The Effect of Environmental Factors on Real Estate Value

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SUMMARY

The objective of this study was to analyze the correlations between environmental quality and property prices. The resulting data were input to develop land value maps with the use of cokriging methods. The key environmental factors affecting property prices were greenery, surface water, noise impacts and landscape features. Those elements were identified during field studies and analyses of thematic maps. The assessment method was point valuation, and environmental quality was a variable in statistical analyses. The surveyed site were undeveloped land plots in the suburbia of Olsztyn, the capital city of the Region of Warmia and Mazury.

The applied methodology is based mostly on the modeling of spatial correlations with the involvement of statistical and geostatistical techniques. Those methods support an assessment of the spatial structure of the analyzed processes and the determination of environmental attributes' direct impact on the prices and value of property. The results are presented as models of selected correlations and thematic maps illustrating the effect of environmental factors on property value.

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1. INTRODUCTION

Environmental factors are largely responsible for the value of property. Man's attitude towards the surrounding environment is not neutral because humans search for locations that deliver a high quality of life. Those expectations particularly concern man's daily surroundings, including residential areas or recreational grounds. The quality of that environment largely affects the decisions made on the real estate market. This factor influences the value of property, and its social popularity generates economic benefits.

The aim of this study was to evaluate the usefulness of information about correlations between environmental quality and property prices for developing land value maps. The applied methodology is based mostly on the modeling of spatial correlations by statistical and geostatistical techniques. Those methods support an assessment of the spatial structure of the analyzed processes and the determination of environmental factors' direct effect on the prices and value of property. The results are presented as models of selected correlations and thematic maps illustrating the impact of environmental factors on property value. The surveyed sites were undeveloped land plots in the suburbia of Olsztyn, the capital city of the Region of Warmia and Mazury in north-eastern Poland, characterized by exceptional environmental and landscape amenities.

2. EVALUATION OF ENVIRONMENTAL FACTORS

From the perspective of economic theory, the environment is a unique resource which delivers an economically utilitarian function for the society. In the above approach, the environment is defined as a set of material (physical and biotic) and non-material elements – objects, forces and phenomena that create a mutually interconnected and dynamic system in spatially limited territory. Man's relationship with that system is one of interdependence. The system creates non-material living conditions for humans by catering to the biological and social needs that have been shaped throughout evolution. One of man's basic needs is an environment characterized by high living standards, security and a high scenic value. The environment can also be defined as a set of natural elements, in particular land features, soil, fossils, water, air, flora, fauna, natural and man-made landscape.

Scenic value is an important determinant of real estate value, and it is the critical factor as regards the prices of recreational and residential property. The significance of this factor is often marginalized in favor of location. Nonetheless, location and, to be more precise, its quality, is largely determined by the esthetic value of the surrounding space. Scenic features significantly contribute to the prices quoted on local property markets. The presence of greenery, forests, water and the arrangement of those spatial features directly affect buyer attitudes and the value of property.

The effect of scenic value on property value should be investigated based on sound knowledge of landscape classification. In areas with a low degree of urbanization, there is a predominance of natural, subnatural, semi-natural and agricultural landscape. Anthropogenic factors wield a growing influence on natural and agricultural landforms. The spontaneity of fauna and flora is decreasing due to growing human control. Natural landscapes are virtually extinct, and sub-natural landforms are rarely encountered (parks, reserves). The urban landscape is fully regulated by human activity. Urban and residential green space is the product of human design, which is why it is far from resembling a truly natural setting.

In literature, there are two predominant approaches to perceiving and evaluating natural scenery. The first view postulates that landscape is an inseparable whole comprising a multitude of components (water, vegetation, land elevation, infrastructure, buildings, etc.). The second approach is based on analyses of individual elements. Evaluations of natural components often fail to produce comprehensive results: due to mutual interactions between natural phenomena, the sum of those elements does not create a complete picture of the existing environment. The selection of variously-sized natural complexes is determined by combinations of overlapping environmental elements that determine scenic diversity. We have a different approach to landscape structure when we analyze its spatial organization, functional attributes or the relations between natural elements.

There are various methods for representing scenic value and its influence on the remaining spatial phenomena. The most convenient method are isolines which connect points of equal numeric value.

Continuous variables are often analyzed in nature research, including in landscape evaluations. Continuous variables constitute quantitative or qualitative data. In a GIS environment, continuous variables are generally analyzed with the involvement of raster data models. Raster layers often comprise point measurements. At experimental sites that have not been sampled, variables are determined by interpolation. Spatial analysis supports the transformation of source data into information describing the surrounding space. In landscape geography, GIS is generally used to *(Urbanski 2010)*:

- reconstruct historical landscape,
- model landscape changes and predict future landscape composition,
- create and analyze various parameters.

Maps of esthetic values which present the existing condition of the landscape as the vector sum of all scenic components are rarely developed. Most analyses investigate constituent elements (water, forest, land elevation, etc.), and landscape maps which are land cover maps are created based on photographs (aerial, satellite), and they do not account for field observations. Scenic attractiveness is determined by one or more natural elements because the spontaneous presence of all desired features is sporadically noted. It should be stressed than not all landscape functions are represented at a given place and time.

There is a general scarcity of studies investigating the correlations between property value and scenic attributes. The methods applied in estimations of landscape value rely on hypothetical data supplied by surveys or economic analyses. In some cases, questionnaire data fall short of reality. Declaring a price for non-market goods is one thing, but paying it is another. An analysis of correlations between property prices and scenic value seems to be the most effective method of determining landscape's effect on real estate value.

3. METHODOLOGY

The correlation between scenic value and real estate function has an obvious effect on property prices. A varied landscape with elevation differences, a high share of forests and lakes is the preferred setting for residential and recreational areas.

In this study, the effect of environmental factors on property value was determined using statistical and geostatistical methods. We set out to validate the theory that a sound knowledge of correlations between landscape features and transaction prices supports the development of land value maps based not only on information about prices but also scenic attributes.

Our methodological approach consisted of the following stages:
1) preparation of source data and space valuation,
2) analysis of spatial structure and spatial interpolation of selected environmental attributes,
3) analysis of spatial structure and spatial interpolation of transaction prices,
4) development of models describing the correlations between prices and environmental attributes,
5) compilation of value maps by cokriging.

The participants of the real estate market (buyers) view landscape as a whole. For this reason, landscape components should be identified at the basic level, and their choice should be limited to the most important attributes. For the needs of our analysis, we identified three sets of environmental attributes that influence property value:
1. Forest cover – a measure of esthetic and climatic attractiveness. Forests are natural filters that purify the environment and contribute to the esthetic value of a given area. Forest cover was determined as the share of forests in the area of evaluation units.
2. The presence of surface water bodies – a measure of scenic and recreational attractiveness which most significantly contributes to an area's appeal for housing and tourism developers. This factor was determined as the share of surface water bodies and water courses in the area of evaluation units.
3. Land elevation – the key measure of scenic attractiveness. Significant differences in land elevation have a positive effect on our perceptions of landscape. This attribute was determined as the number of contour lines intersecting the evaluation unit and its bisectors.

The above elements were identified during field studies and analyses of thematic maps. The assessment method was point valuation, and environmental quality was adapted as a variable in statistical analyses (Table 1). The studied area was divided into a grid of 425 evaluation units which were squares with a side length of 500 m. The area of an evaluation unit was a compromise between the range of information that can be acquired from a single area and the possibility of generalizing the obtained data.

Table 1. Valuation table for assessing landscape attractiveness.

Evaluated attributes						Classification	
land elevation		forest cover		surface water		sum of values [points]	Landscape attractiveness category
number of intersections	value [points]	forest area [%]	value [points]	area of water bodies [%]	value [points]		
≤ 25	1	none	0	none	0	≤ 7	(IV) unattractive
26 – 50	2	< 25	2	< 20	4	8 – 11	(III) relatively unattractive
51 – 75	3	25 – 50	4	20 - 80	8	12 – 16	(II) attractive
> 75	4	> 50	6	> 80	12	≥ 17	(I) highly attractive

Source: Own study based on Dąbrowski 1990.

Basic evaluation units were classified in view of their scenic appeal. None of the units were graded in the highest attractiveness category I. The above can be attributed to the presence of large water bodies which significantly limit elevation differences, a key determinant of landscape attractiveness. Territories classified as attractive (category II) occupied less than 15% of the surveyed sites. Detailed results are presented in Table 2.

Table 2. Classification of landscape attractiveness in basic evaluation units.

Category	Number of evaluation units	Percentage of evaluation units
IV	183	43.06
III	179	42.12
II	63	14.82
I	0	0
Total	425	100

Source: own study

An analysis of the indicators of spatial variability involves the determination of the empirical value of differences between variables, measured at two different points, as a function of distance between those points, and modeling the resulting correlations. In the modeling process, spatial variability is described by a mathematical function where the argument is the vector of distance between data points (*Isaaks and Srivastava 1989)*. The spatial structure of environmental factors and transactional prices may be analyzed based on the correlations presented in the form of semivariograms. An empirical semivariogram can be calculated using the following formula *(Matheron 1967, 1971; Journel and Huijbregts 1978; Cressie 1993; Sarma 2009)*:

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} \left[Z(x_i + h) - Z(x_i) \right]^2$$

where:

$Z(x_i)$ - value of data

x_i - location of sites where measurements were performed

$N(h)$ - number of pairs of points $(x_i, x_i + h)$ separated by distance h

The semivariogram function indicates the rate at which the mutual relations between variables decrease with an increase in distance. The variations in semivariogram values can be characterized by three parameters: nugget effect, sill and range. The spatial correlation between environmental attributes and property prices in different locations is determined mainly by similarities in location features, such as availability, neighborhood and surroundings. Therefore, we can make an a priori assumption that a real estate market is characterized by a spatial autocorrelation of transaction prices because the similarity of location also implies the convergence of key price-forming factors. According to Bourassa, Cantoni and Hoesli *(2007)*, the spatial structure of prices can be investigated with the use of the appropriate variogram models.

In principle, environmental attributes can be evaluated only in selected points of measurement (e.g. in the centroid of an evaluation unit). Therefore, if we assume that the adopted values of environmental attributes have a continuous character, spatial interpolation can be performed with the use of deterministic or geostatistical methods. In our study, we used ordinary kriging methods which rely on previously defined regularities in the form of a semivariogram. Kriging is a group of geostatistical estimation methods which produce linear unbiased value estimators of the analyzed regionalized variable. The value estimated by kriging is a weighted linear combination of regionalized random values. The kriging estimator represented by random function $Z(s_i)$ takes on the following value:

$$Z^*(s_0) = \sum_{i=1}^{n} w_i Z(s_i)$$

where w_i are kriging weights. Those weights are calculated on the assumption of minimized error variance. In ordinary kriging, the sum of weights is constrained to be one.

Kriging and its technical and scientific applications are widely discussed in literature, and the possibilities offered by kriging methods are the subject of an ongoing debate *(Bardossy 1997, Goovaerts 1998, Burrough 2001, Maantay and McLafferty 2001, Sarma 2009)*. The use of kriging in spatial analysis of property transaction prices has also been described in detail by various authors *(Martinez 2000, Bourassa, Cantoni and Hoesli 2007, Páez 2009)*.

The knowledge of variables describing environmental attributes at every point of the evaluated area supports analyses of indirect correlations between those attributes and transaction prices. Simple linear correlation methods, such as correlation analysis or regression analysis, as well as more advanced statistical models that examine non-linear correlations may be used for the purpose. The aim of such investigations is to observe the presence of significant correlations between environmental attributes and prices as well as the studied factor's effects presented in model form.

If the main variable, in this case – transaction price, is significantly correlated with additional variables, i.e. environmental attributes, cokriging methods can be applied to integrate data and develop a land value map. The use of cokriging is justified when the main variable can be measured (or read) only at selected points, but additional variables are easy to measure at any point. In this study, cokriging can be used to forecast values at points where very few or no transactions have been registered. The ordinary kriging estimator is a linear combination of weights and data representing variables at sample points in the vicinity of estimated point s_0:

$$Z^*(s_0) = \sum_{j=1}^{N} \sum_{i=1}^{n} w_i^j Z_j(s_i)$$

where N is the number of additional variables. Weights are selected in such a way as to minimize error variance. Detailed information about the theory of kriging and its practical applications can be found in literature *(Eldeiry and Garcia 2009, Malvić et al. 2009, Yalçin 2005).*

4. OBJECT OF THE STUDY AND SOURCE DATA

The study investigating the impact of environmental attributes on the prices and value of real estate was performed in a selected area in north-eastern Poland which is characterized by high natural and scenic value. The investigated territory was a rural municipality situated around 10 km from Olsztyn, the region's capital city with a population of 180,000. Recent years witnessed rising demand for land plots in the analyzed area, mainly for the needs of residential and recreational development. The examined site's attractiveness can be attributed to the proximity of a large agglomeration (capital city of the region) and, above all, its high scenic appeal resulting from the presence of lakes usable for recreational purposes, large forest complexes, and post-glacial landscape which is characteristic of this part of Poland.

The main sources of information about environmental factors in the analyzed area were topographic maps and field observations. The resources available on the geoportal website of the Head Office of Geodesy and Cartography were also used. Real estate data comprised transactions in undeveloped land plots zoned for residential or recreational development. After preliminary selection, 127 transactions conducted in the previous five years were adopted for the needs of this study. The unit prices of the analyzed real estates ranged from nearly PLN 50/m^2 to more than PLN 150/m^2, with an average of PLN 90/m^2 (approx. EUR 21). The property price index which measures changes in prices over time was determined at more than 10% per annum, and data accounting for change trends over time were used in our work.

5. RESULTS

In our study, special emphasis was placed on three key environmental attributes: the presence of surface water bodies such as lakes, ponds and watercourses, forest cover and land elevation. The investigated areas were analyzed based on evaluation units which were squares with a side length of 500 m. The presence of lakes, forests and land surface features was assessed independently in each evaluation unit. A section of the map of the analyzed area with a division into evaluation units and the location of property transactions is presented in Fig 1.

The spatial structure of the analyzed environmental attributes was expressed in the form of variograms and maps developed by ordinary kriging. The investigated factors were characterized by spatial autocorrelation (Fig. 2).

The range of semivariograms insignificantly exceeded 3 km, and the above distance mapped the spatial similarity of the analyzed attributes. Spatial autocorrelation measured by Moran's I revealed significant spatial correlations and continuous variability of environmental attributes.

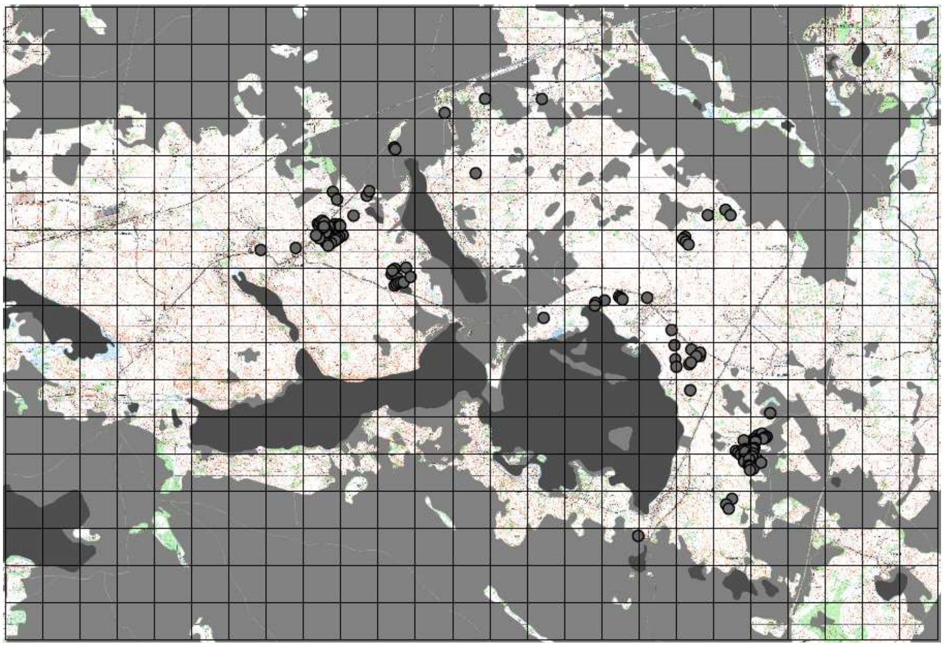


Fig. 1. Map of the analyzed area with a division into evaluation units and the location of property transactions. Source: own study

A spatial structure analysis indicates that kriging interpolation is the most effective method for the cartographic representation of variability in the analyzed environmental attributes in space. A map of environmental attributes as the sum of numerical values assigned to every attribute is presented in Fig. 3.

As a result of a spatial analysis of environmental attributes, the location of every transacted property was assigned numerical values indicative of the proximity of water bodies, forest cover and land elevation. Additional characteristics of every analyzed transactions were thus obtained, and they were used to investigate correlations between land prices and environmental attributes. The spatial structure of transaction prices was also presented in the form of a semivariogram (Fig. 4). A spherical model with a nugget effect was also applied in this case. Fitting the distribution to a theoretical model produced less congruent results. The semivariogram had the range of around 1700 m. It could be hypothesized that this was the limit of locational similarity which was represented by the variability of unit prices. The empirical distribution of unit prices is characterized by rightward skewness which is characteristic of the real estate market (predominance of below average prices).

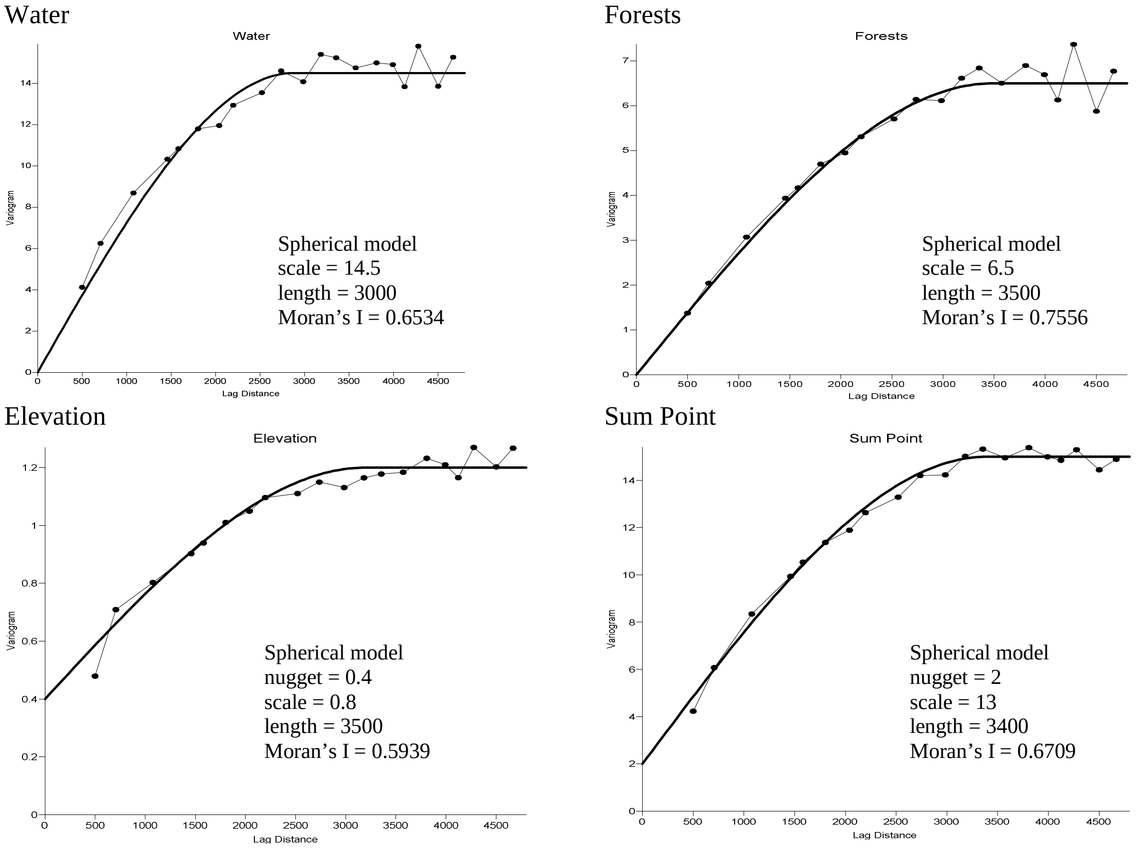


Fig. 2. Spatial structure of the analyzed environmental attributes expressed in the form of semivariograms. Source: own study.

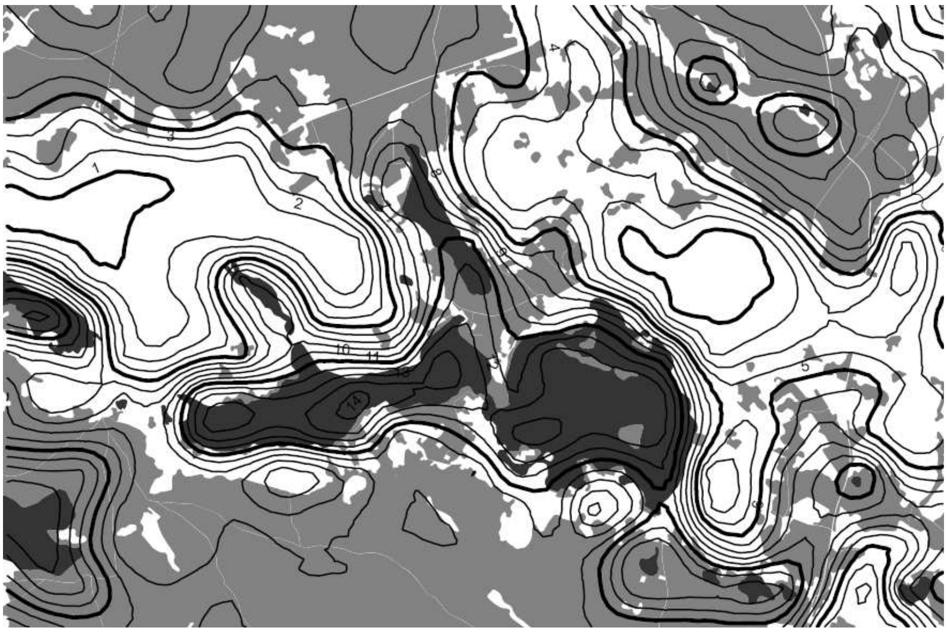
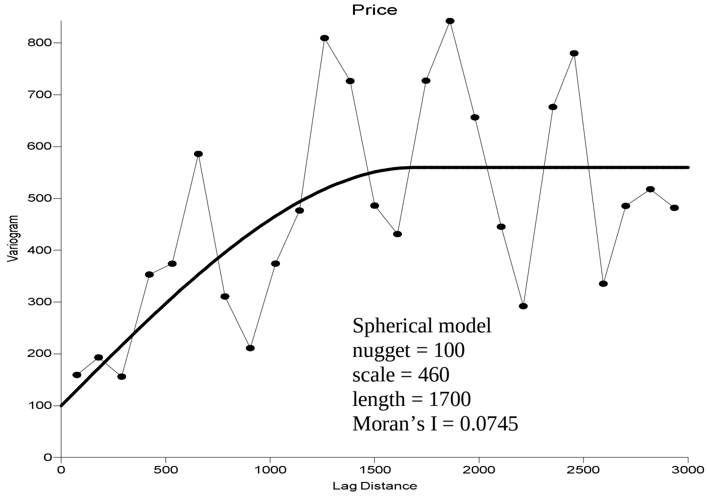
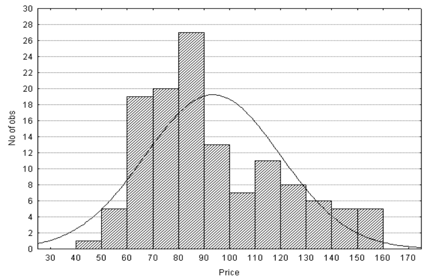


Fig. 3. Map of environmental attributes of the analyzed area.

Source: own elaboration.

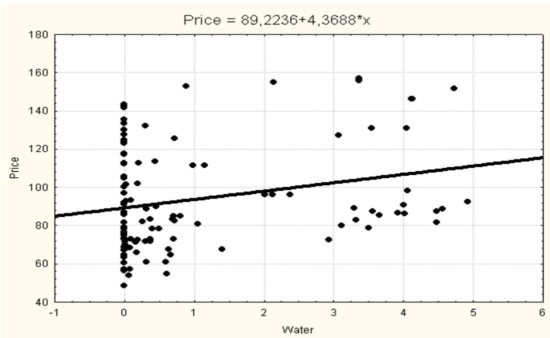


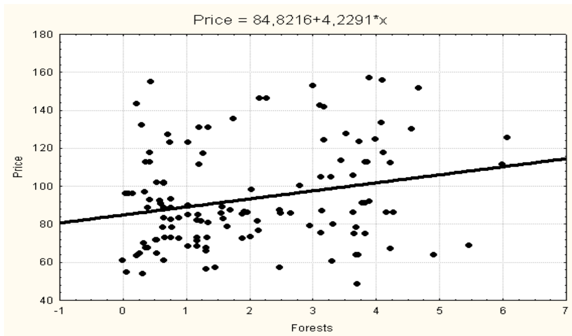


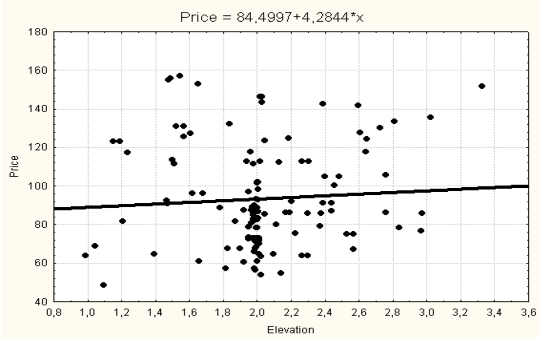
	Basic statistics
Valid n	127
Mean	93.19
Median	86.34
Minimum	48.38
Maximum	157.22
Std. deviation	26.33

Fig. 4. Spatial structure of transaction prices and basic descriptive statistics.
Source: own study.

The effect of environmental attributes on transaction prices can be illustrated quantitatively using simple measures of statistical dependence such as correlation coefficients or linear regression models. Correlation and regression analyses indicate that the attributes indicative of water bodies and forest cover were significantly correlated with transaction prices at a significance level below 0.05. The correlation with land elevation features reached only 0.07, and it was non-significant (Fig. 5).







Correlation matrix

	Water	Forests	Elevation	Price
Water	1.00	-0.09	-0.23	0.24
Forests	-0.09	1.00	0.29	0.24
Elevation	-0.23	0.29	1.00	0.07
Price	0.24	0.24	0.07	1.00

Fig. 5. Linear correlation between transaction prices and selected environmental attributes.
Source: own study.

The similarity of results presented in the form of a multiple regression model suggests that the presence of water bodies and forests has a significant impact on transaction prices (Table 3). Elevation is also a crucial determinant of environmental attractiveness, but its low impact on land prices can be explained by the fact that high differences in elevation are not a desirable feature in housing construction. The studied area was characterized by an abundance of water bodies, therefore, its elevation was not highly diversified.

Table 3. Multiple regression analysis results

Regression Summary for Dependent Variable: Price
$R^2 = 0.33 \quad F = 6.29 \quad p < 0.0005$

	β	Std. Error β	t	p-level
Intercept	72.409	11.796	6.138	0.000
Water	5.015	1.547	3.240	0.001
Forests	4.376	1.527	2.865	0.004
Elevation	3.724	5.733	0.649	0.517

Source: own study.

The presence of water bodies and watercourses is the most influential price-shaping factor. Although legal regulations guarantee free access to water bodies owned by the State, in areas of high recreational value, potential buyers show a preference for land plots that are directly adjacent to the shoreline. The prices of such property may be more that three times higher in comparison with land plots that do not have direct lake access.

The information about correlations between transaction prices and environmental attributes can be used to develop land value maps, in particular in areas where transaction price data are in short supply or are unavailable. Ordinary cokriging methods were used where the main variable was the transaction price, whereas additional variables included the proximity and access to water bodies and forest cover. The results in the form of a land value map are presented in Figure 6.

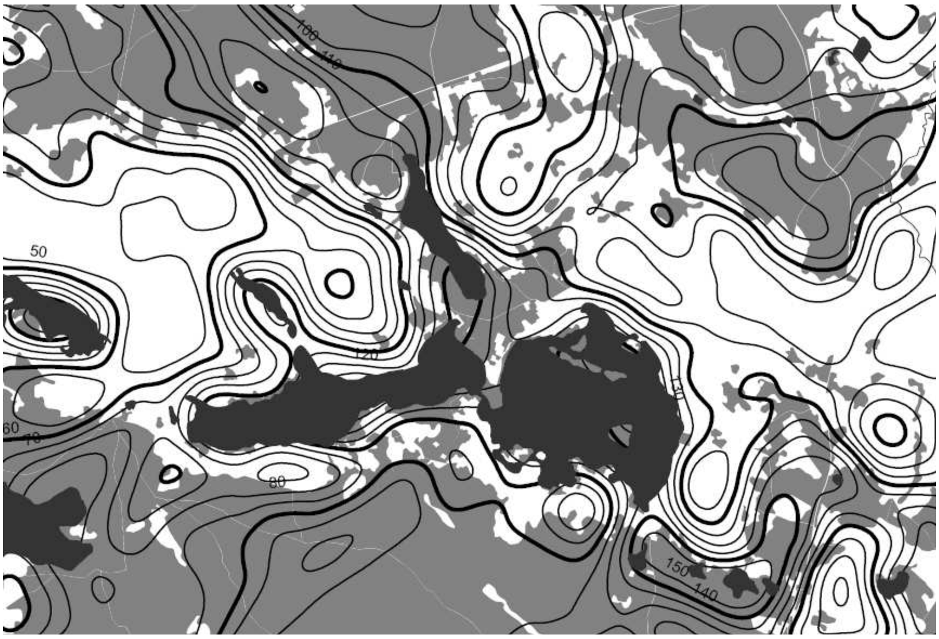


Fig. 6. Land value map in the analyzed area developed by cokriging.
Source: own study.

The land value map was developed based on transaction prices as well as the spatial structure of main environmental attributes that affect those prices. The above implies that in areas of high environmental value, the forecast prices are higher than in regions with a lower scenic attractiveness rating.

6. CONCLUSIONS

The proposed method for analyzing the impact of environmental attributes on the value and prices of property may be a helpful tool in real estate management and spatial planning. It is particularly useful in areas of high scenic value which have been zoned for recreational and residential development. Cokriging supports the development of land value maps when prices are correlated with variables that are easy to measure based on the existing sources of data. The discussed methods can be deployed not only in environmentally valuable areas, but also in regions where market data are available and the spatial structure of environmental attributes that shape transaction prices is known.

REFERENCES

Bárdossy A., 1997, *Introduction to Geostatistics,* Institute of Hydraulic Engineering, University of Stuttgart

Bourassa S. C., Cantoni E., Hoesli M., 2007, *Spatial Dependence, Housing Submarkets, and House Price Prediction*, Journal of Real Estate Finance and Economics, vol. 35, Springer Science, pp. 143–160

Burrough P. A., 2001, *GIS and geostatistics. Essential partners for spatial analysis*, Environmental and Ecological Statistics, vol. 8, pp. 361-377

Cressie, N., 1993, *Statistics for spatial data*, Wiley Interscience

Dąbrowski H. 1990. *Planowanie przestrzenne"*. Wydawnictwo Akademii Rolniczo-Technicznej. Olsztyn.

Eldeiry A., Garcia L. A., 2009, *Comparison of Regression Kriging and Cokriging Techniques to Estimate Soil Salinity Using Landsat Images*, AGU Hydrology Days 2009, March 25 - March 27

Isaaks E. H., Srivastava R. M., 1989, *An Introduction to Applied Geostatistics,* Oxford University Press, New York

Goovaerts P., 1998, *Ordinary Kriging Revisited*, Mathematical Geology, Vol. 30, No. 1

Journel, A.G., Huijbregts, C.J., 1978. *Mining Geostatistics,* Academic Press Inc, London, UK

Malvić T., Barišić M., Futivić I., 2009, *Cokriging geostatistical mapping and importance of quality of seismic attribute(s),* NAFTA vol. 60, no 5, pp. 259-264

Martinez M., 2000, *Kriging Methodology for Regional Economic Analysis: Estimating the Housing Price in Albacete,* International Advances in Economic Research, Vol. 6 Issue 3, pp. 438-450

Matheron, *G.,* 1967, *Kriging or Polynomial Interpolation Procedures?*, CIMM Transactions, 70, pp 240-244.

Maantay J. A., McLafferty S., N., 2001, *Geospatial Analysis of Environmental Health*, Springer Science Business Media B.V.

Matheron G., 1971, *The theory of regionalized variables and its applications*, Ecole Nationale Superieure des Mines de Paris

Páez A., 2009, *Recent research in spatial real estate hedonic analysis*, Journal of Geographical Systems, Volume: 11, Issue: 4, pp. 311 – 316

Sarma D. D., 2009, *Geostatistics with Applications in Earth Sciences*, Springer

Urbański J., 2010. *„GIS w badaniach przyrodniczych"*. Wydawnictwo Uniwersytetu Gdańskiego.

Yalçin E., 2005, *Cokriging and its effect on the estimation precision*, The Journal of The South African Institute of Mining and Metallurgy vol. 105, pp. 223-228

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