The Study of Spatial Autocorrelation of the Land Consolidation in Lubelskie Voivodeship

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Abstract. In Poland land consolidation is carried out mainly in the southern part of the country. In three voivodships, Lublin Voivodship, Podkarpackie Voivodship and Lesser Poland Voivodship, in the years 2003–2014 there were numerous land consolidations, over 20,000 ha in each voivodship. That is above national average of land consolidation. In another three voivodships (Warmian-Masurian Voivodship, West Pomeranian Voivodship and The Kuyavian-Pomeranian Voivodship) there are no land consolidation, even though according to scientists from the Polish, every voivodship requires land consolidations processes. What is the reason for that situation? Why are so many land consolidations conducted in the area of several voivodships in Poland, and in other voivodships considerably less or not at all?
It is known that the location of the implementation of agricultural land consolidations in a particular area is determined by numerous factors, inter alia the construction of line infrastructural projects i.e. motorways, faulty spatial structure found in a particular area, and farmers in Poland applying for the implementation of this project. It is also known that the neighbourhood of the implementation of these works is of significance. Situations are observed in which the appearance of one consolidation object contributes to the development of this measure in the neighbouring area. However, there is no empirical evidence to support this view. Therefore, the subject of considerations will be the investigation into the occurrence of spatial relationships between consolidation objects. Two variables were adopted for the analysis, namely the number and density of consolidations. In order to determine the relationships, spatial autocorrelation was applied.

Keywords: land consolidation, rural areas, local community, land fragmentation, spatial autocorrelation.

Conference topic: Technologies of geodesy and cadastre.

Introduction

FAO classifies land consolidation impacts at three levels: at the micro-level, the objectives of land consolidation focus on changing the farm structure and the direct environment so as to enable farmers to become more competitive. At the meso-level, land consolidation has broader aims for changing rural communities by improving the infrastructure (roads, irrigation and drainage systems, water and disposal installations, etc.), the natural environment, management of natural resources, landscape, and consequently the spatial distribution of economic activities. At the macro-level, the focus is on changes which can positively affect the entire country by reducing the disparities between rural and urban areas, by ensuring more efficient and varied use of rural space, by improving the overall competitiveness of the agricultural and rural sector, by building trust between governments and inhabitants of rural areas, and by enhancing the land market (Demetriou 2014).

In Poland, however, the works are implemented with varied intensity (Dudzińska 2015). From 2004 to 2013, agricultural land consolidations were implemented in Poland over an area of 118 thousand hectares. The highest numbers of consolidations were implemented in Lubelskie, Podkarpackie, and Małopolskie Voivodeships – more than 20,000 ha each. In three other voivodeships, namely Warmińsko-Mazurskie, Zachodniopomorskie, and Kujawsko-Pomorskie, no agricultural land consolidations were implemented (Dudzińska, Kotlewski 2016).

According to the study by Jędrejek (see Jędrejek *et al.* 2014a, 2014b), needs for consolidation works exist in every voivodeship, to the greatest extent in southern Poland, and to the smallest extent in northern Poland (Table 1). Nonetheless, consolidation works should be implemented throughout Poland. Necessary consolidations should be implemented over areas from 1.2% of arable land in Kujawsko-Pomorskie Voivodeship to 13.9% in Opolskie Voivodeship.

Why are so many land consolidations conducted in the area of several voivodeships in Poland, and in other voivodeships considerably less or not at all?

It is known that the location of the implementation of agricultural land consolidations in a particular area is determined by numerous factors, *inter alia* the construction of line infrastructural projects i.e. motorways, faulty spatial structure found in a particular area, and farmers in Poland applying for the implementation of this project. It is also known that the neighbourhood of the implementation of these works is of significance. Situations are observed in which the appearance of one consolidation object contributes to the development of this measure in the neighbouring

area. However, there is no empirical evidence to support this view. Therefore, the subject of considerations will be the investigation into the occurrence of spatial relationships between consolidation objects. Two variables were adopted for the analysis, namely the number and density of consolidations. In order to determine the relationships, spatial autocorrelation was applied.

Autocorrelation is a branch of statistics dealing with an analysis of spatial data and with further description and investigation of spatial phenomena. Spatial statistics are an efficient method for identifying the dependence of individual phenomenon occurrence on geographical space. Measures of spatial autocorrelations show the dependence of variables in respect of spatial localization. Spatial correlation (positive autocorrelation) allows one to determine that the intensification of a given phenomenon is more perceivable in the adjoining objects than in located far away from one another. Two types of measures are used by spatial statistics: global and local measures. Moran's I statistics allow one to identify global autocorrelation measures in spatial objects with reference to the assumed weight matrix. The global measure is a one number indicator of spatial dependence or general similarity of regions.

Correlation statistics were designed to show relationships between variables, autocorrelation statistics are designed to show correlations within variables, and spatial autocorrelation shows the correlation within variables across space (Getis 2007, 2008).

The literature suggests two main reasons for the occurrence of spatial relationship phenomena:

– firstly, the analysed phenomenon is closely related to territorial units (regional, provincial, county, municipal, and village council affiliations). Such assignments do not accurately reflect the nature of most phenomena as boundaries only existing on maps do not typically restrict human activities.
– secondly, the socio-economic dimension of human activities is shaped by distances and the location (Woźniak, Sikora 2007).

The aim of this part of the study is to identify spatial relationships taking place between municipalities of Lubelskie Voivodeship in terms of the presence of the number and density of implemented agricultural land consolidations. Is there spatial autocorrelation between places in which the consolidation of agricultural land has been carried out? The paper presents results of a study into spatial autocorrelation of the consolidations under implementation in Lubelskie Voivodeship. The choice of Lubelskie Voivodeship resulted from the fact that most consolidations in Poland have been implemented in this particular voivodeship. To this end, Morgan's I global statistics were used.
The study was performed in Lubelskie Voivodeship which runs the highest number of land consolidation projects in Poland.

Study methodology

The study was divided into the following stages:

At the 1st stage of the study, the number and density of implemented agricultural land consolidation in Lubelskie Voivodeship were determined. At the 2nd stage of the study, a matrix of spatial weights adopted for the analysis was determined. At the next stage, global Moran's I statistics were determined for the adopted variables. The final stage of the study involves drawing conclusions based on the completed research.

Spatial autocorrelation is defined as the degree of correlation of the observed variable value in a given location with the value of the same variable in another location (Suchecki 2010).

Spatial autocorrelation can be employed when the occurrence of a phenomenon in a spatial unit causes an increase or decrease in the probability of the occurrence of this phenomenon in the neighboring units (Janc 2006).

Spatial autocorrelation measures may have both a global (determining the strength and character of spatial autocorrelation for the whole set of units) and a local character. The most often used global spatial autocorrelation measures are I statistics, expressed by the following formula (Cellmer 2013):

$$I = \frac{1}{\sum\limits_{i=1}^{n}\sum\limits_{j=1}^{n} w_{ij}} \cdot \frac{\sum\limits_{i=1}^{n}\sum\limits_{j=1}^{n} w_{ij}\left(x_i - \overline{x}\right)\left(x_j - \overline{x}\right)}{\frac{1}{n}\sum\limits_{i=1}^{n}\left(x_i - \overline{x}\right)^2} ,$$

where: w_{ij} – weight of connections between unit i and j, x_i, x_j – values of variables in the spatial unit i and j, $\overline{x}$ – arithmetic mean of variable value for all units.

The value of Moran I statistics usually ranges from −1 to 1. The "0" value means a lack of spatial autocorrelation, negative values mean the occurrence of a varying level of the studied phenomenon in the neighborhood, and positive values mean positive autocorrelation i.e. the occurrence of a similar level of the studied phenomenon in the neighborhood.

The statistical significance of Moran's I statistics is verified by normalised Z_I statistics, with a normal distribution at the expected value of 0 and variance of 1:

$$Z_I = \frac{I - \mathrm{E}(I)}{\sqrt{\mathrm{Var}(I)}}$$

using the following approximations of the expected value and variance:

$$\mathrm{E}(I) = -\frac{1}{n-1} \qquad \mathrm{Var}(I) = \frac{n^2 S_1 - n S_2 + 3 S_0^2}{(n^2 - 1) S_0^2} - \frac{1}{(n-1)^2}.$$

Results and discussion

Stage 1: The scope of the implementation of agricultural land consolidations in lubelskie voivodeship in the years 2004–2013.

The geographic location of Lubelskie Voivodeship, and the scope of land consolidation and land exchange measures conducted in the voivodeship are presented in Figure 1.

Lubelskie Voivodeship occupies an area of 25 122.15 km². It is the third largest voivodeship in the country, followed by Mazowieckie and Wielkopolskie voivodeships.

The number of population amounts to 2 242 thousand, placing it on the 7th position in the country. The density of population is relatively low i.e. approximately 85 persons per 1 km². Only four other voivodeships, namely Warmińsko-Mazurskie, Podlaskie, Lubuskie, and Zachodnio-Pomorskie are distinguished by a lower population index. The natural growth index amounts to 0.4. The population of the voivodeship constitutes 5.8% of Poland's inhabitants.

Rural areas in Lubelskie Voivodeship occupy the area of 24 152 km², constituting 96.1% of the region. The rural settlement network includes 3 319 chair villages, 171 of which are municipal rural centres.
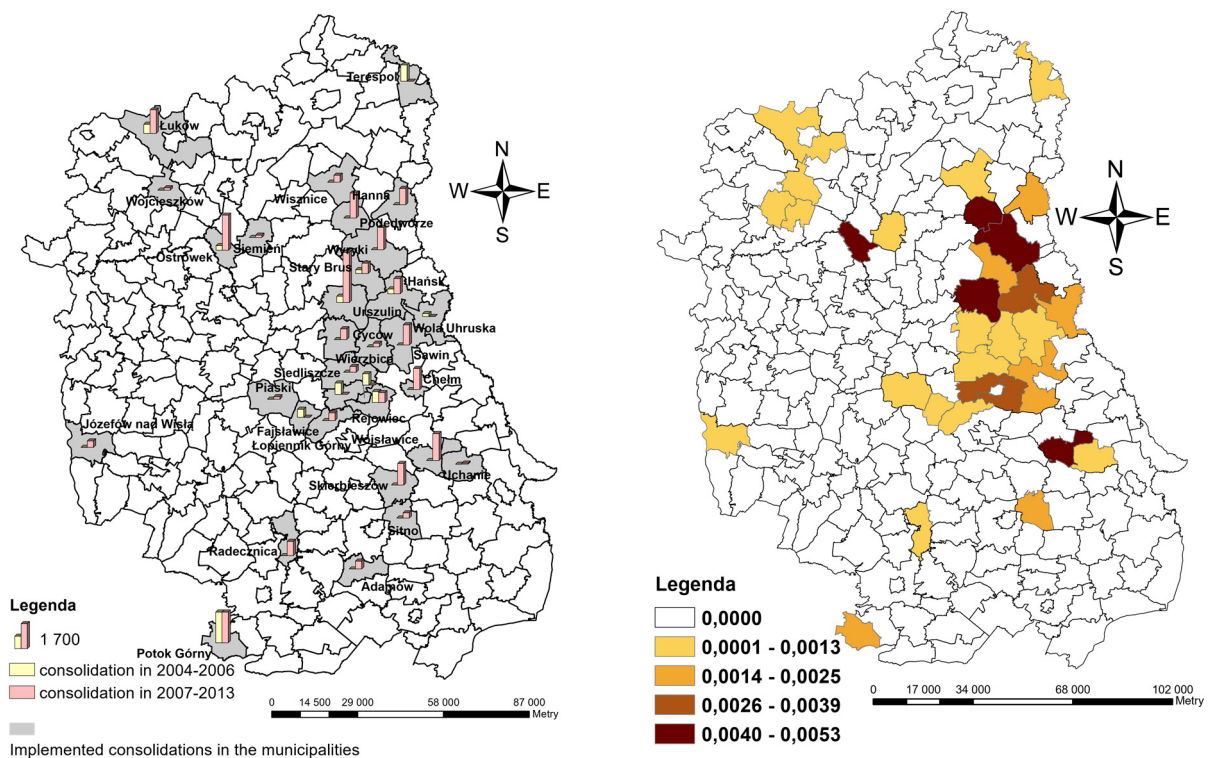

Fig. 1. Implemented consolidations in municipalities of Lubelskie Voivodeship, and the density
of agricultural land consolidations (source: own compilation)

In Lubelskie Voivodeship, agriculture is of high importance. It benefits from environmental conditions considerably better than the national average, as suggested by the indicator of valorisation of agricultural production space amounting to 74.1 points (Poland: 66.6 points). It is also distinguished by a relatively low level of the use of agricultural production potential (Fotyma, Krasowicz 2001; Krasowicz, Igras 2013).

Its agricultural character is proved by the fact that the majority of population inhabit rural areas (villages), 53%, while most of the country's inhabitants live in cities (61%). Rural areas are 96.2% of the total area of the voivodeship,

and agriculture is one of the most important sectors of its economy. Contribution of agriculture, hunting, forestry, fishing and fish breeding to the creation of gross value added (WDB) of the voivodeship is decreasing, but it is still higher than the averages in the country. In 1998–2010, the contribution dropped from 10.7% to 7.4%, whereas it dropped from 4.9% to 3.7% respectively in the country (Kopiński, Krasowicz 2013).

In Lubelskie Voivodeship, 13 consolidation measures (7 970 ha) were conducted in the years 2004–2006, and 39 consolidation measures (27 502 ha) in the years 2007–2013. Lubelskie Voivodeship comprises 191 rural municipalities, and land consolidation projects covered 31 municipalities. The highest number of four consolidation measures were carried out in the municipalities of Chełm and Urszulin each. The municipalities of Łuków, Ostrówek and Wojsławice performed three consolidation measures each.

The implemented consolidation objects feature various sizes, from 74 ha in the case of objects Łuszczów and Łuszczów kol. in the municipality of Uchanie to 2 101 ha for object Potok in municipality Potok Górny (Fig. 2). The largest area of consolidated land concerned measures implemented in the period 2004–2013 in municipalities of Potok Górny and Urszulin, and amounted to 4 202 and 3 863 ha, respectively (Fig. 1).

The implementation of most consolidation objects in Lubelskie Voivodeship was initiated in 2011 (Fig. 2). The highest density of implemented consolidations (the number of consolidations per agricultural farm) was noted in 5 municipalities (Podedworze, Wyryki, Urszulin, Ostrówek, and Wojsławice), and ranged from 0.0040 to 0.0053 consolidations per farm (Fig. 1).
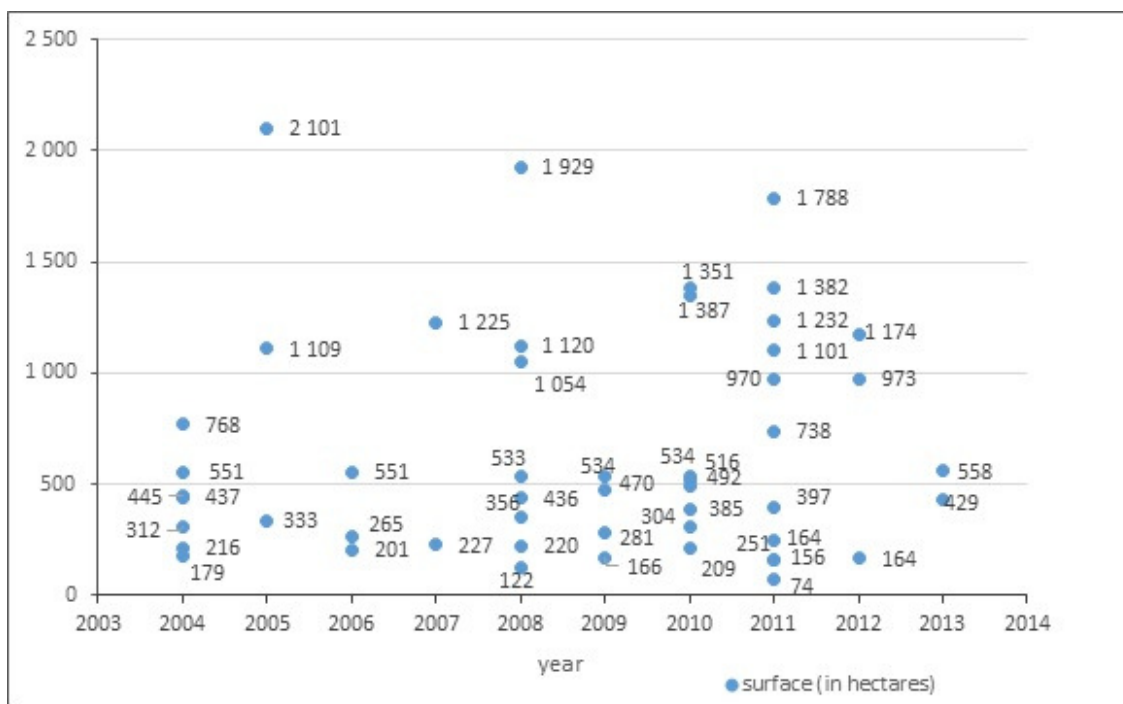

Fig. 2. The distribution of consolidation objects in the years 2004–2013 (source: own compilation)

Stage 2: Determination of a matrix of spatial weights for the analysis.

In order to investigate the tendency of a phenomenon towards autocorrelation, it is necessary to previously determine the spatial relationships taking place between spatial units, i.e. the level (intensity) of the neighbourhood. These relationships are in the form of matrices of spatial weights, which are recorded using a graph or a matrix. The determination of matrices of spatial weights is a very important element of spatial analysis as it identified spatial links, the distance and strength of mutual relationships between spatial objects. The following criteria for the assessment of neighbourhood are possible (Bivand 1981):

 – – the length of a mutual boundary – a neighbour is only the unit for which a section of a mutual boundary exists (a "rook" relationship),
 – – the existence of a mutual boundary – just one point of a mutual boundary is sufficient (a "queen" relationship),
 – – the distance between objects (it is necessary to determine how many neighbours of a neighbour of a particular unit are neighbours of this unit),
 – – the determined distance (neighbours are all units located at a distance not greater than that established in km) (Mordwa 2013).

In order to depict the spatial relationship of the distribution of the variable of the area of implemented consolidations, Moran's I statistics were calculated on the basis of the matrix of weights of types B and W, based on tangency (direct neighbourhood). For spatial analysis, a matrix of coincidence of type B satisfying the criterion of a common boundary (neighbourhood or adjacency matrix), which provides the best representation of the proximity of objects, was adopted (Fig. 3).
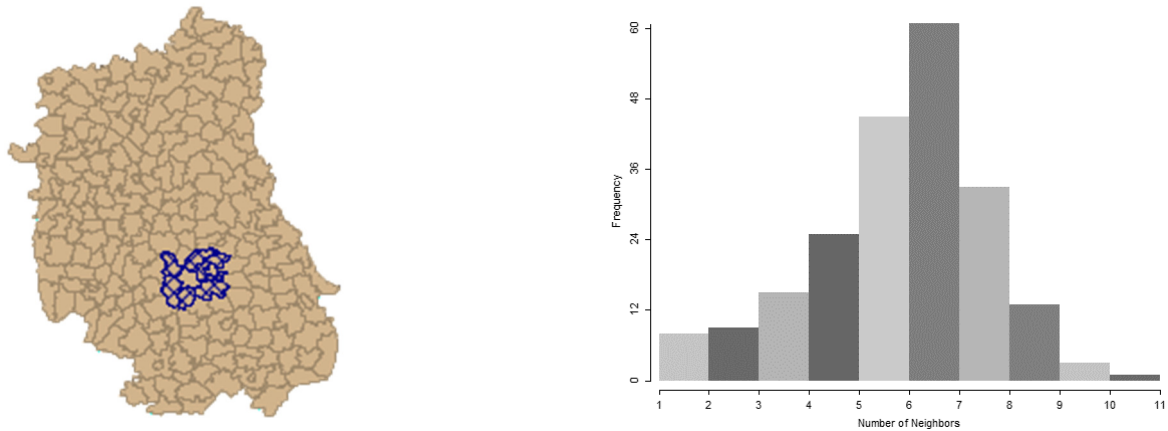

Fig. 3. Histogram and map of the matrix of spatial weights – Lubelskie Voivodeship

The summary of matrices of neighbourhood weights according to the criterion of a common boundary is presented in Table 1. This matrix is the most often used matrix in socio-economic analyses and theoretical considerations in econometrics.

Table 1. Number of links between spatial objects

Number of neighbours	1	2	3	4	5	6	7	8	9	10
Number of objects	8	9	15	25	45	61	33	13	3	1

Table 1 presents the number of spatial objects and the number of their links with neighbours. As can be seen, only 9 municipalities have two neighbours, and 8 have only one. This is due to the fact that these are municipalities located at the edge of the area under study, or inside the area. The shape of the area under study has an effect on the intensity, scope and type of the estimated process of spatial relationship, and on the significance. At the boundaries of the area under study, the so-called edge effect occurs, which reveals itself in municipalities having fewer neighbours than the objects located inside. As a consequence of this effect, differences may appear in estimating the spatial relationships.

One may read an object with the highest number of neighbours from the graph (Table 1). This is the object of Chełm, which has boundaries with as many as 10 neighbours. However, in the area under study, most municipalities (61) had boundaries with 6 objects, while 45 municipalities had boundaries with 5 objects, and 33 municipalities had boundaries with 7 objects.

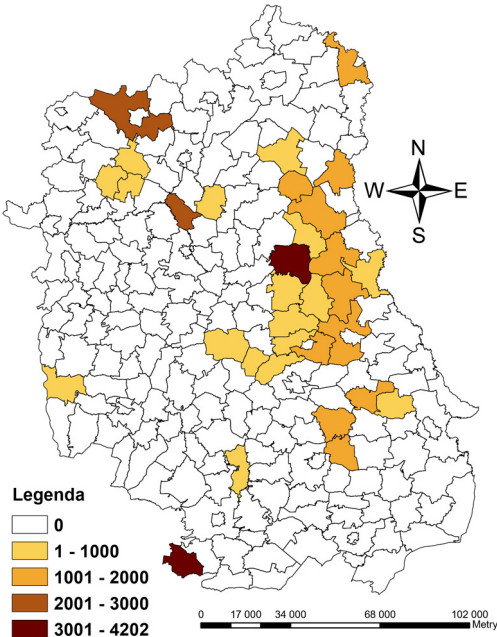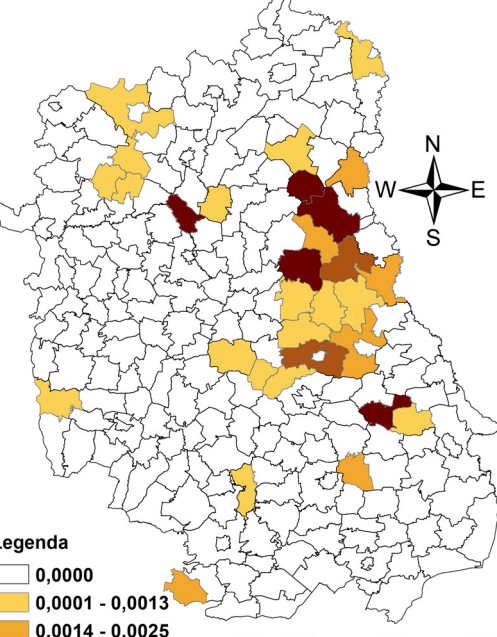*Stage 3:* Global Moran's I statistics for the adopted variables

Global spatial autocorrelation measured by Moran's I statistics proved statistically significant in all the analysed cases (Table 2). Therefore, the hypothesis about the absence of spatial autocorrelation was rejected for these variables.

This implies the existence of a positive spatial autocorrelation in the analysed variables depicting the presence of agricultural land consolidations.

The obtained results indicate that the adopted variables show a tendency towards clustering. As regards the variables of the number of consolidations, a low tendency towards clustering occurs, while for the variable of density, the tendency towards clustering is at a higher level.

This means that for the analysed variables, a spatial regime (the distribution of values within the space) occurred, which was clearly different from a random one.

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Table 2. The values of global Moran's I statistics for the presence of agricultural land consolidations within the arrangement of municipalities of Lubelskie Voivodeship

The number – the area of consolidations implemented in municipalities. **Legenda** ☐ 0 ☐ 1 - 1000 ☐ 1001 - 2000 ☐ 2001 - 3000 ☐ 3001 - 4202	Moran's Index: 0,10864 Expected Index: −0,00472 Variance: 0,0015 Z Score: 2,90737 p-value: 0,00365
Density I – the number of consolidations per agricultural farm with an area of more than 1 ha. **Legenda** ☐ 0,0000 ☐ 0,0001 - 0,0013 ☐ 0,0014 - 0,0025 ☐ 0,0026 - 0,0039 ☐ 0,0040 - 0,0053	Moran's Index: 0,25462 Expected Index: −0,00472 Variance: 0,0015 Z Score: 6,49865 p-value: 0,00000

Conclusions

1. During the period of the study, one may notice a positive spatial relationship between the adopted variables: the number and density of agricultural land consolidations. This confirms the presence of the impact of the space of the development of variables' values in municipalities. The performed analyses of spatial relationship

of the phenomenon of distribution of agricultural land consolidations indicate the formation of territorial unit clusters with similar values.

2. The above study confirms the thesis according to which the location of the implementation of consolidation works is not only determined by factors associated with unfavourable spatial structure of farms but also by other determinants and phenomena e.g. the occurrence of a spatial relationship phenomenon.

References

Demetriou, D. 2014. *The development of an integrated planning and decision support system (IPDSS) for land consolidation.* Springer. https://doi.org/10.1007/978-3-319-02347-2

Dudzińska, M. 2015. Potencjał uwarunkowań przestrzennych gospodarstw w gminach województwa dolnośląskiego, na obszarze których zrealizowano scalenia gruntów rolnych [Spatial parameters farms in rural areas and the land consolidation measures: case studies fromlower Silesia], *Acta Scientiarum Polonorum, Administratio Locorum* 19: 7–20.

Dudzińska, M.; Kotlewski, L. 2016. Relations between the process of land consolidation and socio-economic conditions in municipalities in Lower Silesia, *Acta Geobalcanica* 2(1): 45–53. https://doi.org/10.18509/AGB.2016.05

Jędrejek, A.; Szymański, L.; Woch, F. 2014a. Evaluation of the plot size (farm land) of family agricultural holdings and the needs for land consolidation in Poland, *Infrastruktura i Ekologia Terenów Wiejskich*, IV/1/2014: 1111–1125.

Jędrejek, A.; Woch, F.; Szymański, L. 2014b. Ocena rozdrobnienia gospodarstw rolnych do określenia rozmiarów prac scaleniowych w Polsce [The assessment of beak-up of farms for the needs of determination of the scope of land consolidation works in Poland], *Przegląd Geodezyjny* 10: 3–10.

Getis, A. 2007. Reflections on spatial autocorrelation, *Regional Science and Urban Economics* 37: 491–96. https://doi.org/10.1016/j.regsciurbeco.2007.04.005

Getis, A. 2008. History of the concept of spatial autocorrelation: a geographer's perspective, *Geographical Analysis* 40: 297–309. https://doi.org/10.1111/j.1538-4632.2008.00727.x

Woźniak, A.; Sikora, J. 2007. Autokorelacja przestrzenna wskaźników infrastruktury wodno-ściekowej woj. Małopolskiego, [Spatial autocorrelation of water supply and sewage disposal infrastructure indicators in the małopolskie province], *Infrastruktura i ekologia terenów wiejskich* 4(2): 315–329.

Krasowicz, S.; Igras, J. 2003. Regional differentiation potential of agriculture in Poland [Regionalne zróżnicowanie wykorzystania potencjału rolnictwa w Polsce], *Pamiętnik Puławski* 132: 233–253.

Fotyma, M.; Krasowicz, S. 2001. The potential productivity of arable land in Poland. Regional coverage [Potencjalna produkcyjność gleb gruntów ornych Polski w ujęciu regionalnym], *Pamiętnik Puławski* 124: 99–108.

Krasowicz, S.; Igras, J. 2013. Environmental and organisational-economic considerations of competitiveness of Lubelszczyzna's agriculture, *Economic and Regional Studies* VI/ 3: 76–82.

Bivand, R. 1981. Autokorelacja przestrzenna a metoda analizy statystycznej w geografii [Spatial autocorrelation and the method of statistical analysis in geography], in Z. Chojnicki (Ed.). *Analiza regresji w geografii*. PWN Warszawa-PoznaN.

Mordwa, S. 2013. Zastosowanie autokorelacji przestrzennej w badaniach przestępczości [Spatial autocorrelation in crime rate research], *Archiwum Kryminologii* XXXV: 61–78.

Suchecki, B. (Ed.). 2010. Ekonometria przestrzenna [Spatial Econometrics], in *Metody i modele analizy danych przestrzennych*. C. H. Beck, Warszawa.

Janc, K. 2006. Zjawisko autokorelacji przestrzennej na przykładzie statystyki I Morana oraz lokalnych wskaźników zależności przestrzennej (LISA) – wybrane zagadnienia metodyczne [Spatial autocorrelation as exemplified by Moran's I statistic and local indicators of spatial association (LISA)], in T. Komornicki, Z. Podgórski (Eds.). *Idee i praktyczny uniwersalizm geografii, Dokumentacja Geograficzna* 33: 76–83.

Cellmer, R. 2013. The use of the geographically weighted regression for the real estate market analysis, *Folia Oeconomica Stetinensia* 11(1): 155–171.

Kopiński, J.; Krasowicz, S. 2013. Environmental and organisational-economic considerations of competitiveness of lubelszczyzna's agriculture, *Economic and Regional Studies* VI(3): 76–82.