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Method for determining influence of proximity to lake on undeveloped land prices: A case study of the Czorsztyn Reservoir

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Abstract: Empirical studies consistently demonstrate a positive correlation between proximity to environmental amenities – particularly blue spaces such as lakes and coastlines – and property values. This study aims to assess how proximity to a lake influences the prices of undeveloped investment land using an averaging method to isolate this specific attribute. The research methodology based on spatial analysis and linear regression was designed to maximise automation in determining the relationship between land prices and the distance from the lake through standardisation and algorithmisation of the process. This standardisation enhances the applicability of the results to other areas with similar characteristics. The study area encompasses a 3,000-metre-wide buffer zone surrounding Lake Czorsztyn, located in southern Poland. The results indicate that with every 100-metre increase in distance from the lake, the price of land within the study area decreases by an average of 2.1%. This quantitative relationship can be directly applied in real estate valuation. The findings can also support spatial planning aligned with the principles of sustainable development. Accounting for economic factors – such as the impact of proximity to the lake on land values – enables more rational land-use decisions that consider both environmental and economic aspects of the region.

Keywords: blue space, environmental amenities, property price, QGIS, spatial analysis, undeveloped land

INTRODUCTION

Environmental amenities of a given area are among the key factors determining property value. These amenities are often difficult to define, and their value cannot always be expressed in monetary terms. The literature provides various classifications of environmental amenities (Panduro and Veie, 2013; Schaeffer and Dissart, 2018). The most commonly mentioned amenities in real estate market analyses include: proximity to the open space (including green areas, parks, forests, and bodies of water), clean air, low noise levels, and scenic landscapes. Open spaces, especially in urbanised regions, provide numerous benefits to people, including recreational opportunities, aesthetic value, and the simple advantage of being near undeveloped land (Irwin, 2002). Properly designed elements of green-blue infrastructure reduce excessive surface runoff, store and purify water, and decrease flood risk, while simultaneously enhancing the environmental quality of a given area (Millward and Sabir, 2011; Czyża and Kowalczyk, 2024; Taking *et al.*, 2025).

Most analyses presented in the literature regarding the impact of proximity to open spaces on property prices focus primarily on green areas (Tyrväinen and Miettinen, 2000; Senetra, 2015; Zygmunt and Gluszak, 2015; Votsis, 2017; Janeczko *et al.*, 2022). Green spaces coexist directly with urbanised areas, naturally generating conflicts arising from the desire to expand development into neighbouring areas. An exemplary development scenario related to the expansion of urbanisation around Glasgow was presented by Pacione (2013). The conclusions of his work address issues of justice and sustainable development in spatial planning, as well as the ongoing conflicts between private profit and public interest in the process of shaping the built environment. The potential influence of green spaces, as factors increasing the market value of properties, may constitute a strong argument for preserving these areas around buildings without excessively restricting them. Mansour *et al.* (2022) highlight the need to investigate the impact of green spaces on society, arguing that only the use of modern measurement methods will allow for the fair provision of access to these areas for residents.

Open spaces have a significant impact on human health: they offer places for outdoor physical activity, contribute to improved mental well-being, reduce air pollution, regulate air temperature, and provide a temporary escape from the stressors associated with living in densely urbanised areas (Larson, Jennings and Cloutier, 2016). These benefits are examples of ecosystem services (Sterner *et al.*, 2020), which encompass a broad range of advantages that nature provides to people. Among open spaces, particular attention is given to blue spaces (White *et al.*, 2010), i.e., water bodies – both natural and artificial – which include seas and oceans, lakes, ponds, reservoirs, rivers, and canals. In the case of blue spaces, ecosystem services include, among others, recreation, aesthetic and cultural value, and biodiversity support. These services play a key role in influencing the market value of land adjacent to blue spaces.

The objective of this study is to investigate the influence of blue space, represented by Lake Czorsztyn, on real estate prices. Specifically, the paper proposes a method for determining the impact of Lake Czorsztyn's proximity on the prices of undeveloped land designated for investment, located within its surrounding area. The novelty of the research lies in the application of an averaging method (Bitner, 2008) to isolate a single property attribute (namely, distance from the lake) from among many, and to determine its influence on land prices. Another innovative aspect is the high degree of automation in the process, which enables the integration of information related to the studied transactional properties from different digital sources, such as the land parcel identification system (LPIS) and the land and buildings cadastre database. The research procedure, designed for large databases, allows the findings to be applied to areas with similar characteristics. The study identified the relationship between unit prices of undeveloped investment land and their distance from the shoreline of Lake Czorsztyn. The spatial analyses were conducted using QGIS software. The results may support spatial planning strategies aimed at promoting sustainable development in the studied area. They also have direct applications in real estate valuation, offering a quantifiable relationship between land prices and proximity to the lake.

MATERIALS AND METHODS

STUDY AREA

The study area encompasses land located within a 3,000-metre-wide buffer zone surrounding the Czorsztyn Reservoir (also known as Lake Czorsztyn). Lake Czorsztyn is an artificial retention reservoir created on the Dunajec River, located in the southern part of Poland within the Lesser Poland Voivodeship (Fig. 1). It is in close proximity to the Gorce National Park and

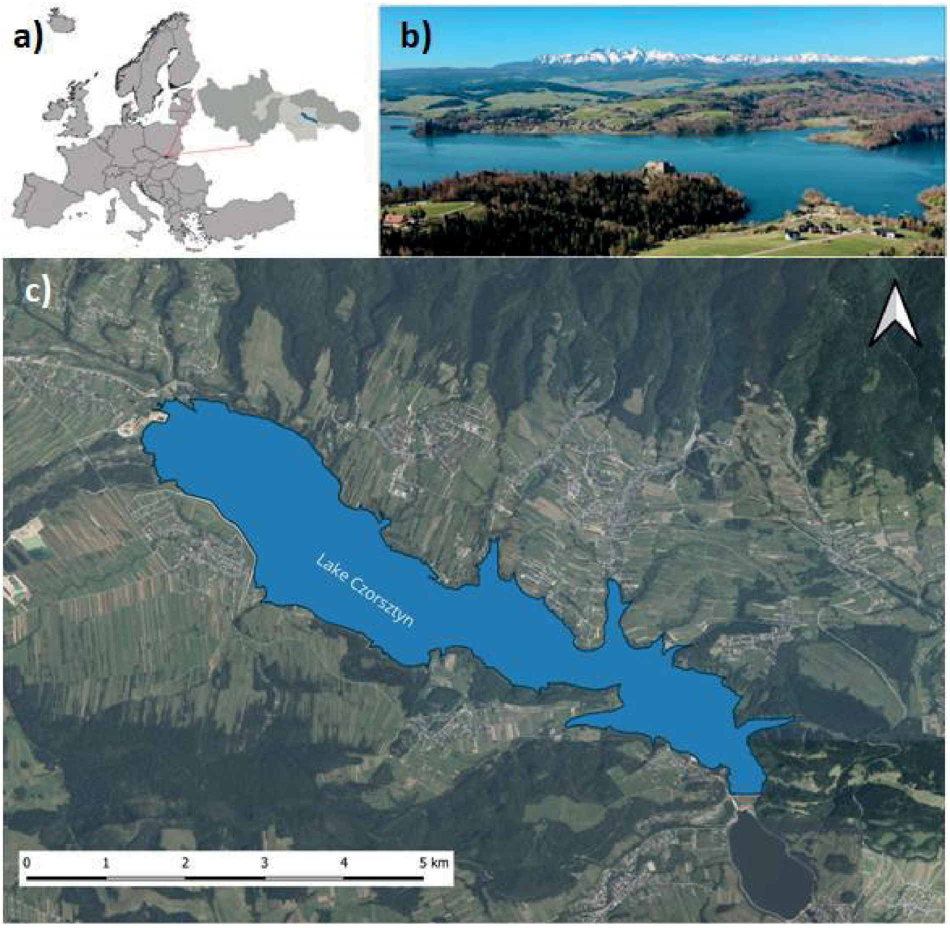

Fig. 1. Lake Czorsztyn: a), c) location, b) panorama with a view of the lake and the Tatra Mountains; source: a), c) own study based on the GUGiK (no date) BDOT10k (Pol.: Baza danych obiektów topograficznych) database and an ortomosaic from Head Office of Geodesy and Cartography (Pol.: Główny Urząd Geodezji i Kartografii), respectively; b) Urząd Gminy Czorsztyn (no date)

the Pieniny National Park. This area is characterised by exceptional landscape values. The reservoir is situated on the border of two geographical regions: the Gorce Mountains and the Pieniny Mountains. Administratively, the reservoir is located in the Nowy Targ Powiat, covering the territories of three gminas: Czorsztyn, Łapsze Niżne, and Nowy Targ.

The Czorsztyn Reservoir is part of the Czorsztyn-Niedzica and Sromowce Wyżne Water Reservoir Complex named after Gabriel Narutowicz, constructed between 1975 and 1997. The primary reason for building the dam on the Dunajec River was the recurring and devastating floods. In addition to its flood control and retention functions, the reservoir also serves an energy generation purpose. The Hydroelectric Power Plant Complex (Pol.: Zespół Elektrowni Wodnych Niedzica S.A.) is a run-of-river and pumped-storage facility, consisting of a bigger dam in Niedzica and a smaller dam in Sromowce Wyżne, located downstream of the Sromowce Reservoir, which serves as a compensation basin (Żelaziński, 2012).

Lake Czorsztyn has a shoreline that is nearly 30 km long. The lake is 9 km in length and has an average width of 1.3 km. Its surface area is approximately 11 km^2. The lake's capacity is close to 200 mln m^3. The deepest part, located at the base of the Nidzica Dam crest, exceeds 50 m. The average depth of the reservoir is about 19 m and decreases toward the main inflows in the west, which include the Białka and Dunajec Rivers (Jaguś and Rzętała, 2010).

The construction of the reservoir significantly impacted the local landscape (Wróbel and Zarzycki, 2010) and the land use of adjacent areas (Urząd Marszałkowski Województwa Małopolskiego, 2016). Previously agricultural lands were transformed into recreational and tourist areas, which contributed to the development of accommodation facilities, sports venues, and tourist infrastructure. The entire Czorsztyn Gmina is part of the Southern Lesser Poland Protected Landscape Area (Pol.: Południowomałopolski Obszar Chronionego Krajobrazu), which aims to protect both forest and non-forest ecosystems (Uchwała, 2020). This is achieved through measures such as maintaining natural ecological nodes and corridors, restoring ecotone zones, afforesting and planting trees on lands of low agricultural value, preserving the area's aesthetic and landscape qualities, and protecting open spaces from scattered development.

DATA

The source data used in the analysis included information on undeveloped land properties that were subject to transactions between 2012 and 2021, as well as vector data containing information about cadastral parcels and the area of the Czorsztyn Reservoir. The property data were provided by the District Office in Nowy Targ. Properties primarily designated as forests, agricultural lands, meadows, pastures, roads, or those lacking information on land use were excluded from the database. Land-use designation in the zoning plan was determined as of the date of each property's sale. Additionally, transactions involving shares in properties, those intended to improve the conditions of adjacent plots, transactions in which one party was a local government unit or the State Treasury, and transactions where information indicated that a building permit or building project approval had been issued were also excluded. The applied selection criteria ensured the identification of investment land properties within the original source database.

Ultimately, the analysis covered 709 transactions involving undeveloped properties designated for investment purposes located within a 3-km wide buffer zone along the lake shore. Due to the 10-year study period, property prices were adjusted to the date of the latest transaction in the database. To determine the price change index over the study period, the method described by Bitner (2015) was used, employing a linear regression model.

The vector data included cadastral parcels located within the gminas of Nowy Targ, Czorsztyn, and Łapsze Niżne. Due to the ten-year period of transactional data, it was necessary to obtain historical vector data depicting cadastral parcels. Cadastral data are not routinely archived on an annual basis. The only data to which access was obtained were from 2016, 2018, and 2022. The 2016 and 2018 data originated from the Land Parcel Identification System (LPIS) database. This resource is primarily used within the European Union for managing and monitoring agricultural land and for granting subsidies. It is designed as a spatial database containing geographic references to agricultural parcels, which is essential for verifying farmers' compliance with environmental and agricultural policies. In Poland, this database supported the management of cadastral parcel records, as not all regions of the country had access to a digital cadastre of land and buildings. The vector data from 2022 were obtained from the district land and building cadastre database through the web feature service (WFS). These data represent the status consistent with the land and building cadastre but do not contain legal information regarding cadastral parcels; however, they do include cadastral parcel identification numbers.

The boundary of the Czorsztyn Reservoir (Lake Czorsztyn) was obtained from the Topographic objects database (Pol.: Baza danych obiektów topograficznych – BDOT10k). The BDOT10k is a vector-based, object-oriented spatial database characterised by uniformity and consistency, with a defined data model, covering the entire territory of Poland. Currently, BDOT10k is the only topographic database that contains information about the actual location of objects in the field, maintaining positional accuracy in accordance with the standards specified in the legal regulations applicable nationwide. The area of Lake Czorsztyn was determined based on a polygon representing the extent of the normal storage level, obtained from the surface water layer derived from the land cover database.

STAGES OF DATA PREPARATION

The research procedure applied in this study aimed to maximise the automation of the process of determining the relationship between the distance from the lake and the prices of undeveloped land properties. Standardisation and algorithmisation enabled the application of the obtained results to areas with similar characteristics, as well as streamlining, organising, and accelerating the process. The presented method is primarily applicable to large databases, where speeding up the process of extracting information is particularly important.

The research procedure was divided into three main stages: 1) acquisition and preparation of property transaction databases, 2) determination of geodetic coordinates for property locations, and 3) delineation of buffer zones around the lake, assignment of properties to respective zones, and averaging property prices within each zone. The data prepared in the aforementioned stages were subjected to further analysis, and the interpretation of the obtained results is presented in the "Results" chapter.

The first stage began with acquiring a database of properties involved in transactions between 2012 and 2021. Next, the data selection criteria were defined in accordance with the specifics of the local real estate market and the objectives of the study. The applied selection criteria are described in the "Data" section. Thorough data selection is a step that cannot be fully algorithmised. It requires expertise in the real estate market, knowledge of property market characteristics (Prystupa, 2024), and the specifics of the studied market. This is a time-consuming process that, for certain transactions, demands individual assessment of property features. Only data meeting these clearly defined criteria were included in further analysis. Given that property prices changed over the studied period, this factor had to be accounted for by updating the prices accordingly. The database covers transactions over a ten-year period, requiring an analysis of the price trend during this time. To determine the price change index, a method based on a linear regression model described by Bitner (2015) was applied. The resulting trend line equation, fitted to the data using the least squares method, is as follows: $y = 0.025x + 79.96$. This indicates that prices increased by 0.025% per day (0.75% per month) during the study period. Using the obtained index equal to 0.025%, property prices were adjusted to the date of the last transaction in the database. Ultimately, the analysis included 709 transactions carried out between 2012 and 2021.

The second stage involved creating vector representations of the transactional properties to enable their spatial positioning on the map. For each cadastral parcel, an attempt was made to link it with vector data from 2016, 2018, or 2022 using the "Join attributes table" tool available in QGIS. The cadastral parcel database changed over the years; sometimes parcels involved in transactions before 2016 were divided or merged with others, resulting in a loss of their graphical representation. Vector data from the land parcel identification system (LPIS) were used, in conjunction with data from the land and buildings cadastre database. Due to its intended purpose, the LPIS data exhibited a lower level of geometric accuracy. Nevertheless, despite these differences in precision, the combination of both data sources enabled the location of objects, even with the dynamic changes occurring within the land and buildings registration system. To minimise the influence of less detailed data, the search for graphical representations of transactional parcels prioritised the 2022 database. If a parcel was not found, the 2018 database was consulted, and finally, the 2016 database. Many transactions involved multiple parcels, which further complicated the process. Therefore, in some cases, it was not possible to link transactional parcels with vector data. Ultimately, parcels sold in 518 transactions were identified. This means that by using vector data from three different years, 73% of transactions were spatially automatically identified. The next step in this stage was to replace the polygons of cadastral parcels involved in the individual transactions with centroids that define their location on the map (Fig. 2). In the case of transactions concerning single parcels, the centroids were determined as the geometric centres of the polygons representing the parcels. For concave polygons, however, the geometric centre could fall outside the boundaries of

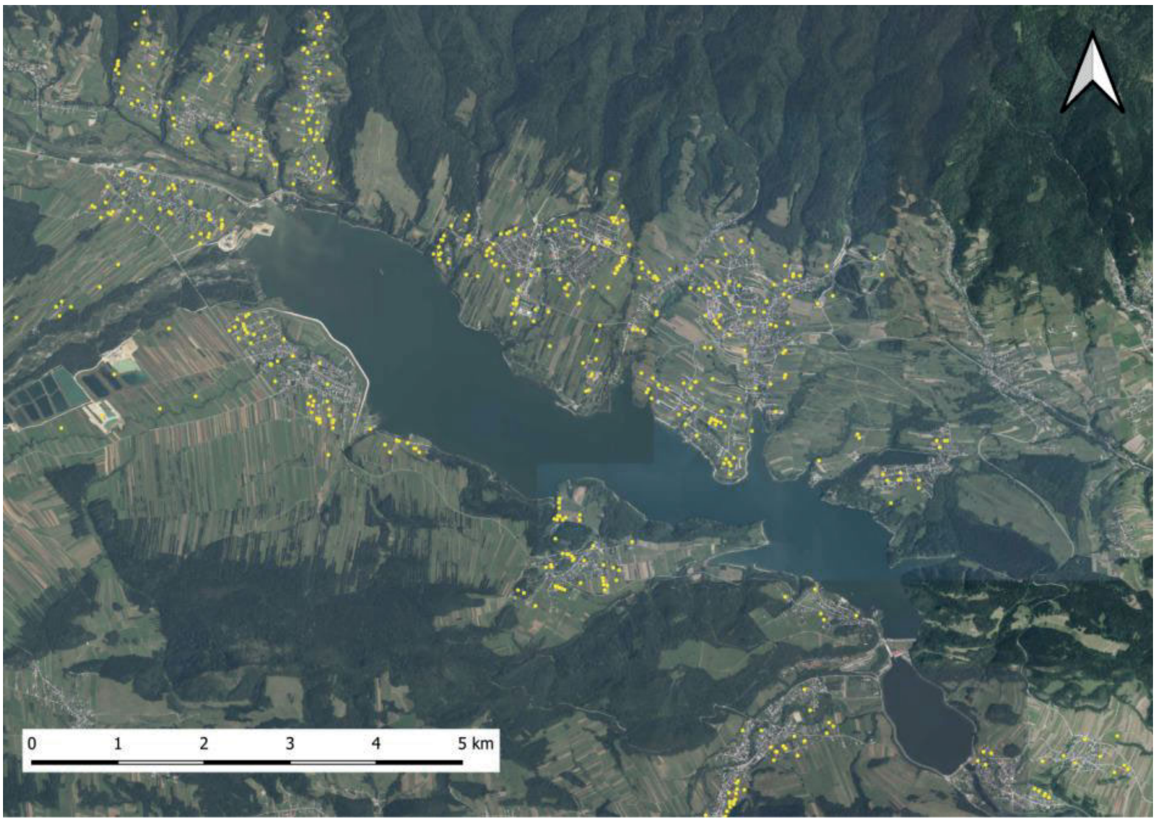

Fig. 2. Spatial distribution of transacted properties; yellow points = centroids corresponding to spatial objects created from parcels involved in individual transactions, for transactions involving more than one parcel, the centroid was calculated based on the geometry of the merged parcels treated as a single spatial object; source: own study

the parcel. In such cases, centroids were assigned as points near the geometric centre, but within the polygon. When a transaction involved multiple parcels, they were treated as a single spatial object (polygon), for which a centroid was then calculated. In such instances, the resulting centroid was not necessarily located within the resulting object.

In the third stage, the study area, which was a buffer zone with a width of 3,000 m, was divided into nine different ways into smaller buffer zones using the "Buffer" tool in QGIS. Depending on the division, the number of zones ranged from 3 to 30, with buffer zone widths varying from 100 m to 900 m. The divisions of the study area into buffer zones of the specified widths can be observed on Figure 3.

Once the centroids of the transacted properties and buffer zones had been defined, the properties were then assigned to the appropriate buffer zones. This was done using the "Intersect" tool built into QGIS. The following spatial assignment rule was applied: a property was assigned to a given zone if its centroid fell within it. This rule is a key element of the analysis. Redefining this relationship – for instance, by assigning a property to a zone if any of its points fell within it – would have resulted in different analytical outcomes. To practically apply the developed methodology, it was necessary to automate the entire process. Iteratively searching databases containing graphical representations from three time periods and determining various variants of impact zones were accomplished using Python scripts. For the scripts, the variables were first transactions, then cadastral parcels, and finally, distance zones. This enabled automation, eliminating the need for manual execution of individual steps in favour of the automated code contained within the script.

RESULTS AND DISCUSSION

The study area, defined as a 3,000-metre-wide buffer zone along the shoreline of Lake Czorsztyn, was divided into buffer zones as shown in Figure 3. For the delineated buffer zones, average unit prices of transacted properties located within each zone were calculated. For this purpose, a zonal analysis was carried out using the "GroupStat" plugin in QGIS. Property price analyses were carried out based on divisions into 30, 15, 10, 7, 6, 5, 4, and 3 zones. These zones had widths of 100, 200, 300, 400, 500, 600, 700, 800, and 900 m, respectively. The distributions of average unit property prices in relation to the distance from Lake Czorsztyn are presented in Fig. 4. The best distribution of average prices, showing the smoothest changes in values, was observed for

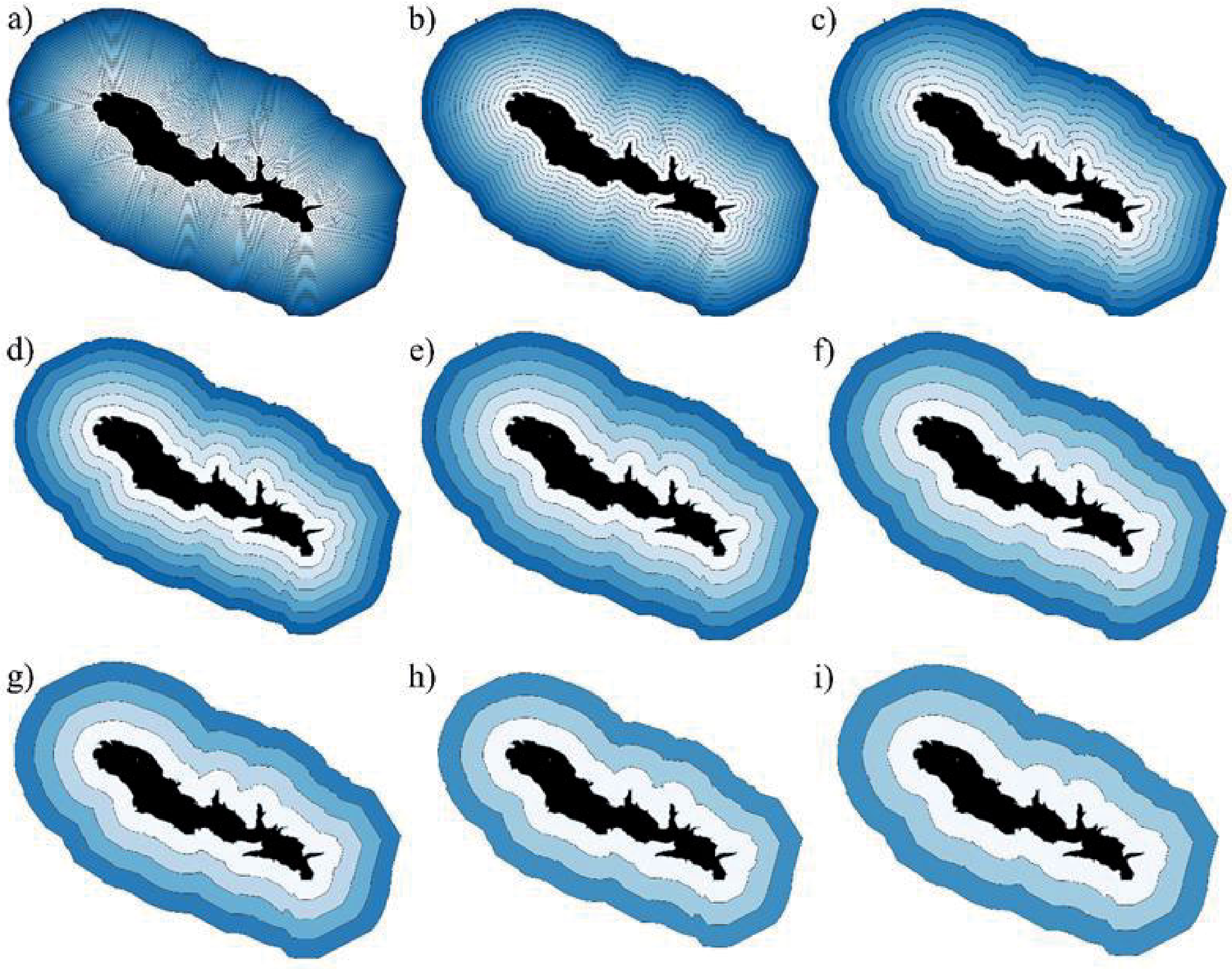

Fig. 3. Divisions of the study area (the buffer zone with a width of 3,000 m) into buffer zones: a) 30 zones of 100 m, b) 15 zones of 200 m, c) 10 zones of 300 m, d) 7 zones of 400 m, e) 6 zones of 500 m, f) 5 zones of 600 m, g) 4 zones of 700 m, h) 3 zones of 800 m, i) 3 zones of 900 m; source: own study

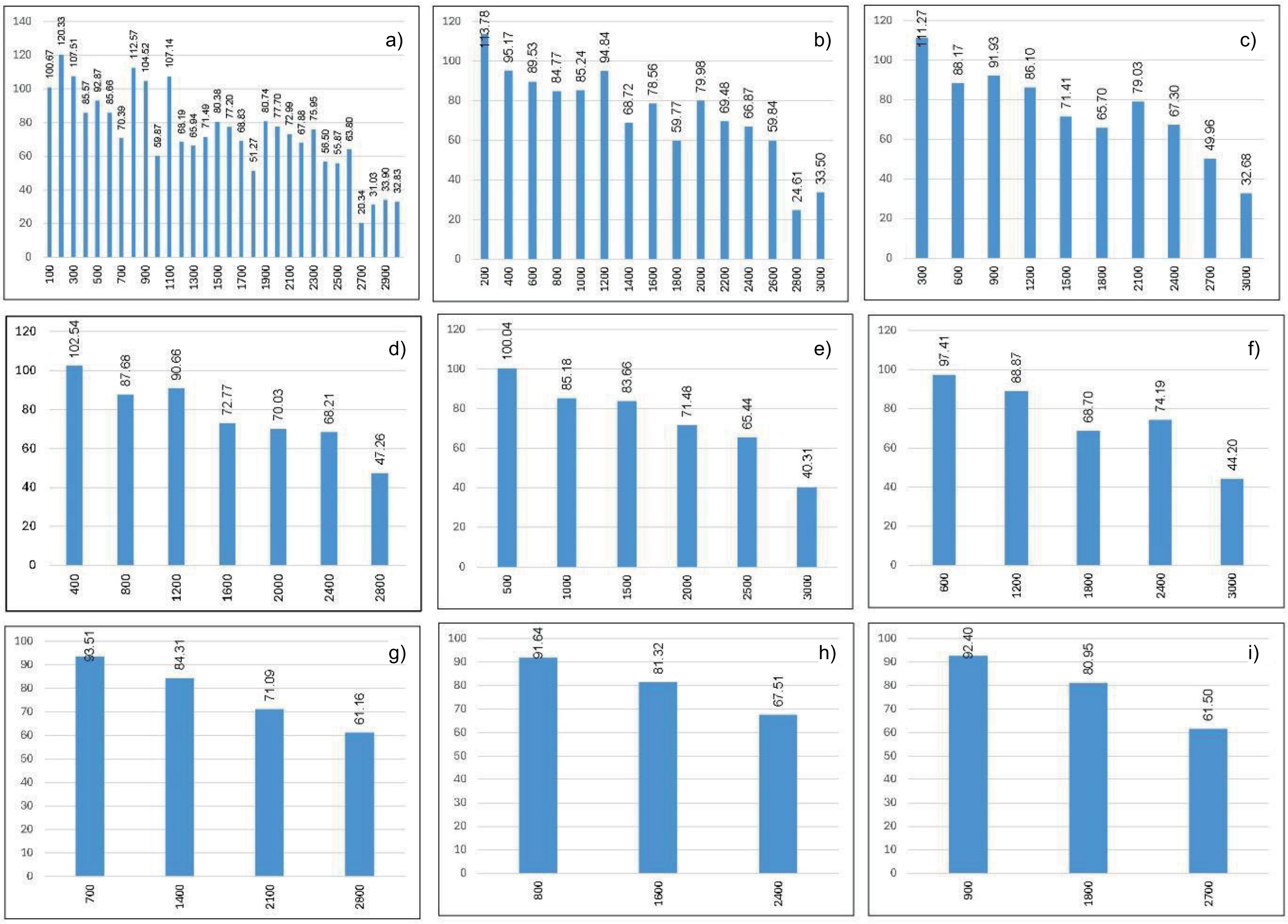

Fig. 4. Relationship between average unit prices of undeveloped land properties and the distance from the shoreline of Lake Czorsztyn, based on divisions into zones of: a) 30, b) 15, c) 10, d) 7, e) 6, f) 5, g) 4, h) 3, i) 3; the *X*-axes show the distances from the lake shoreline (m), reflecting the respective zone divisions; the *Y*-axes present the average unit prices of undeveloped land properties (PLN·m^{-2}) calculated for each zone; source: own study

the division into 500-metre-wide buffer zones, particularly within 2,500 m of the lake. Regular changes in average prices, without sharp fluctuations, were also observed for zones with widths of 300 m, 400 m, and 600 m.

The presented research procedure for determining the relationship between property prices and distance from the lake shoreline makes use of information contained in large databases and is characterised by the absence of subjectivity in data selection. Transaction data is selected based on clearly defined criteria. A key component of this research procedure is the averaging method, which standardises the characteristics of properties within each zone. This method has been described in detail by Bitner (2008). The premise of this method is that each zone includes properties with highly diverse characteristics within the analysed property type. The greater the variation in property attribute assessments within a given zone, assuming a sufficient number of transactions, the better. As a result of applying the method, these characteristics are averaged, and the resulting attribute displays similar values across the zones. This significantly reduces variation in property attributes other than the distance from the lake, thereby enabling the identification of the relationship between price and proximity to the lake.

In order to determine the studied relationship, a linear function $y = a + bx$ was fitted to the data presented in Figure 3 using the least squares method. The coordinates of the points to which the lines were fitted are defined by the midpoints of the zone widths and the average unit prices within each zone. The slope coefficients of the fitted lines, expressed as percentages and accompanied by their errors, are presented in Table 1.

The calculated slope coefficients of the regression lines indicate the percentage decrease in property prices for every 100-metre increase in distance from the lake, within the 3,000-metre buffer zone surrounding it. As mentioned earlier, the best results, showing the smoothest changes in average prices (Fig. 4), were obtained with the division into 500-metre-wide buffer zones. For this division, the slope coefficient is –2.10 ±0.29% (see Tab. 1). This means that, on average, property prices in the study area decrease by 2.1% for every 100 m further from the lake.

The calculated slope coefficients exhibit very similar values and estimation errors for buffer zone divisions with widths up to 600 m. For zones wider than 500–600 m, estimation errors become much more variable, and the slope coefficients change, indicating that properties with substantially different prices are being grouped within the same zone. Therefore, a width of 500–600 m appears to be the threshold for the buffer zone width in the context of the relationship under study. The average slope coefficient, calculated from the results for zones up to 600 m wide, was –2.1%, or approximately –2%.

The obtained result, indicating a 2.1% decrease in land price for every 100-metre increase in distance from the lake, is consistent

Table 1. Summary of results for various buffer zone divisions using linear regression model

Number of zones	Zone width (m)	Slope coefficient (%)	Estimation error (%)	Coefficient of determination
30	100	−2.15	0.29	0.66
15	200	−2.18	0.32	0.79
10	300	−2.16	0.32	0.85
7	400	−1.99	0.27	0.92
6	500	−2.10	0.29	0.93
5	600	−2.04	0.45	0.87
4	700	−1.67	0.08	0.99
3	800	−1.63	0.14	0.99
3	900	−1.83	0.27	0.98

Source: own study.

with findings reported in other studies. For example, McCord *et al.* (2024) analysed the real estate market in the Belfast Metropolitan Area, Northern Ireland, and found that proximity to the shoreline of a bay or lake leads to price increases of 7.3% and 5.3%, respectively. Lansford and Jones (1995) analysed the impact of recreational and aesthetic factors related to proximity to Lake Austin in Texas, USA, on residential property prices. They determined that approximately 22% of the property price can be attributed to the recreational-aesthetic component. Luttik (2000) investigated the influence of proximity to open spaces on house prices in the Netherlands. The highest increase in property prices related to environmental factors (up to 28%) was observed for houses with a garden facing water, which is connected to a sizeable lake. For houses overlooking water, he observed a price increase of around 8–10%. Osland, Östh and Nordvik (2020) observed that properties located closer to lakes in the Oslo region in Norway experienced price increases of up to 13.7% compared to those situated further away (around 6.3 km from the lake). The decrease in prices is the steepest for distances up to 2 km from the house.

Property prices increase as the distance to the blue space decreases, as reported in the cited studies, which refer to developed properties (i.e., houses) located in urbanised areas, whereas the 2.1% value obtained in this study applies to undeveloped land designated for investment purposes. The Lake Czorsztyn region is not a highly urbanised area, and a wide range of environmental amenities is relatively accessible within it. These distinctions may explain the lower value of the indicator compared to the findings reported in the literature.

CONCLUSIONS

The presented research procedure for assessing the impact of Lake Czorsztyn on land prices in its vicinity utilises information contained in large databases. The analysis includes all properties meeting the objective criteria described in the "Data" chapter. Averaging prices within individual buffer zones is a fundamental element of the proposed research procedure. By averaging, the diverse assessments of property characteristics were averaged, enabling the determination of the relationship between property prices and their distance from the lake. The results presented in Table 1 and Figure 4 indicate a clear downward trend in unit prices of undeveloped investment land properties as the distance from Lake Czorsztyn increases. This decline amounts to approximately 2% per 100 m within the study area up to 3,000 m from the lake shore. This trend is stable regardless of the zoning division. As stated in "Study area" section, Lake Czorsztyn is an artificial retention reservoir. The findings of the study indicate that planning for blue spaces may improve the attractiveness of a region and support property value growth in areas with lower initial economic appeal.

An additional goal of the presented research procedure for assessing the impact of distance from the lake on property prices was to automate this process. The automation primarily involved streamlining the determination of the locations of properties involved in transactions on the digital cadastral map using QGIS software. This was made possible by obtaining cadastral databases from three different years within the study period.

Large databases typically cover long time periods, which significantly complicates the process of determining the locations of properties using cadastral data. Cadastral data are provided only upon request to the relevant public administration authority and represent only the current status of parcels. The status of cadastral parcels in individual years is not routinely archived, for example, at the end of each year. Due to the lack of archiving of cadastral data in public offices, it is impossible to automatically obtain data for a specific date. Regular, periodic archiving of cadastral data would significantly facilitate the identification of parcels involved in transactions in previous years. These parcels undergo processes of consolidation and division at different times after the transaction date. Moreover, archiving cadastral data would enable monitoring changes in parcel boundaries over time.

CONFLICT OF INTERESTS

All authors declare that they have no conflict of interests.

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