest in usable land around water bodies. The assessment results align with the respondents' indications of their favorite water bodies in the city, but more importantly with their preferences for BI functionalities.

With the finding of the particular importance of these two functionalities, it is worth using this knowledge to plan development investments for other water bodies that will enhance their recreational quality. This will increase the attractiveness of neighboring settlements and thus improve the quality of life. It is worthwhile to make a functional inventory of the city's water bodies in order to plan the revitalization of the city's least attractive settlements in an informed and sustainable manner. A more elaborate scale can be used to assess the functionality of reservoirs, which will not only indicate areas that need investment, but also show a detailed list of deficiencies.

An essential methodological step is inventory-taking using various data sources, but field inventory should not be disregarded, as cartographic and satellite depictions might lag behind the dynamic changes occurring in urban spaces. The developed methodology is flexible and can be tailored to the preferences of the local community and additional factors. The narrow scope of the study sheds new light on the importance of BI in the city, playing a pivotal role in urban development and improving the quality of life. The undertaken research has triggered the need for further studies. In the future, refining the geo-survey tool will be necessary to facilitate respondents' pinpointing of preferred locations on maps. In the conducted study, imprecise indications were encountered and excluded from analysis. Furthermore, the impact of BI on the attractiveness of residential neighborhoods concerning other natural and anthropogenic features needs verification.

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