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Original research paper

Selection and significance evaluation of agricultural parcels determinants

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Abstract: Many different characteristics affect the land prices. This work attempts to analyse the characteristics of agricultural parcels, which significantly affect the variability of agricultural land prices. The article presents the methodology of selection land parcel characteristics, rules for the selection of factors and possibility of automatic acquisition of data in mass valuation process. The research aims at selecting determinants of agricultural land parcels price and evaluate theirs significance in a local market for the purpose of land values map elaboration. Using advanced statistical analysis of a non-linear influence of a parcel inherent characteristics on its price we proved that in the relatively small area, like commune, only a few characteristics are essential, They are: parcel size, shape and location expressed by distance to the commune centre, paved roads and homestead buildings. Therefore, these ones should be used for elaboration of land values map. Soil quality and a cropland type although significant for the land prices do not diversify land prices in local market. The novelty of the research relays on determination of non-linear influence of parcel characteristics on variation of agricultural land values based on the correlation ratio (η eta). The research was conducted for the undeveloped agricultural lands located in south-west Poland, the rural municipality Krotoszyce.

Keywords: land parcel characteristics, agricultural lands, value map

1. Introduction

The land values map, showing an estimated property value in a given area, is of significant importance for land administration, land management and fiscal purposes. It helps the economic assessment of investments and making plans for the future use of a given area. Land values maps for rural areas are essential in land consolidation (Demetriou, 2016; Long, 2014; Sobolewska-Mikulska et al., 2014), land administration (Cellmer et al., 2014), monitoring of uncontrolled land take and urban sprawl (Heimlich and Anderson, 2001). Land values maps are draw up for both urbanised (such as towns and cities) and agricultural lands. For the latter a land values map generally covers lower level administration units, like commune, village or parish (Taupier, 1999). In some countries, like Cyprus (Demetrious, 2016), Lithuania (Sabaliauskas and Aleksienë, 2002), Poland (Maleta and Bielecka, 2014; Budzynski and Karsznia, 2014) agricultural land values maps are governed by the state law, regulations and policies. In Poland, the obligation of elaborating agricultural land values maps belongs to the Surveyor General, the president of the Head Office of Geodesy and Cartography, acting as the national mapping agency (Regulation, 2011).

A land values map bases on estimation a value of a large number of land parcels done in mass valuation. Therefore, one of the basic conditions for land values map making is understanding the physical and economic factors that affect the productive capacity of agricultural lands. Farmland price determinates are generally of two types, one - focus on rents derived from agricultural production as primary agricultural price determinant, and the second - assessing the influence of non-agricultural factors as the main price determinants (RICS, 2011; O'Donoghue et al., 2015). The first approach uses such determinants as physical (structural) characteristics, land rents, and agricultural structure. While, the second considers the influence of parcel location, population density, infrastructure, and urban access. Dresher et al. (2001) noticed that in general, undeveloped land parcel price highly depends on farm returns, parcel size, capital gains and capitalised policy benefits as well as urban proximity. However, according to Delbecq et al. (2014) and O'Donoghue et al. (2015) farm-generated income only partially determines agricultural land price and are rather seldom analysed by researchers.

Each property is spatially unique and location is always an intrinsic attribute that directly determines the quality of a mass appraisal model. This is consistent with Tobler's first law of geography (Tobler, 2004), which states that "everything is related to everything else, but near things are more related than distant things" and Pearson's well-known statement "location, location, location" (Peterson and Flanagan, 2009). Van Thunen's theory (Sincler, 1967) also strongly relates to location, especially distance to the city, which primary force the transport cost and finally parcel value. Location reflects proximity of a farmland not only to a city centre but also to paved roads (Choumerta and Phélinasb, 2015), the homestead (Kuethe et al., 2011), forest and water bodies (Demetriou, 2015). Grausová et al. (2014) adds that the distance of the agricultural land from a larger city play a significant role as well. Greater distances to city centre, the homestead and paved roads are a reason of smaller income due to greater transport-related costs (Demetriou, 2016). Close vicinity of forests, water bodies, and protected area also reduce agriculture production income due to legal and environmental restrictions. However, among recent studies of agricultural land, only a few have analysed the influence from surrounding natural resources and landscapes. Koreleski (2008) stated that forest neighborhood changes microclimatic conditions and has a negative impact on the productivity of agricultural land. Nivens et al. (2002) employed remote sensing data to examine the effects of water bodies, cropland and pasture within a 1600 meter radius on farmland prices in Kansas, USA. Ma and Swinton (2011) found multicollinearity of forest and grassland in parcel neighbourhood with soil productivity. Similar observations were made by Maleta and Calka (2015) for the rural areas located in west-south of Poland.

Productivity of agricultural parcel highly depends on its size and shape, i.e. its physical characteristic. These parcel characteristics are the strongest predictor of price per acre, explaining over 40 percent of the variation in a simple regression (Albouy and Ehrlich, 2013). As stated by Porta, (1983) a parcel of a regular shape facilitates cultivation operations. However, the optimal length-width ratio varies depending on country, e.g. in Cyprus is equal 1:2–1:3 (Demetriou, 2016), while in Poland 1:5 (Noga, 2006).

Most researches agreed that agricultural parcel value highly depends on soil productivity. Choumerta and Phélinasb (2015) noticed that in Argentina soil quality among distance to market and the nearest city as well as cropping pattern strongly affect land values. Similar findings were achieved by Wilkowski (2014) and Bitner et al. (2017) when they analysed the prices of agricultural land in Poland and Sklenicka et al. (2013) for the Czech Republic. Also in Germany quality of soils together with crop pattern are valuable factors in agricultural land valuation (Drescher and McNamara, 2000).

Today, land values maps are generally computer assisted maps. This requires access to digital data on agricultural plots attributes, that are stored in cadastre or land information systems (Wyatt, 1997; Enemark et al., 2005; Bielecka and Calka, 2014). The research conducted so far has focused on the analysis of various factors influencing the price of agricultural lands. Generally the impact of the attributes on the price of agricultural land was analysed by using econometric models (O'Donoghue et al., 2015; Feichtinger and Salhofer, 2016; Dirgasová et al., 2017). The method proposed in the paper presents the analysis of both linear and non-linear impact of selected characteristics on agricultural land prices and the analysis of variability of agricultural land values in the local market. The analysis allowed to find out more about the analysed phenomenon and to select appropriate attributes which influence the prices of agricultural lands, as well as significantly influence on variation of the prices of agricultural lands.

This research aims at selection of agricultural land parcel characteristics that could be used for land value map elaboration, that is: are available in a digital format, are determinants of land value, and are not correlated with each other. Moreover, these determinants should diversified the land values on a relatively small area, like communes. During the research, the following research questions were formulated. Which land parcel characteristics have the biggest impact on variation of agricultural land values? What is the size of no-linear impact of parcel characteristics on its price?

The novelty of the research relays on determination of non-linear influence of parcel characteristics on variation of agricultural land values based on the correlation ratio (η eta). The analysis enabled an understanding the size of no-linear impact of parcel characteristics on its price. The remainder of the article is structured as follows: section 2 describes research methods, section 3 – study area and data used. The results together with the discussion are presented in section 4, while the conclusions in section 5.

2. Research methodology

It was assumed that agricultural land parcel value is the value at which undeveloped land, used for agriculture production (field crops, vegetables, pastures, and other), could be sold under current market conditions, if allowed to remain on the market for a reasonable amount of time. It is equivalent to land price. The measures included in the analysis express the local agricultural market diversification on land price. Moreover, only parcels that have no potential for converting to a higher value use, such as residential or commercial, were analysed. We hypothesise that in the relatively small area, a commune (the third level administration unit covers approximately below 125 square kilometres) some factors that affect the agricultural land parcels price does not diversify prices in the local agricultural market. Hence the main goal of the paper is to select determinants of agricultural land parcels price and evaluate theirs significance in a local market for the purpose of land values map elaboration.

The research was conducted in the two stages. The first, based on literature study and heuristic, aimed at selection of agricultural land parcels characteristic influencing their market price. The second relayed on statistical analysis of significance and variability of determinants in analysed local market. When specifying a set of land value determinants, attention was paid on location, physical and environmental characteristics as well as cause-and-effect relations to parcel price. It was assumed, in accordance with Maleta (2017) that the value of coefficient of variation should exceed 30%, whereas correlation coefficient should be not lower than 0.4.

Agricultural parcels prices were updated using Multiline Regression Model (Maleta, 2013). Further statistical analysis was carried out with reference to prices updated for the day of the last transaction, i.e. for December 31, 2013.

Significance of the attributes were verified using coefficients of variation and correlations. Coefficient of variation (CV) specifies what part of average level of examined attribute is the attribute's average variability measured by standard deviation. For each attribute (variable x), position measure and dispersion measure have been determined, along with variation coefficients, equation (1) was used for calculations.

$$CV = \frac{\sigma_x}{\overline{x}} \times 100\%, \tag{1}$$

where:

σ_x – standard deviation of variable x,

$\overline{x}$ – arithmetic mean of variable x.

Correlation coefficients allowed to determine the strength and direction of the relationship between parcels attributes and parcel price (variable y), as well as the type of regression. The following coefficients were used: Pearson's correlation, Spearman's rank correlation, Pearson's nonlinear correlation coefficient called the correlation ratio (η eta) as well as correlation charts. The Pearson's correlation coefficient and the Spearman's rank correlation coefficient were both determined using equations that can be found in literature. The correlation ratio (eta) η_{xy} and η_{yx} were calculated using equations: (2) and (3).

$$\eta_{xy}^2 = \frac{\sigma_{\overline{x}}^2}{\sigma_x^2}, \quad \text{where} \quad \sigma_{\overline{x}}^2 = \frac{\sum_y n_y (\overline{x_y} - \overline{x})^2}{\sum_y n_y} \quad \text{and} \quad \sigma_x^2 = \frac{\sum_{y,i} (\overline{x_{yi}} - \overline{x})^2}{n}, \tag{2}$$

$$\eta_{yx}^2 = \frac{\sigma_{\overline{y}}^2}{\sigma_y^2}, \quad \text{where} \quad \sigma_{\overline{y}}^2 = \frac{\sum_x n_x (\overline{y_x} - \overline{y})^2}{\sum_x n_x} \quad \text{and} \quad \sigma_y^2 = \frac{\sum_{x,i} (\overline{y_{xi}} - \overline{y})^2}{n}, \tag{3}$$

where:

η_{xy}, η_{yx} – the correlation ratio of variable x and y,
$\overline{y_x}$ – the mean of the variable y of the category x,
$\overline{y}$ – the mean of the variable y (the whole population),
$\overline{x_y}$ – the mean of the variable x of the category y,
$\overline{x}$ – the mean of the variable x (the whole population),
σ_x^2, σ_y^2 – variance of variable x and y,
n_x – the number of observations in category x,
n_y – the number of observations in category y,
n – the number of the whole population,
i – the label of the particular observation.

The correlation ratio is a measure of the relationship between the statistical dispersion within individual categories and the dispersion across the whole population.

The Pearson's correlation coefficient was used for analysis of the direction of the correlation. On the basis of the Pearson's nonlinear correlation coefficient, correlation strength was determined. Advantage of the correlation ratio (η) relays on the fact that it does not depend on regression shape, and can be used to study linear and non-linear correlations for both quantitative and qualitative attributes. The Spearman's rank correlation coefficient was used for analysis of direction of the correlation for qualitative attributes, i.e. of effect exerted on parcels price by particular attributes. Shape (linear, non-linear) of correlation was determined by additional analysis of scatter graphs of attributes.

Attributes of agricultural parcels characterised by small variation, high mutual correlation, and low correction with parcel price were considered as insignificant. As a result it is not recommended to apply them when elaborating land values map.

3. Study area and data used

3.1. Study area

The study was carried out for Krotoszyce municipality, located in south west Poland, in Lower Silesian province, Legnicki county (Figure 1).

It is a small municipality, area of which is 68 km^2 (Central Statistical Office, 2014). Krotoszyce economy is strictly related to agriculture, this is due to fertile soil (alluvial

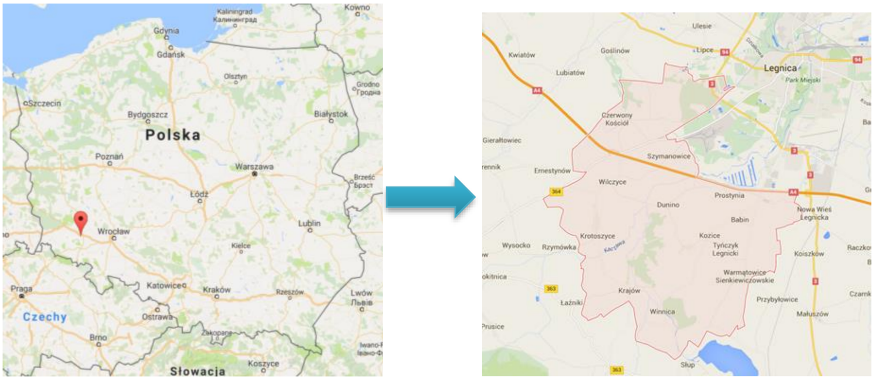

Fig. 1. Krotoszyce municipality location (Source: https://www.google.pl/maps)

soil, black earth). Land structure is dominated by cropland 84% (87% of which is arable land), and 8.1% of the municipality area is taken by building sites, whereas 7.9% by forests. Build-up areas are mainly located along the main roads.

Watercourse density index, specified as relation of examined area's watercourse length to municipality area (km/km^2), is small, its value equals 0.59. Krotoszyce municipality woodland, i.e. percent ratio of area covered with forest to the total area is also small, 7.9% (Central Statistical Office, 2014). In comparison, woodland of Lower Silesian municipality is 29.7% (Central Statistical Office, 2015), and of Poland – 30.7%.

3.2. Data used

Study covered 2979 parcels intended for agricultural purposes in Local Spatial Development Plan of the Municipality. The parcels were undeveloped agricultural properties, both single and multi-cropland use. Information on parcels attributes were taken from the register of lands and buildings (EGiB), and from the Database of Topographical Objects (BDOT10k). The lands and buildings register is one of public registers, maintained by the District Governor's Office in Legnica under responsibility of the Surveyor General of Poland. It covers continuously the whole country territory and comprises 33 mln cadastral parcels. Information about parcel consists: its location, boundaries, area, land use, soil quality, and the denotations in land and mortgage registers. Database of Topographical Objects is seamless (BDOT10k) vector database, storing topographical data for the whole country. Details level and content range is the same as in case of civil topographical maps of a 1:10 000 scale. For the purpose of this study, theme layers providing information on forests, watercourses and roads network, were used.

Information about purchase-sale transactions of agricultural lands were obtained from the Register of Real Estate Prices and Values (RCiWN). RCiWN deliver data on purchase-sale transaction prices of agricultural lands, buildings and apartments T.he data concerned 370 parcels from 2003 to 2013 (Figure 2) were taken into consideration.

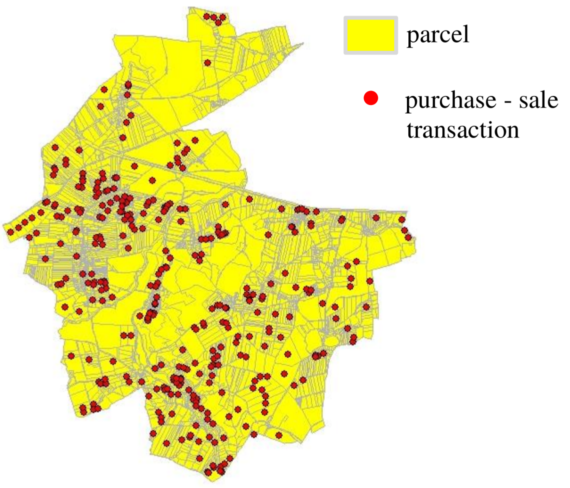

Fig. 2. Spatial distribution of real estates of known transaction prices

4. Results and discussion

Literature analysis allowed to distinguish 9 attributes of agricultural parcels that determine the parcel value. They are as follows: area (parcel size), shape, cropland type, soil fertility, waters vicinity, forests vicinity, distance of paved roads, distance of the municipality centre and distance of the homestead buildings. Two factors, i.e. waters and forest vicinity were rejected at the early stage of the research. The reason of such decision laid back on the analysis of spatial distribution and area covered by forest and water bodies. Forest mainly occupy areas at the municipality border, and along the only one watercourse. In general, forest take 7.9% of the municipality area. River network density, calculated as watercourse length per one square km, is also very low, and equals 0.59. In addition, there are no drainage and irrigation facilities in the analysed area.

Remaining attributes values were taken directly from source datasets (EGiB, BDOT10k) or calculated using functions of a GIS program (Table 1).

In Krotoszyce municipality, area of agricultural parcels varies within the range of 0.02–139.78 ha (Table 2). Small parcels of area up to 2.59 ha dominate. As the parcel size increases, the number of parcel decreases. The shape coefficient takes values, from 0.01 to 0.92, at average value of 0.49. For 134 parcels the shape coefficient is the greatest, i.e. 0.79, this means that the parcel are of a regular and symmetric shapes (Figure 4).

Distance of paved roads also varies and comprises within broad range, 0.5–1032.5 m. The decreasing parcels number with the increasing distance of the road is clearly observed. 30% of parcel is located not farther than 50 m from the paved road. The distance to homestead differs from 16 to 4560 m, wherein most parcels (third quartile) are placed not farther than 1387 m from the homestead.

Distance between particular agricultural parcels and the centre of the municipality is 44.5 m, for parcels located close to the centre, and up to 8477.5 m for those located close

Table 1. Data sources for analysed attributes

Data source	Attribute type	Attribute	Comments
EGiB	physical, quantitative	area	Cadastral parcel attribute (accuracy 0.01 ha)
EGiB	physical, quantitative	shape	Calculated from the shape coefficient equation as relation of area to parcel perimeter (accuracy 0.01)
EGiB	environmental, qualitative	soil fertility	Results of the intersect analysis of cadastral parcel and soil quality layers
EGiB	environmental, qualitative	cropland type	Results of the intersect analysis of cadastral parcel and land use layers
EGiB	location-related, quantitative	distance to the homestead	Euclidean distance in metres from parcel centroid to homestead buildings (accuracy 0.5 m)
EGiB	location-related, quantitative	distance to the municipality centre	Euclidean distance in metres from parcel centroid to centre of commune, represented by local authorities office (accuracy 0.5 m)
BDOT10k	location-related, quantitative	distance to paved roads	Distance (along local and field roads) in metres from parcel centroid to paved road (accuracy 0.5 m)

Table 2. Descriptive statistics of quantitative attributes of agricultural parcels in Krotoszyce

Attribute	Statistics			
	Minimum	Maximum	Arithmetic mean	Standard deviation
Area (ha)	0.02	139.78	1.80	5.47
Shape	0.01	0.92	0.49	0.19
Distance to paved roads (m)	0.5	1032.5	161.0	152.5
Distance to the municipality centre (m)	44.5	8477.5	3820.5	2108.5
Distance of the homestead buildings (m)	16.0	4561.0	888.5	642.5

to east border of the studied area. For 50% of the parcels the distance to the municipality centre is shorter than value of arithmetic mean of distance calculated for all analysed parcels, i.e. 3820.5 m (Figure 6).

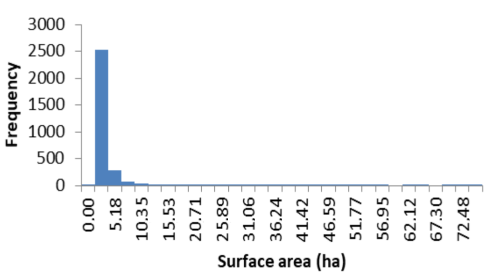

Fig. 3. Parcels' area distribution

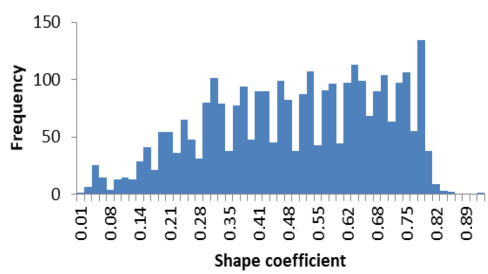

Fig. 4. Distribution of parcels' shape coefficient

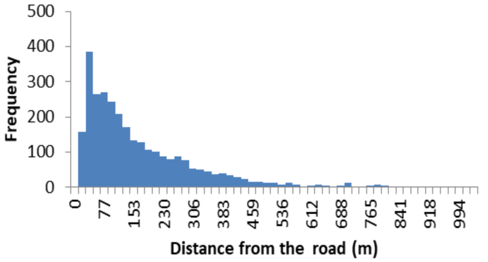

Fig. 5. Distribution of distance from the paved Road

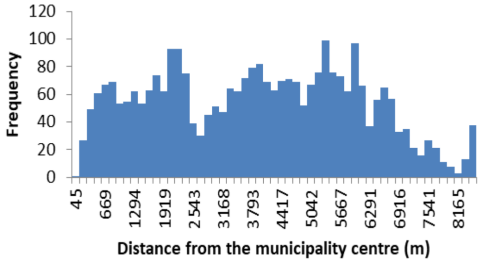

Fig. 6. Distribution of distance from the municipality centre

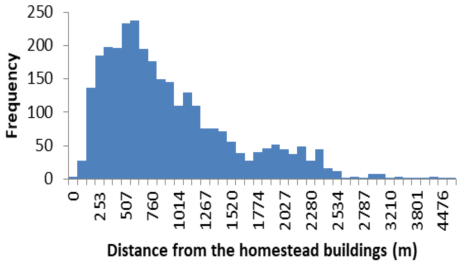

Fig. 7. Distribution of distance from the homestead buildings

Agricultural land is characterised as: croplands, meadows, pastures, orchards, ponds and ditches lands, croplands covered with bushes and trees. The studied area comprises mainly croplands (1898 parcels). Orchards are in great minority – 34 parcels (Figure 8).

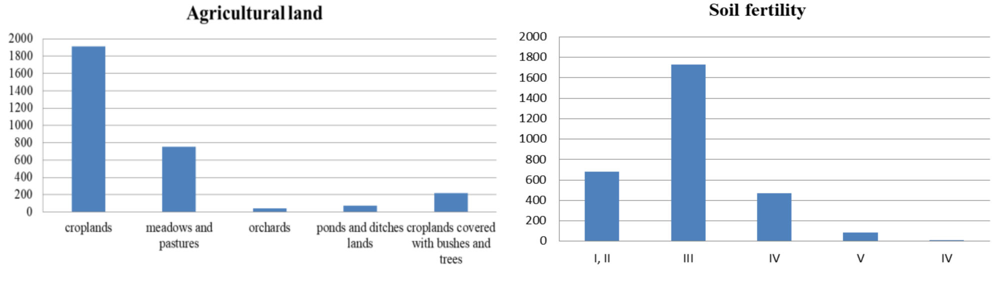

Fig. 8. Quantitative distribution of cropland and soil fertility

Soils were characterized in accordance with their fertility, specified in Government Regulation of 12 September, 2012, on the pedological classification of land (Journal of Laws of 2012, item 1246). Class I is for the highly fertile soils, classes II and III are fertile soils, classes V and VI are infertile. At the municipality area there were only fertile and highly fertile soils of class I and II (684 parcels) and III (1728 parcels). As for parcels located on infertile land (class VI), there were only 14.

The coefficient of variation (CV) of above described attributes (Table 3) varies significantly, it takes values of 18.42% for soil fertility and 303.45% for parcel area.

Table 3. Values of coefficients of variation of agricultural parcels attributes

Attribute	Soil fertility	Area	Shape	Cropland type	Distance to paved roads	Distance to the municipality centre	Distance of homestead buildings
Coefficient of variation (%)	18.42	303.45	38.78	25.76	94.75	55.19	72.34

Low value of the coefficient of variation for the soil fertility confirms that soils condition is practically equal in the whole municipality. Comparable, variation of the cropland type is insignificant, i.e. 25.76. Both attributes did not meet the assumed minimum threshold criteria of 30% of variation.

The greatest value of coefficient of variation was determined for parcel size (area) – 303.45%, this shows that there is considerable variation when it comes to parcels area, with very small parcels in Prostynia, where average parcels' area was 0.52 ha, and very large parcels of average area 4.30 ha in Bielowice, placed south – east.

Values of the Pearson's correlation coefficient, the Sperman's rank and the Pearson's nonlinear correlation ratio are presented in Table 4. Values of non-linear and linear correlation are different. Analysis of the correlation coefficients let one state that the studied attributes influenced variation of agricultural parcels value with different levels of significance. Values of the Pearson's correlation coefficient range between 0.02 and 0.11, this means that linear correlation of variables is poor. Values of the Pearson's nonlinear correlation ration range was 0.09–0.98. This means that correlation between variables is of non-linear nature. Distance to the municipality centre takes the greatest value of nonlinear the correlation coefficient (0.98), whereas soil fertility the lowest (0.09). Values of the Spearman's rank correlation coefficients, determined for soil fertility and cropland

Table 4. Coefficients of correlation of attributes with agricultural parcels price

Attribute	Correlation with price of agricultural property		
	Pearson's correlation coefficient	Pearson's nonlinear correlation coefficient (correlation ratio)	Sperman's rank coefficient
Soil fertility	0.02	0.09	0.12
Area	−0.11	0.88	–
Shape	−0.08	0.40	–
Cropland type	0.09	0.19	0.32
Distance to paved roads	−0.06	0.89	–
Distance to the municipality centre	0.04	0.98	–
Distance of the homestead buildings	−0.09	0.94	–

types, confirm the poor, positive correlation between a land price and the quantitative coefficients. This is an effect of Krotoszyce's a homogenous land structure, 87% of which are croplands and soil of good quality.

On the basis of results it has been stated that correlation between a parcel price and soil fertility was very poor, positive, and non-linear. This means that parcels characterised with better soils obtained higher unit prices in purchase-sale transactions, however this insignificantly influences the diversification of agricultural land prices in the municipality.

Very strong, negative non-linear correlation was obtained for the following variables: area, distance of homestead buildings and distance to paved roads. This means that the greater parcel's area, and the farther it is located from both homestead buildings and main paved roads, the less expensive it is. Values of the non-linear correlation coefficients range between 0.88 and 0.94. Negative, non-linear correlation occurs between a price and the shape of the parcel. Influence of the shape on parcel's price is crucial, although not too significant. The correlation ratio takes value is 0.40. Parcels of irregular, long, rectangular shape reach higher unit prices. The obtained result complies with general belief that the most demanded parcels when it comes to agricultural production are those of the width-long ratio from 1:2–1:3 (Demetriou, 2016) to 1:5 (Noga, 2006).

Very strong non-linear correlation was obtained for distance to the municipality centre (0.98). Relation between the distance to the municipality centre and the price was positive, which means that agricultural lands placed in a greater distance from the municipality centre were more expensive. The obtained result is accordant with the reverse theory of agricultural location by Thunen (Sinclair, 1967), which says that results of crops production and productivity from one land unit are greater if increase distant the parcel from the municipality centre and the lesser influence of urbanisation (Wigier, 2012).

Shape of correlation was determined by additional analysis of scatter graphs of attributes. The correlation graphs (Figure 9) present non-linear influence of the analysed quantitative attributes on agricultural parcels price. They confirm results obtained on the basis of the coefficient ration (η).

The assumed threshold criterion, stated that the non-linear correlation of variables at a level greater than 0.40, was not met by two attributes: soil fertility (0.09) and cropland (0.19). Finally, they should be excluded from the set of explanatory variables of an agricultural land parcel value during elaboration of a land value map. Qualitative homogeneity of soils and overwhelming majority of croplands cause slight variation of agricultural parcels price in Krotoszyce. Although, influence of these attributes on a more environmentally diversified area, might be essential. Thereby, the hypothesis formed at the beginning got confirmed, that in the relatively small communes, some factors that affect the agricultural parcels price do not diversify prices in the local agricultural market. The obtained results confirm Pietrzykowski study (2011), who stated that in Poland agricultural land pricing due to soil quality is connected with regional differentiation, and at the same time individual attributes of local agricultural market. Crucial in such a case is selection of price-influencing factors representing different attributes types (Sandquist, 2002), such as location features.

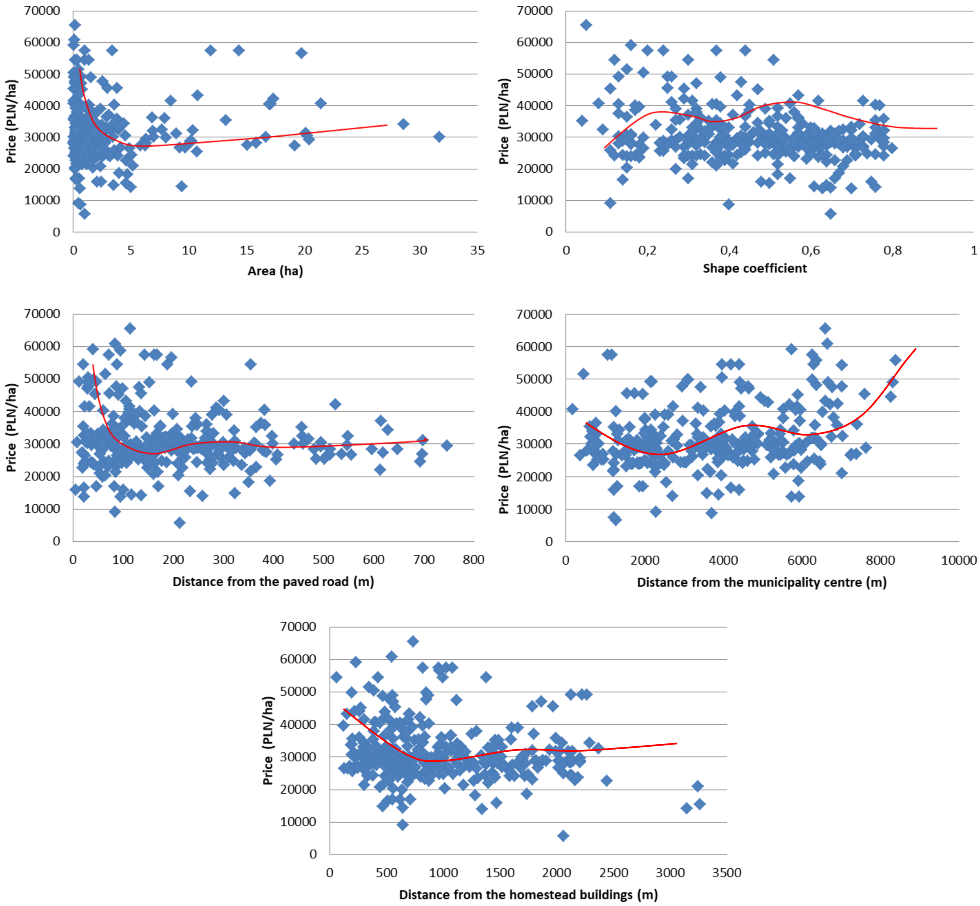

Fig. 9. Graphs of attributes dispersion: area, shape, distance to paved road, distance to the municipality centre, distance of the homestead buildings

On the basis of the obtained results, answers to the research questions were received. The biggest impact on variation of agricultural land values have the location attributes: distance to the municipality centre, distance of homestead buildings, distance to paved roads and physical attributes: area and shape, which coefficients of variation and correlations takes higher values. The most significant no-linear impact on the prices had land parcel characteristics which values of the Pearson's nonlinear correlation ratio (η eta) range were 0.89–0.98.

5. Conclusions

When selecting attributes for the purpose of land values map elaboration, it is necessary to choose such attributes that describe real estates both with regard to location and with reference to physical and environmental characteristics of a property. With this, it is possible to provide better characteristics of the parcels and to select, from the set of attributes, those attributes that significantly influence variation of prices. When speaking of mass valuation, necessity to determine values of attributes concerns few thousand agricultural parcels. As far as fast acquiring of information on agricultural parcels attributes is concerned, GIS tools, along with the possibilities they offer, play crucial role.

Especially important, when it comes to selection of the attributes, is analysis of nonlinear correlations. Such analysis allows better understanding of analysed phenomenon and degree of attribute influences on a price of land at the local rural market. Carried out studies lead to a conclusion that in local agricultural market of slightly differentiated water, forest and soil conditions, barely few attributes are important. The most significant determinants of parcels value are: distance of homestead buildings, distance to the municipality centre and to paved roads as well as physical parcel characteristics, such as: parcel's size (area) and shape. Therefore, these ones should be used for elaboration of land values map.

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