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The description of parcel geometry and its application in terms of land consolidation planning

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ABSTRACT

Land consolidation is the current issue occurring around the world. In the course of consolidation works the state of fragmentation of farms and its impact on their productivity is analyzed. Various methods of fragmentation assessing and variants of implementation of consolidation procedures are being developed. There are many factors of a different nature affecting the need for consolidation. One of the basic elements needed in these works is a quantitative description of flawed shape of plots based on the parameters of their spatial shape. GIS systems allow quick collection of spatial data of the plots or any other surface structures, including parcels. In this paper we focus only on the geometric shape of a parcel as a condition to carry out the consolidation. The paper proposes a methodology for obtaining parameters of the geometry of parcel description, which supports the process of decision-making in the field of land consolidation works. In this paper we proposed an algorithm to replace parcel with equivalent rectangle (*ER*). The presented solution enables quick processing of the large amounts of data. The results of algorithm use are shown on the example of the fragment of village in the Southern Poland.

1. Introduction

Proper configuration and arrangement of parcels of the farm is the primary criterion, which enables carrying out efficient production (Gawroński, 2003). Over the years, the shape of the territory of the farm was dependent on many factors, which largely determined the final form of the land layout of the village (Magel, 2015). Both the turnover of land, and adopted rules for the distribution of land during the transfer of farms to the successors, led to an increase in the number of new parcels or parcels of inferior spatial parameters (King and Burton, 1982). Growing with time irregularities in the spatial structure of land, negatively affected the process of their cultivation, forcing undertaking of relevant arrangement-agricultural works correcting their bad condition (Schultz, 1964). This issue is known in almost all parts of the world (Vitikainen, 2004; Brizoza and Havugimana, 2013; Manjunatha et al., 2013; Niroula and Thapa, 2005). There are many factors which have a significant impact on the processes of arrangement-agricultural works, ranging from social, through economic to technical (Demetriou, 2016; Dzikowska, 2010). Defective farms shape and their individual parcels is one of the elements affecting the initiation of processes of land consolidation.

The process, including the reconstruction of the flawed ground layouts, was launched in many European countries in the second half of the last century. This process was especially intensified in the countries of Central and Eastern Europe, which was related to political transformations (Hartvigsen, 2014; Muchová et al., 2016). The methods for their implementation developed then were preceded by an assessment of the existing condition of the land. Unfortunately, for various reasons, this process did not expand to the most of European countries (Lipton, 2009), therefore still in some of them, in spite of the membership in EU structures and associated with it requirements of creation more favorable conditions in agriculture, introduction of new solutions is a serious barrier (Pijanowski and Sobaś, 2015).

The availability of modern technology now allows the use of more and better solutions, improving the performance of tasks, which until recently were impossible to implement (Demetriou et al., 2013b). Their implementation, however, requires a broader view on solutions for existing research. Modern data processing algorithms contained in the GIS can help in decision-making in the arrangement-agricultural work. Currently, there are many methods and information technology tools that allow obtaining data on cadastral plots, parcels and crop fields (Gawroński and Jasnowska, 2007). Unfortunately, some of them are not widely available (not open access software), making it impossible to easily acquire data, including all the features of the spatial configuration

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of selected surface structures. Determination of some of these features, such as the length, width or extension apparently is not an easy task (Gąsiorowski and Bielecka, 2014). In the case of irregular borders of parcels determination of mentioned parameters involves the use of complex research methodology, and the use of simplified solutions in this field leads to erroneous results. So far a number of parameters which describe the spatial flawed structures have been developed (Demetriou et al., 2013a; Janus and Taszakowski, 2015). Search for methodological solutions still seems reasonable. These methods should make it possible to develop simple, and the time available solutions, enabling accurate determination of mentioned parameters, according to the actual shaping of the surveyed surface elements, which in effect will help automation of the process of consolidation of parcels. Therefore it is important to search for new solutions in this sphere and the development of new calculation algorithms. Proposed in this paper, solution is simple and easy to write program.

2. Indices of land fragmentation

Many indices can be found in the literature. Their task is a mathematical description of flawed structures of parcels (Januszewski, 1968; King and Burton, 1982; Demetriou et al., 2013a; Gąsiorowski and Bielecka, 2014; Janus and Taszakowski, 2015). Some of the solutions are focused on the fragmentation of entire farms, and some of the indices describe the flawed geometry of parcels. In the next part the work we will focus on the indices describing the geometry of the parcels.

In their publication, the King and Burton (1982) proposed the following factors affecting the fragmentation of parcels:

- the landholding size,
- the number of parcels belonging to the holding,
- the size of each parcel,
- the shape of each parcel,
- the spatial distribution of parcels,
- the size distribution of the parcels.

On the other hand, Demetriou and colleagues (2013a) also offered 6 parameters describing the fragmentation:

- dispersion of parcels,
- size of parcels,
- shape of parcels,
- accessibility of parcels,
- dual ownership,
- shared ownership.

For the needs of planning of land consolidation works Janus and Taszakowski (2015) offered indices, which they called:

- index related to the size of farms,
- index of land fragmentation,
- index related to soil quality,
- index showing lack of road access to parcels,
- index related to analysis of aerial photographs.

According to Gąsiorowski and Bielecka (2014) fragmentation of land can be analyzed using six measures of the parcels and information on parcel land use:

- area (*PA*),
- shape of parcel (*SI*),
- number of parcel boundary points (*NoBP*),
- dispersion of parcels (*DoP*),
- land use on parcel (*PoAL*) pastures and orchards and built-up land (*PoB*),
- parcel percentage of a whole holding area (*PPoH*).

For geometry of parcels analysis Demetriou with colleagues (2013b) introduced the parcel shape index for parcel *i* (*PSIi*), which consists of weighted factors:

- length of sides,
- acute angles,
- reflex angles,
- boundary points,
- compactness,
- regularity.

For automated description of the geometry of parcels the following indicators proposed by Peura and Iivarinen (1997) can be used:

- convexity,
- principal axes,
- compactness,
- circular variance,
- elliptic variance.

The authors of the paper want to propose a solution enabling determination of selected geometrical parameters of the parcels on the basis of the data contained on the numerical map of the land and buildings registry. The adopted methodology, based on digital data using common informatics tools, will allow specifying the length and width for any number of parcels. The applied solution should help in making decisions about the need to carry out the consolidation works. The adopted solution consists in determining the moments of inertia of plane figures, allowing determining the optimal geometrical figure which is the equivalent of the analyzed parcel. As a result, it will be possible to determine the coefficient for distortion of the parcel which will allow extracting the parcels with the correct or flawed shape. For practical reasons, verification of the proposed methodology will be performed on the selected object of the South Poland.

3. Determination of the shape parameters of the parcel

Due to many natural and anthropogenic factors, shapes and dimensions of the parcels, even in a small area can be differentiated. Unfavorable geometric layout of parcels interferes with the effective managing of the agricultural economy, therefore, on the basis of geometrical parameters of parcels decisions are made about the transformations (eg. land consolidation) (Gonzalez et al., 2003). In order to determine the geometrical parameters of parcels, which can be mutually compared and analyzed it is necessary to make a figure of simple geometry. The optimal shape of a parcel is a rectangle, and therefore it seems reasonable to introduce to analyzes and calculations just simple geometry in the form of a rectangle.

In the literature it is possible to find many references on research whether the object is a rectangle and if not, how much it is deformed (Rosin, 1999). Various parameters are entered in the assessment of the object squareness (Zandonadi et al., 2013; Peura and Livarinen, 1997). This gives a view on the issue of a figure shape analysis and it allows gaining an understanding of the applied calculation algorithms.

Natural, sometimes very complex shapes of parcels will be replaced for analysis with a virtual equivalent rectangle (*ER*). The equivalent rectangle (*ER*) should fulfill a number of assumptions regarding their geometry in relation to the actual parcel: