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Compliance of the Plots Elongation Parameter in the Study of the Spatial Structure of Land

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Abstract. The study will present the results of research, including comparative analysis of the parameters of spatial shaping of plots, obtained by two independent methods for the same area: The first method – commonly used in studies of the spatial structure, requiring the use of several information tools and the second one – simpler with different methodological approach. The starting material will be the data included in the descriptive part of the real estate cadastre and on the digital map of the land and buildings registry. The basic element of the research will be continuous parts of parcels covered by one form of use. Detailed analysis will concern determination of the scale of differences for the studied parameters in both methodological variants. As a consequence this will determine the possibility of interchangeability of both methods in the works related to the assessment of rural land systems.

Keywords: spatial structure of land, land consolidation, GIS.

Conference topic: Technologies of Geodesy and Cadastre.

Introduction

The initiatives aimed at restructuring the current spatial structure of agricultural land, are aimed at creating more favorable conditions in terms of management and production. The change of the spatial structure of land itself however, requires actions preceding this intention. One of the important steps in this context are detailed studies related to the evaluation of the existing condition of the land of existing farms. On this basis, the degree of demand for a specific range of agricultural arrangements works can be determined, and the effect of changes of such transformations can be predicted (Mielewczyk 2016; Janus 2011; Gniadek 2014). Changes resulting from the undertaken works may affect, depending on many factors, to a varying degree improvement of these conditions, because it is not always possible to completely eliminate faulty shape. So it is advisable to take measures controlling the results of the land consolidation, not only in order to determine the degree of improvement of the spatial structure of land, but also to promote the agricultural arrangements works, which in some European Union countries still encounter the lack of public acceptance (Pijanowski 2014).

The results of such research should exactly reflect the actual state of the tested surface structures. However, due to different methodological approach, presented by various authors regarding how to determine the necessary parameters (González *et al.* 2004; Demetriou *et al.* 2013; Zandonadi *et al.* 2013; Gąsiorowski, Bielecka 2014), there may be some discrepancies relating the actual state in the terrain, but also between the values of determined parameters, obtained by various methods. The lack of control of implementation of such solutions can make the obtained results will be inaccurate to a certain extent, which will limit or prevent correct determination of changes in the efficiency of agricultural production. Due to the importance of the problem, it is therefore necessary to verify such solutions, so that future studies of the spatial structure of land could provide the most reliable results.

The aim and scope of the study

The study contained the results of research, including comparison of the size of the elongation parameter for plots in the context of assessing both the urgency of changes in rural land systems, as well as changes resulting from carried out land consolidation works. For practical reasons, selected for the tests object was characterized by a great diversity of registry plots shapes in southern Poland. Detailed study involved comparing the results of the verification of two independent research methods in relation to the same area. The first (basic) used in the assessment of rural land systems – requiring the use of specialized information tools, and the second using publicly accessible data and GIS tools. The new solution has allowed determining the size of the spatial parameters for plots in both variants. The resulting research material enabled a comparative analysis allowing determination of the consistency of the obtained results of the study. The resulting values of the studied parameters allowed to state whether and to what extent the second method can find widespread use in the works related to the assessment of changes in spatial structure of land and thus become widely available tool, allowing to obtain quick information on the status of spatial structure of land in the selected area.

Applied tools and methods

Two methodological solutions considered in the study, allow defining the basic parameters of the spatial shape of plots for any of their number in a specific area. One of them is the plot elongation parameter, which recognizes the ratio of the length of its sides. This parameter provides valuable information about the configuration of the plot and permits to determine whether it has the correct shape. Typically, this index is estimated on the basis of data shown on digital maps. Unfortunately, in the case of shapeless plots its determination is not easy and requires the use of complex software solutions.

The elongation of a plot can also be determined using other solutions, which are based on the plot area and its circumference. However, due to different methodological approach, there is a possibility of some discrepancies between values of the examined parameter obtained for the same surface structure. Verification of both solutions on the same test object will help to determine whether the analyzed methods can be used interchangeably.

M1 – the first of mentioned methods used so far in the works related to the assessment of rural land systems permits to cover with research all land, included in the existing farms in the study area. This method, however, requires the use of specialized software, supporting the process of assessment itself. It is necessary also to use additional tools to enable: acquiring and preparing output data, the initial processing and defining the necessary spatial and technical parameters for plots and farms. In that method, the basic surface elements adopted to the study may be: both registry plots, as well as their continuous part under one form of use – corresponding to the cultivated fields. From the point of view of the efficiency of agricultural production, studies using that method are related just to the said cultivated fields, which are subject to the uniform land use. Determination of the width and length of these fields is associated with the determination of so-called cultivation length and cultivation width. These parameters in accordance with the (Gniadek, Harasimowicz 2000) do not arise from the geometry of field itself, although to a large extent they relate to it. The basic assumption in determining the cultivation length parameter of fields is to determine the cultivation width. The width is used to determine the so-called cost of turning, and should refer to their number. If we assume that the working width of the machine is (s_m) and by the cultivation of the field (i_n) turnings are made then the field cultivation width can be determined according to the following formula (1) as the product of the number of turnings and the width of the machine, which is used for cultivate the field.

$$s_u = s_m i_n \,. \tag{1}$$

The width of cultivation does not depend on the working width of the machine, but only on the shape of the field. For its determination it is necessary to adopt the direction of the field cultivation. The main component of the field cultivation width is the maximum width, measured perpendicularly to the direction of cultivation. To the width of a field, sometimes there is necessary to incorporate additional segments, related to those parts of fields which have not been covered by cultivation, after performing turnings referring to the maximum width. When considering the cultivation width of a field the route of the machine during the field cultivation should be described, and each performed turning should result with the increase of the cultivation width of the machine.

Determination of the cultivation width of the field in turn allows to determine its cultivation length of the field (d_u), which according to equation (2) is the ratio of the area and the width of cultivation.

$$d_u = \frac{p}{s_u} \,. \tag{2}$$

This length determines the average path of the cultivating machine between subsequent turnings. The presented methodology for the first method (M1), enables the specification of the elongation index to any field or plot. As has been mentioned, this index is one of the indicators of its shape and it allows carrying out evaluation of any surface structure.

The second of mentioned methods – M2, allowing determination of the plot elongation index, is based on two attributes: the plot area and its circumference. According to the test results (Szewczyk 2015) the solution can be applied to study the morphology of the plots in terms of the space shaping, including the planning of the agricultural arrangements works. As has been shown, the method is adapted to analysis of large geospatial sets in all kinds of GIS software, what undoubtedly is a big advantage of this method.

In the presented method, determined plot elongation factor reflects the shape of the plot in relation to the theoretical model, which is a rectangle. The value of this parameter increases with increasing disparity between the length and width of the rectangle. For the geometric figure in the shape of a square, the value of this parameter is equal to 1.

As has been mentioned, to determine the plots elongation (W) its attributes such as area (A) and perimeter (P) should be estimated. On the basis of these values the mathematical relationship is determined in accordance with the following formula.

$$\mathbf{W} = \frac{P + \sqrt{|P^2 - 16A|}}{P - \sqrt{|P^2 - 16A|}}. \tag{3}$$

Analysis of the compliance of the elongation parameters

To determine the compliance of results obtained from discussed methods M1 and M2 an object, characterized by both diversity of existing plots areas, as well as the great diversity of shapes was selected. Such an assumption was aimed at determination of deviations between the values of estimated elongation indices, obtained on the basis of both methods.

Chosen for verification object Marcówka is located in the southern Poland, in Zembrzyce commune, in Małopolskie Voivodship. The village is located in the area of the Western Beskid and covers an area of 431 ha. Its mountainous character is reflected in the shape of plots that exist there, which strongly differentiated areas and configurations result of the existing terrain relief.

There are 1621 registry plots within the village, whereof 1069 are plots designed for agricultural production. Figure 1 shows the existing system of the parcels borders in the studied village.

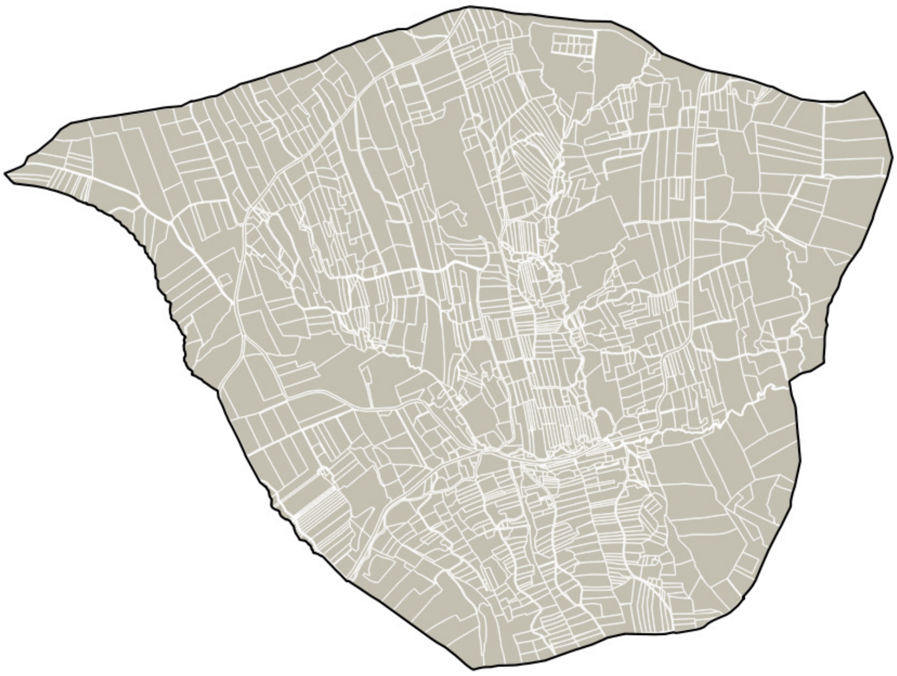

Fig. 1. The system of borders of the registry plots in the village Marcówka
(source: own elaboration)

Due to the presence of several areas with different mode of use within the plots, the verification of methods was carried out in relation to the continuous parts of the plots covered by arable land and permanent grassland. These areas in further part of the elaboration will be abbreviated as plots. Finally, the study included a selected population of 593 plots, which belong to existing farms in the village. So selected material was subject to detailed examination related to comparative analysis of elongation indices values estimated for plots by M1 and M2 methods. Then, the values of these indices for each method were summarized in the table and the mutual interdependence line was determined, the graph of which is shown in Figure 2. Based on this chart, a good agreement between the obtained results can be found. In the present case the coefficient $\boldsymbol{a}$ is close to 1 and the coefficient $\boldsymbol{b}$ is about 0.8. If the values of obtained parameters in both methods were consistent then the formula of the function would take the form $\boldsymbol{y = x}$.

However, there is a group of plots, for which the estimated values of elongation differ significantly from each other. In addition, the values of elongation index for a large group of plots in the method M2 are greater than in the method M1. The reason for this discrepancy is the different methodology of applied solutions. In the method M1 the starting point is the direction of plots cultivation possible to determine the length and the width of cultivation and consequently the determination of the elongation index. In the method M2 the index of elongation is determined on the basis of a mathematical pattern of a geometric figure. Therefore, the obtained values of elongation indices for the same parcel can (which is confirmed by the study) take slightly different values. The largest of them was observed for plots of very irregular shape. Graphic illustration of these cases presents the next Figure 3.

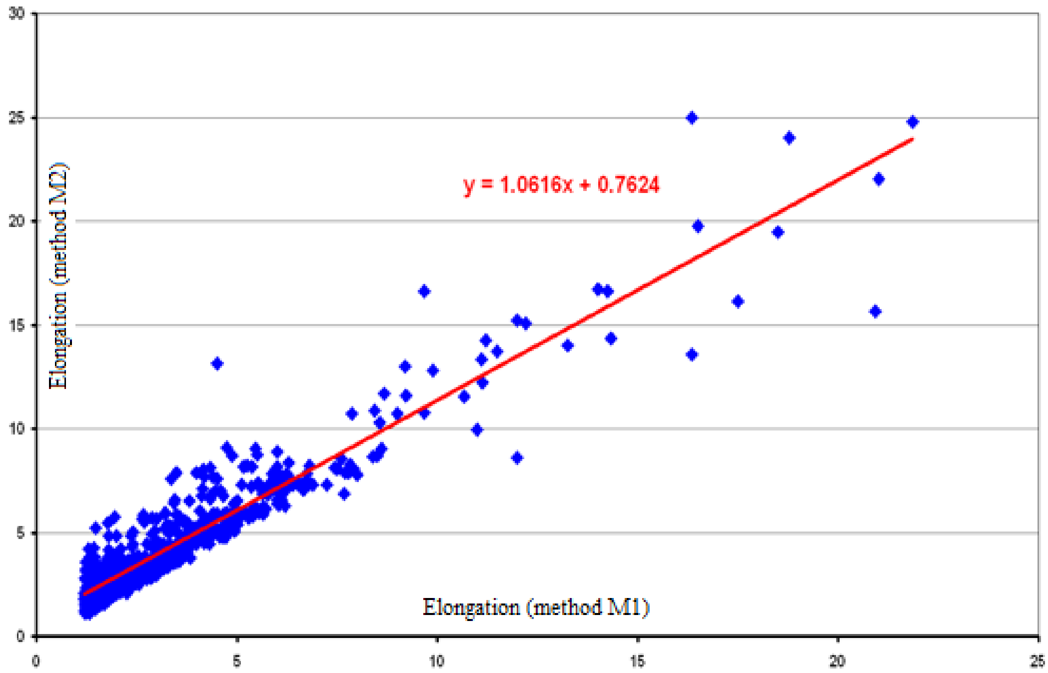

Fig. 2. The dependence of values of plots elongation indices obtained on the basis of the methods M1 and M2 (source: own elaboration)

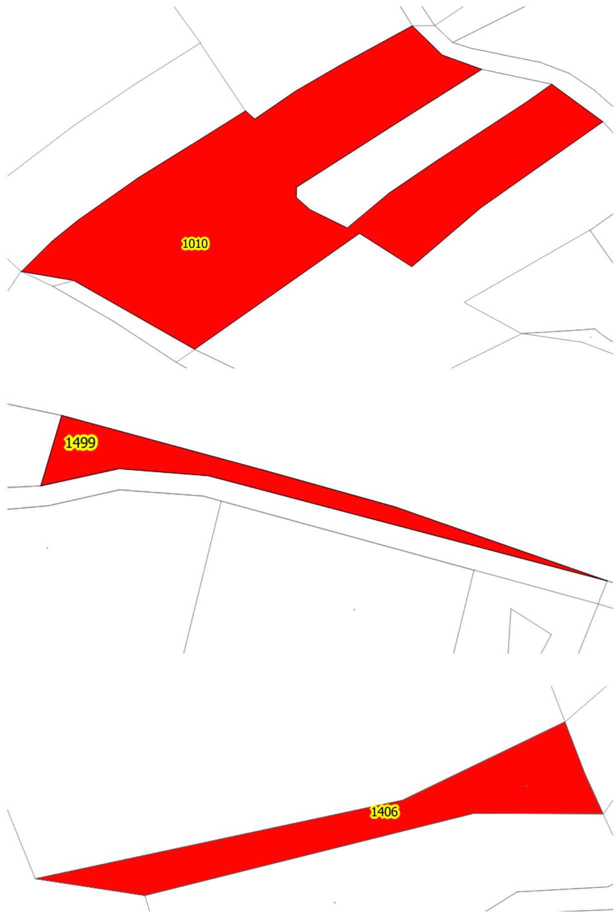

Fig. 3. Examples of shapeless plots (source: own elaboration)

As it can be seen, deformation of certain plots is a serious problem for the observer in determining its actual elongation. Such cases often require an individual examination of each of them. It can be stated, that the use of available computer tools, based on various algorithms for so distorted plots, will supply results which are not uniform to some extent.

The research of elongation indices allowed the statement of closely matching of the obtained values and separated a group of plots for which the results were inconsistent. In the next stage of the study the inspection of these discrepancies consisting in determining the differences at fixed area intervals was carried out. The detailed information is included in Table 1 below.

According to the survey, observed differences of average values at fixed area intervals take values below 1. For a few cases, this value has been exceeded and reaches 1.7. From the point view of assessing the same shape of the plot observed discrepancies do not substantially affect the assessment of its shape. However, in the case of method M1, which allows as a consequence estimate the costs associated with the cultivation, resulting from the spatial shape of the plot, the change of elongation can significantly affect the level of estimated costs.

Table 1. The discrepancies of values of elongation indices for plots in the area intervals (source: own elaboration)

Intervals of plots area [ha]	Number of plots in the interval	Average plot area in the interval [ha]	Average plot elongation by the method M1	Average plot elongation by the method M2	The difference in average elongation	The difference in average elongation [%]
up to 0.10	297	0.05	4.1	5.3	1.2	22.6
0.11 - 0.20	165	0.14	3.2	4.1	0.9	22.0
0.21 - 0.30	58	0.25	2.7	3.5	0.8	22.9
0.31 - 0.40	22	0.34	1.9	2.5	0.6	24.0
0.41 - 0.50	15	0.46	2.3	3.4	1.1	32.4
0.51 - 0.60	18	0.55	2.3	2.8	0.5	17.9
0.61 - 0.70	7	0.67	2.1	2.8	0.7	25.0
0.71 - 0.80	2	0.79	2	2.9	0.9	31.0
0.81 - 0.90	2	0.85	2.3	2.5	0.2	8.0
0.91 - 1.00	1	0.93	3.3	5	1.7	34.0
beyond 1.00	5	1.19	2.2	2.9	0.7	24.1

Conclusion

Basing on the carried out studies, involving comparison of two methods to estimate the index of the plot elongation it was found that both methods give similar results concerning the estimated elongation index. The observed discrepancies between the elongation indices obtained by M1 and M2 methods result from methodological assumptions, as well as from the characteristics of the research object, which has been deliberately chosen due to unusual specificity of the spatial land structure. Large variety, both of the areas of plots and of their shapes caused, that the discrepancies between the estimated elongation indices of plots were strongly exposed. It can be assumed, that the comparison of the two methods on the object, characterized by the regularity of borders of the plots existing there, would give the results proving a very high similarity of estimated elongation indices.

For plots with a large shape deformations, with the increasing distortion of the plot differences are getting bigger. Regardless of the adopted methodical solution, the results obtained on these plots will differ significantly from each other. Therefore, it can be concluded, that in the case of testing the land system with a large distortion of plots, there is no perfect mathematical model that would fully reflect the shape of plots.

The observed differences in the elongation index, confirm the initial assumptions about the discrepancies in the values of estimated indices between the two reviewed solutions. Their scale, intensified by the nature of the land system suggests, that in the case of its research with respect to the effectiveness of farm production, resulting from the shaping of the farmlands in the old (defective) ground system, it is preferable to use the method M1. Taking into account the second aspect of the test, concerning the assessment of the efficiency of production, resulting from the already rebuilt land system (land consolidation), both methods provide similar results. Their convergence, however, will depend on the regularity of the shape of the borders of newly designed parcels.

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