

Research paper

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Land divisions and their impact on the regression of parameters of the spatial arrangement of plots

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Summary

The results presented in the study concern the analysis and assessment of the arrangement of plots on the example of a precinct that in the 1930s in Poland was subject to a process of partial land consolidation. The aim of the study was to assess the spatial arrangement parameters of the cadastral plots involved in plant cultivation. The research assumed the determination of the degree of defectiveness of the present land layout and the estimation of the degree of deterioration of the arrangement of plot boundaries between the present boundary layout and the boundary layout formed in the previous century. In addition, it was attempted to answer the following question: to what extent does the progressive fragmentation of plots over the years reduce the efficiency of agricultural production carried out in their area. The arrangement of the plots was studied using the 'Qgis' software, with the help of which all the necessary parameters of the spatial arrangement of the plots were estimated. In the research process, cadastral data and orthophotomaps, obtained from the geoportal of the Central Office of Geodesy and Cartography in Poland, were used. The assessment of the arrangement of the plots in both old and present variants was carried out through a synthetic measure of their arrangement in the form of the so-called cultivation costs, which depend on the spatial arrangement of the plots. The obtained result provided a basis for indicating the defects of the surveyed layout of boundaries, and for concluding that the defectiveness of the arrangement of plots depends to a large extent on the original layout of boundaries and on the degree of introduced changes in the land layout, which in the surveyed case was estimated at several percentage points.

Keywords

land fragmentation • land consolidation • assessment of the layout of agricultural land



1. Introduction

The plots forming part of an agricultural holding should have a correct shape and be located close to a farm centre. This factor has a significant impact on the efficiency of the agricultural production process by minimising the losses related to the unfavourable arrangement of the plots, and reducing the incurred expenditure on transport. The results in scientific studies prove that both misshapen and excessively fragmented plots make their agricultural use less efficient than is the case with plots of correct arrangement and optimal area [Harasimowicz 2000, Mielewczyk 2010]. The defects in the land systems necessitate the implementation of management and agricultural measures aimed at correcting the defective land system so that its agricultural use is more efficient and profitable. Corrective actions, included in the scope of the undertaken operations of land consolidation and exchange, should be preceded by an assessment of the existing land condition that includes an analysis of the basic spatial-technical parameters for the plots in the study area [Harasimowicz 2002, Gonzalez et al. 2004, Gniadek et al. 2013]. Once the necessary corrective actions have been completed, it is advisable to reassess the new land layout to see to what extent it has been improved. A number of methods can be found in the available literature that allow performing tasks related to the assessment or correction of the rural land layout [Gonzalez 2007, Mielewczyk 2010, Rahman and Rahman 2009, Demetriou et al. 2013, Manjunatha et al. 2013, Kwinta and Gniadek 2017, Leń 2018, Wójcik-Leń et al. 2018, Janus and Taszakowski 2018, Janus 2020, Janus and Ertunç 2022, Zandonadi et al. 2013]. However, it should be remembered that the application of appropriate technical and procedural solutions for this type of work may vary from country to country [Vitikainen 2004]. One of the solutions that allows to make an assessment of the rural land layout is to relate the estimated values of the spatial-technical parameters to the values of the parameters considered to be correct. It also takes into account the so-called synthetic measure of arrangement in the form of cultivation costs that depend on the spatial arrangement of the plot [Gniadek et al. 2013]. By applying this solution, it is possible to estimate the efficiency of the agricultural production process, by taking into account all the basic arrangement parameters of any surface structures with or without access to the plot.

Any rural land layout is subject to change over time, which usually leads to the deterioration of its spatial land structure.

The question can therefore be raised once again as to whether the properties from the last century can have the correct land layout to allow for the current level of mechanisation of field work, and to what extent the subdivisions of plots of land reduce the efficiency of agricultural production. Answering these questions requires detailed research, including a comparison of the previous and current land layouts.

This paper represents a continuation of research concerning changes in the land layout of villages in southern Poland. Its aim is to analyse and evaluate the spatial and technical parameters of land plots in the area of the solectwo of Piotrkowice Małe in Małopolskie Voivodeship, which was partly covered by the land consolidation process. The objective of the study was to determine the degree of defectiveness of the present land layout and to estimate the degree of deterioration in the arrangement of plot boundaries between the present boundary layout and the boundary layout from the previous century.

2. Object of the study

The object of the study is the area of the sołectwo Piotrkowice Małe, which is part of the municipality of Koniusza in the Małopolskie Voivodeship, located in Poland. The location of the study area is presented in Figure 1. The object is characterised by favourable soil conditions for agricultural production. The village should be classified as typically agricultural, which is confirmed by the productive capacity of the soils and the almost complete coverage of the area with land used for agricultural production. The object is characterised by an even coverage of the agricultural transport network, which was shaped in the course of the consolidation works carried out in the last century and the changes made in land divisions. The area of the village is 458 ha and consists of 600 cadastral plots.



Source: Authors' own study

Fig. 1. The location of Piotrkowice Małe precinct against the maps of Poland and the municipality of Koniusza

3. Research methodology

The research process, which involved making an assessment of the land layout of the village of Piotrkowice Małe in its old (post-consolidation) and current state, used the widely available Qgis software. On the basis of cadastral input data obtained from the geoportal of the Central Office of Geodesy and Cartography in Poland and an orthophotomap, the current state of land use in the village was identified. This allowed the selection of cadastral plots (hereinafter referred to as plots) used exclusively for agricultural production. Other plots of land with other uses, such as built-up areas, forests, bushland, waters or roads, were excluded from further study. In order to reconstruct the layout of boundaries as it existed in the previous century, all boundaries introduced as a result of land divisions over the previous decades were eliminated. This task was completed on the basis of plot identifiers present on the map. In the course of performing this task, cartographic documentation of the consolidation of part of the land in the village of Piotrkowice Małe from 1933 and land register maps from 1963 were used. The obtained result allowed to illustrate the differences in the layout of plot boundaries that appeared in the studied period.

For each variant of the boundary layout (previous and current state), the values of basic spatial arrangement parameters were estimated for the surveyed plots in the Qgis software. The obtained values of the features were the basis for the research, which involved comparing the values of the studied parameters with those considered correct or optimal (stage I). Detailed research was performed using a synthetic measure of plot arrangement in the form of cultivation costs (plot layout costs) dependent on the spatial arrangement of the plots, which are estimated in cereal units per hectare of area and the value of 1 cereal unit corresponds to the value of 1 decaton of rye (stage II). This solution can be considered universal, as it eliminates the fluctuation of cereal prices on the markets, and the final monetary values can be estimated in any currency.

The size of the layout cost for a field (in this case a cadastral plot) was estimated based on the following formula [Harasimowicz 2000]:

$$K_r = z_l l + z_b b + jp \frac{1}{4} l$$

where:

- z_l parameter determining the costs associated with the length of the field (boundary losses),
- z_b parameter determining costs related to the width of the field (returns, boundary losses, costs related to the return strip),
 - parameter determining the costs related to field crossings,

l, b, p – field length [hm], field width [hm], field area [ha].

In order to estimate the incurred costs, parameter values were adopted that were dedicated to cultivation with a 55 hp tractor: $z_l = 0.65$, $z_b = 5.20$, j = 0.82 and a cereal yield of 5 t/ha.

In order to prepare and expose the obtained results of the changes in the land layout of the surveyed village, statistical tools were used to determine basic descriptive statistics, perform numerical distributions, and for the necessary mapping studies.

4. Spatial and technical parameters of the plots

Of the total cadastral plots with agricultural use, 346 plots currently and 287 in the old (post- consolidation) state were surveyed. A view of the boundary layouts of the surveyed plots in the old and current state is shown in the following Figures 2 and 3.



Source: Authors' own study

Fig. 2. The boundary layout of cadastral plots with agricultural land in village of Piotrkowice Małe (old state)



Source: Authors' own study

Fig. 3. The boundary layout of cadastral plots with agricultural land in village of Piotrkowice Małe (current state)

The specified basic descriptive statistics for the analysed parameters are given in Table 1. The obtained material shows that in the analysed area there are plots with an average area of 1.13 ha in the old state and 1.08 ha in the present state. This result confirms a slight decrease in the average area of plots in the current state, but this size is still suitable for the mechanical cultivation [Harasimowicz 2002].

Variable	Average	Minimum	Maximum	Median
Plot area [ha] - old state	1.13	0.01	28.11	0.58
Plot area [ha] - current state	1.08	0.01	28.11	0.58
Length of plot [hm] – old state	2.19	0.14	9.57	2.05
Length of plot [hm] – current state	2.25	0.14	9.57	2.07
Width of plot [hm] – old state	0.43	0.02	2.94	0.36
Width of plot [hm] – current state	0.42	0.02	2.94	0.34
Elongation of plot – old state	7.69	1.19	22.19	5.09
Elongation of plot – current state	8.16	1.07	22.19	5.85
Cultivation costs depending on the spatial arrangement of the plot [grain unit/1 ha] - old state	4.98	2.00	35.00	33.00
Cultivation costs depending on the spatial arrangement of the plot [grain unit/1 ha] - current state	4.92	2.07	35.22	33.15

 Table 1. Basic descriptive statistics of the studied plots with agricultural land in the village of Piotrkowice Male in the old and current state

More detailed data are presented in Figure 4. The included distribution of the size of plots in particular class ranges gives a real picture of their area structure. According to Woch [2001], a size not smaller than 1–2 ha is regarded as the minimum area allowing full mechanisation of field work. The results show that the analysed plots are strongly differentiated in terms of the occupied area.

Only about 33% of the plots in the old and current states have the correct acreage. The remaining plots with too little acreage account for 67% in both variants. The coincidental overlap of the percentages may erroneously suggest no change between the compared boundary systems. However, the land divisions that have taken place, implemented over successive decades, have led to an increase in the size of the plots in the surveyed communities. The actual picture of the changes that have taken place, together with the visible deterioration, will be highlighted in the next stage of the research, which will take into account the synthetic measure of formation in the form of cultivation costs. The result obtained at this stage confirms the shortcomings of the studied area structure of plots in both variants and indicates the need for changes in terms of increasing their area.

284



Fig. 4. The numerical distribution of plots with agricultural land depending on their area (old and current state)

The average cultivation length for the plots surveyed is 219 m in the old state and 225 m in the current state (Table 1). This parameter covers a wide range from 14 to several hundred metres. As is evident from the available literature, plots that are below the length of 100 to 150 m generate excessive costs associated with cultivation, reducing the income from production [Harasimowicz 2000]. From the data presented in Figure 5, it can be inferred that the most numerous group are plots with lengths between 200 and 300 m, and there are about 40% of them indicating a slight decrease in the current state. Plots falling within the range of minimum lengths considered suitable for the use of mechanical cultivation are 9% in both compared variants. In total, about 84% of the plots in both variants have sufficient length for the use of full mechanised fieldwork and 16% of the plots should be considered too short.

An important parameter that affects the results of the production is the width of the plot. Its average value in the studied area for both compared variants of land layouts is 43 and 42 m for the old and present state, respectively (Table 1). These values indicate that the plots have sufficient widths, as according to Harasimowicz [2002] the minimum correct plot width for tractor cultivation should not fall below 30 to 50 m. Figure 6 accurately depicts the surveyed communities. The data it contains do not confirm the initial assumptions about the correct plot widths. A large proportion of the plots – about 40% – are below the acceptable threshold, which means a slight increase for the current state.



Fig. 5. The numerical distribution of plots with agricultural land depending on their length (old and current state)



Fig. 6. The numerical distribution of plots with agricultural land depending on their width (old and current state)

The average elongation of the examined plots is about 1:5 for both variants (Table 1). According to Harasimowicz [2002], the optimal elongation of a plot depends on its area, and its value may vary with the size of the plot acreage.

A detailed picture of the elongation of the surveyed plots in both variants is presented in Figure 7. The obtained result proves that the elongation of almost 40% of the plots is less than 1:4, which is not sufficient and may indicate a decrease in the level of generated income from the agricultural production. In the range from 1:4 to 1:6, which can be considered correct for plots of 1 ha, there are only a dozen or so percent of plots with a slight decrease in the current state. The remaining parts of the community of compared layouts have too great an extension (this applies to 45% of the plots in the old state and 49% in the current state).



Fig. 7. The numerical distribution of plots with agricultural land depending on their elongation (old and current state)

The achieved results of the research, including evaluation of such parameters as plot area, its length, width or elongation, conducted separately for each feature may leave some unsatisfactory impression concerning precise estimation of plots with correct or incorrect shape. Due to the adopted direction of the research, concerning the comparison of the surveyed land layouts in the old state and the present one, that takes into account the past land divisions, it is necessary to use a synthetic measure that would include the full characteristics of the arrangement of the plots for both variants, and allow for precise estimation of the changes in the spatial structure of the surveyed land layouts.

5. Assessment of the arrangement of plots using a synthetic measure

A detailed study of the evaluation of the arrangement of plots with agricultural land for both variants of boundary layouts (old and current state) was carried out using a synthetic measure of their arrangement i.e. the so-called cultivation costs depending on the layout of the plot.

The size of these costs for a plot with a correct arrangement and optimal area according to Harasimowicz [2000] should not exceed 4 cereal units/1ha. The increase in the value of this parameter beyond the above-mentioned threshold suggests irregularities in the arrangement of the plot, which implies a limitation of its production possibilities and, as a result, a decrease in its profitability.

On the basis of the research, it can be concluded that the average value of the cultivation costs for the old and the current state is in the range of 5 cereal units/1 ha (Table 1). Similar values suggest that there are the abnormalities mentioned earlier, which reduce the effective management of the study area in both variants.



Source: Authors' own study

Fig. 8. The numerical distribution of plots with agricultural land depending on cultivation costs related to their arrangement (old and current state)

More detailed information on the productive capacity of the plots in both variants of the boundaries (old and current) is presented in Figure 8. On its basis it can be observed that about 55% of the plots in the old state were correctly arranged. Compared to the current state, a significant reduction in the community of this bracket by 13 percentage

points is evident. The decrease in the number of correctly arranged plots with optimal area has resulted in an increase in the number of incorrectly arranged plots. This is most evident in cultivation costs in the range of values between 4 and 6 cereal units/1ha. The growth between the old and current state was by 10 percentage points in this interval. The remaining difference of 3 percentage points is evident in the next two ranges.

The observed change in the value of the estimated cultivation costs depending on the spatial arrangement of the plot, between the boundary systems (old and current), is attributable to changes in the boundaries of the cadastral plots caused by land divisions resulting in their fragmentation. As can be seen, the subdivision of about 59 plots of land in recent decades has led to significant changes in the ability to manage this land efficiently.

6. Summary and conclusions

A study of the evaluation of the land layout in the village of Piotrkowice Małe on the basis of the key parameters of spatial arrangement and a synthetic measure in the form of cultivation costs that depend on the spatial arrangement of the plot allowed for the identification of regularities and defects in the compared land layouts (old and current).

A detailed analysis of the obtained sizes of the spatial-technical parameters of the plots revealed a partial defectiveness of the spatial structure of the studied land in the old state.

This result should certainly be explained by the alignment of the formed layout of the boundaries to the farming methods of the time with the solutions used in the first half of the last century. In spite of this, part of the land would meet the current criterion, enabling full mechanisation of fieldwork.

As demonstrated, the modifications to the layout of boundaries that have taken place in recent decades have contributed to an increase in the number of plots of land by approximately 17%. This rise has resulted in changes that, in the current land layout, are responsible for a deterioration in the capacity of the plots to be developed effectively. The research undertaken in stage I - which analysed the area of plots, their lengths, widths and their elongations (old and current state) - provided a preliminary picture of the changes in the state of the plots under study. Admittedly, the results obtained therein comprehensively expose the changes in the values of individual parameters, but they do not allow for a synthesis that would lead to the formation of final conclusions with regard to the state of the boundaries of individual land layouts. The final determination of the deterioration of the production capacity of the plots, in terms of their area and configuration of the boundaries, was possible at stage II. This stage included the evaluation of the boundary layout with the use of cultivation costs as a synthetic measure of arrangement that depends on the spatial arrangement of the plot (old and current state). When comparing the values of the index of cultivation costs dependent on the spatial configuration of the plot in the individual class ranges for the old and the present boundary layout, it was found that the production efficiency in the present boundary layout, in terms of plot configuration, deteriorated by 13 percentage points.

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