http://dx.doi.org/10.15576/GLL/2023.4.357

GLL

Geomatics, Landmanagement and Landscape No. 4 • 2023, 357–370

REGRESSION OF THE LAYOUT OF PARCELS AFTER LAND CONSOLIDATION

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Summary

The results of the research presented in this paper concern the analysis and evaluation of the shape of parcels using the example of a precinct that underwent a land consolidation process in Poland in the 1930s.
The aim of the study was to assess the spatial parameters of the record parcels involved in the cultivation process. The study included the determination of the degree of defectiveness of the present land layout and the estimation of the degree of deterioration of parcel boundaries between the present boundary layout and the boundary layout achieved after the consolidation. It also attempted to answer the following question: can a post-consolidation site from the last century have a land layout that allows for the current level of mechanisation of field work, and to what extent does the gradual fragmentation of parcels over the years reduce the efficiency of agricultural production in their area.
The survey of the shape of the parcels was performed using the 'Qgis' software and the 'SWORG' Land Configuration Evaluation Support System. Cadastral data was used in the research process. The evaluation of the land parcel layout in both variants after the consolidation and in the present state was done with a synthetic measure of their layout, the so-called cultivation costs, which depend on the spatial layout of the parcels. The obtained result provided a basis for indicating the defects of the examined arrangement of borders and for determining that the defectiveness of the land parcel layout largely depends on the arrangement of borders designed in the consolidation process and on the degree of changes introduced in the land layout, which in the examined case was estimated at several percentage points.

Keywords

land configuration • GIS systems • land parcel layout

1. Introduction

The basic tool for correcting the defective layout of the boundaries of cadastral parcels is consolidation and replacement works, which result in a new layout of boundaries with more favourable parameters of parcels in relation to the state before consolidation, reduction of their fragmentation, and closer location of parcels to the farm settlements. The objectives, procedures, and technologies of this type of work usually

vary from country to country [Vitikainen 2004] and are based on developed solutions, adapted to the needs of the area. Topics including consolidation works have been and are considered by many authors. In their studies, they present results, concerning the improvement of the consolidation process [Janus 2020, Janus and Ertunç 2022] as well as the assessment and selection of agricultural production space for its reconstruction [Gonzalez 2007, Rahman and Rahman 2009, Mielewczyk 2010, Demetriou et al. 2013, Manjunatha et al. 2013, Kwinta and Gniadek 2017, Leń 2018, Wójcik-Leń et al. 2018, Janus and Taszakowski 2018].

According to [Tokarski 1980], the term 'consolidation' comes from the Latin roots 'com-' ('together') and 'solidare' ('to make solid'), which means to bring things together to make something solid, stronger or easier to handle. In each consolidation procedure, a change in the arrangement of boundaries requires adaptation to the existing terrain conditions, the agricultural transport network (which may be modified if necessary), the number of participants in the procedure, the size of individual shares, and the level of mechanisation of field work. Taking into account these aspects, it should be borne in mind that the obtained effects of consolidation works can strongly differ regarding the possibility of reducing the number of parcels, improving their spatial and technical parameters, as well as their distribution in relation to settlements. The new layout of agricultural land boundaries achieved as a result of consolidation and exchange works is subject to transformations in the long term, as a result of land divisions and continuous real estate turnover. This process may significantly reduce the possibility of effective management of such land and reduce the income from farming, which can be identified through the application of appropriate survey methods, adapted to the existing conditions and the level of applied mechanisation of field work in a given region.

Given the changes taking place in the layout of agricultural production space, the question can be raised as to whether a post-consolidation site from the last century can have a land layout that allows for the current level of mechanisation of field work, and to what extent the fragmentation of land parcels over the years has reduced the efficiency of agricultural production in their area.

The aim of the study was to analyse and evaluate the parameters of the spatial layout of farms in the area of the village, which was subjected to a land consolidation process a few years before World War II. The study included the determination of the degree of defectiveness of the present land layout and the estimation of the degree of deterioration of parcel boundaries between the present boundary layout and the boundary layout achieved after the consolidation.

2. The study's object

The study covered the area of the Przysieka village located in Poland in the Kozłów municipality in the Małopolskie voivodeship. Its location is shown in Figure 1. The object is characterised by favourable soil conditions for agricultural production and mild gradients of the terrain which do not obstruct the organisation of cultivation

processes. Przysieka should be classified as a typically agricultural precinct, which is evidenced by the productive capacity of the soils and the almost complete coverage of the area with arable land. The present layout of the agricultural transport network and the layout of the boundaries of the record parcels is the result of the consolidation works carried out in the last century and the changes in the property divisions, as well as the completed linear investments. The area of the village of Przysieka is 639 ha and consists of 794 record parcels.

Source: Author's own study based on Wikipedia

Fig. 1. Location of Przysieka village against the map of Poland and the map of Kozłów municipality

3. Methodology of the study

The research was based on the 'Qgis' software and the 'SWORG' Land Configuration Evaluation Support System, which allows for the automation of the process of evaluating the farmland configuration. Together they include all the necessary parameters of the spatial arrangement of land parcels or fields, as well as the estimation of the configuration costs incurred on each parcel or field [Gniadek 2005]. The basic Source

of information necessary to carry out the study was cadastral data obtained from the geoportal of the Head Office of Geodesy and Cartography in Poland and an orthophotomap, which served as the basis for identifying the current state of land use in the study area.

In order to estimate the changes in the layout of the boundaries in relation to the original (post-consolidation) state, the boundaries that resulted from the subdivisions of land parcels done over successive decades were eliminated. This exercise was carried out on the basis of parcel identifiers. This made it possible to visualise the state of the boundary layout that was adopted after the consolidation.

Due to the limited input data, which made it impossible to identify whether the parcels belonged to individual farms in the current state and immediately after the consolidation, the study was narrowed down to an assessment of the layout of the parcels alone, without taking into account the actual routes between settlements and parcels. The omission of access routes was counterbalanced by an additional analysis of the accessibility of the parcels to roads in the current state, which made it possible to identify parcels without such access.

The adopted methodology made it possible to determine, for each surveyed parcel of land both in the post-consolidation and present state, the basic spatial-technical parameters, together with information on the existing access to a public road. The final assessment of the layout of parcels was made with the use of a synthetic measure of their layout i.e. the so-called land configuration costs, which depend on the spatial layout of a parcel. These costs include all expenses and production losses related to the cultivation of the parcels, such as yield losses at the field boundaries, losses related to headlands at the field ends, costs of residual passes, costs of empty passes, or costs related to the management of the headland strip. Land configuration costs are a synthetic measure of parcel layout and can be expressed in grain units per hectare of land. It is assumed that 1 grain unit corresponds to the value of 1 decitonne of rye. The use of such a measure without estimating final money sums provides a universal solution that is not affected by changes in grain prices in the markets.

The magnitude of the land configuration cost index for an arable land field (in this case a record parcel) was based on the following formula [Harasimowicz 2000]:

$$K_r = z_l\, l + z_b\, b + j p^{¼}\, l$$

where:

- z_l – parameter determining the costs associated with the length of the field (boundary losses),
- z_b – parameter determining the costs associated with the width of the field (headlands, boundary losses, costs associated with the headlands strip),
- j – parameter determining the costs associated with field passes,
- i, b, p – field length [hm], field width [hm], field area [ha].

The following parameter values, dedicated to the cultivation of arable land with a 55 HP tractor, were adopted to estimate the costs incurred: $z_l = 0.65$, $z_b = 5.20$, $j = 0.82$.

The detailed examination of the parcels consisted of an assessment of their layout by comparing individual features of parcel configuration with the sizes considered to be correct or optimal.

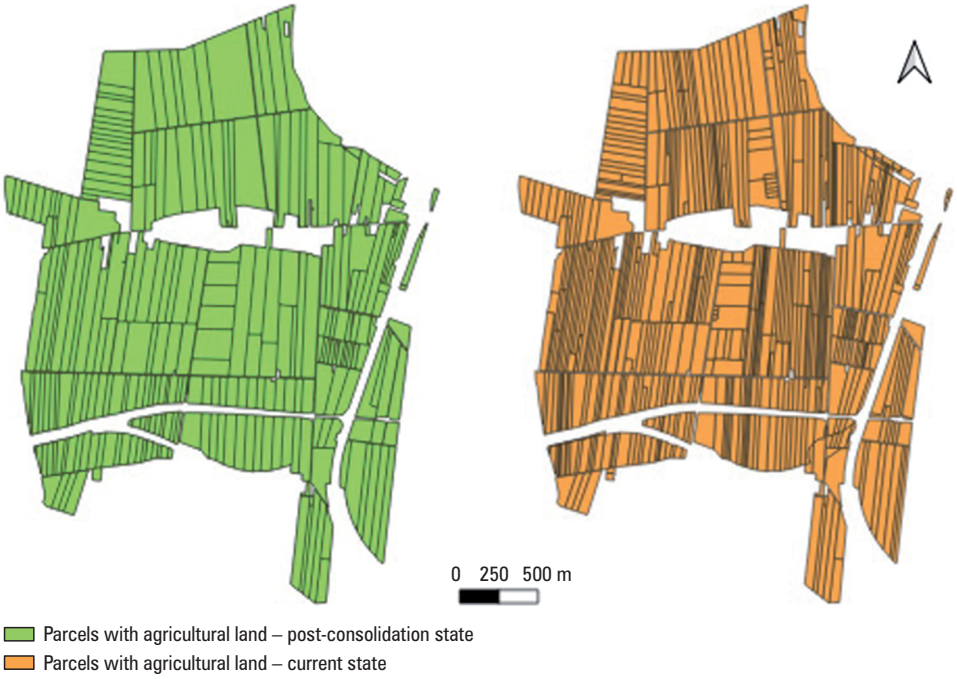
Statistical tools were used in the research process and the results obtained are presented in the form of map studies, basic descriptive statistics, and strength distributions.

4. Spatial and technical parameters of the parcels

On the basis of data obtained from the geoportal and the orthophotomap, land uses were identified using the 'Qgis' software, distinguishing areas of agricultural development, roads, areas where crops are grown and areas excluded from agricultural activity (Fig. 2). The attributes entered into the database made it possible to select land included in the agricultural production process, the so-called agricultural land, for which a detailed study was carried out of the characteristics of the spatial layout of the record parcels and the cultivation costs depending on their layout for both the post-consolidation and present state, which in the following will be referred to as parcels. Of the 794 land parcels in the current state, 563 parcels with agricultural land were surveyed in detail. In relation to the post-consolidation state, 281 parcels with agricultural land were surveyed. A view of the surveyed parcels in the post-consolidation and current state is shown in Figure 3.

Source: Author's own study

Fig. 2. Current layout of boundaries of Przysieka with identified land uses



Source: Author's own study

Fig. 3. Layout of boundaries of parcels with agricultural land in the village of Przysieka in the post-consolidation and current state

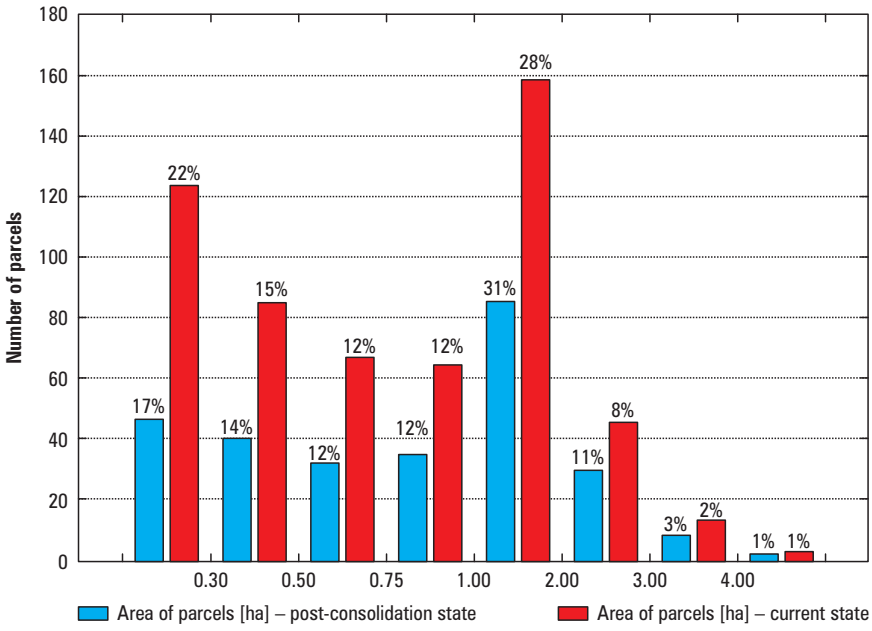
Based on the data presented in Table 1, it can be preliminarily concluded that most of the average values of the parameters of the studied characteristics of the parcels in both variants (after consolidation and the present one) in the studied village can be considered correct. The exception here is the small value of the average width of parcels, which influences the increase of the index of cultivation costs without access, exceeding the value of 4 units of grain/1 ha considered correct [Harasimowicz 2000]. However, it should be remembered that the average values of such parameters do not provide a complete picture of the existing condition, but only inform in a general way.

Table 1. Basic descriptive statistics of the studied plots with agricultural land in the village of Przysieka in the post-consolidation and current state

Variable	Mean	Minimum	Maximum	Median
Area of parcels [ha] – post-consolidation state	1.07	0.01	4.22	0.92
Area of parcels [ha] – current state	0.95	0.01	5.64	0.77
Length of parcels [hm] – post-consolidation state	2.82	0.14	8.93	2.25
Length of parcels [hm] – current state	2.92	0.07	8.93	2.47

Width of parcels [hm] – post-consolidation state	0.37	0.03	1.32	0.32
Width of parcels [hm] – current state	0.32	0.01	1.33	0.27
Elongation of parcels – post-consolidation state	11	1.2	36	6.81
Elongation of parcels – current state	13	1.1	38	8.21
Cultivation costs depending on the spatial arrangement of the parcel [crop unit/1 ha] – post-consolidation state	5.27	2.45	37.38	3.85
Cultivation costs depending on the spatial arrangement of the parcel [crop unit/1 ha] – current state	6.39	2.32	84.99	4.2

Source: Author's own study



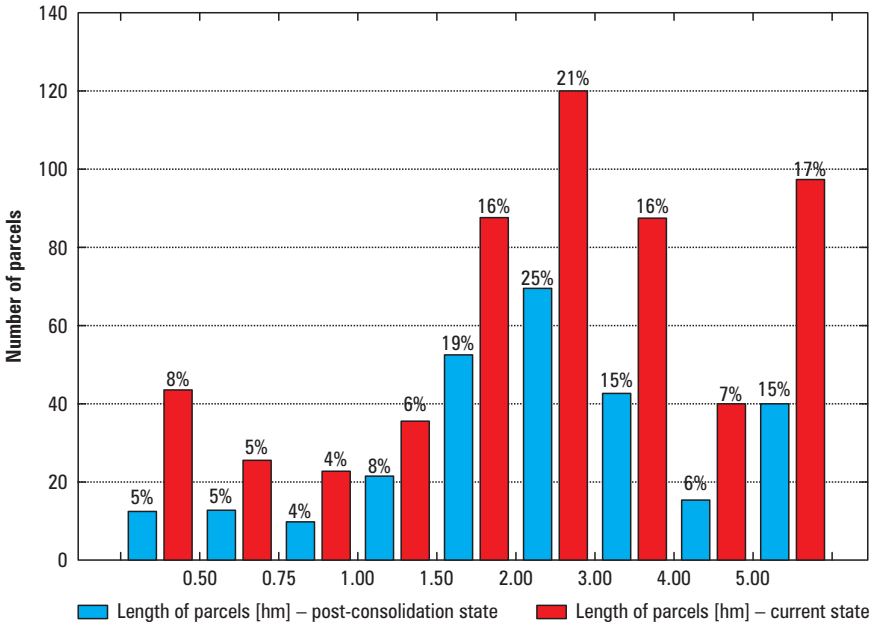
Source: Author's own study

Fig. 4. Strength distribution of parcels by area in post-consolidation and present state

As can be seen from Figure 4 showing the strength distribution of parcels according to their area, the minimum area for parcels considered suitable for the use of mechanical cultivation in field work should be no less than 1 ha [Harasimowiczem 2000, Woch 2001]. In the discussed case, there are about 40% of parcels with such areas in the current state. The remaining 60% of the parcels are not adapted to solutions allowing full mechanisation of field work. Considering this fact and the number of parcels with the correct area, which is close to about 40%, it should be concluded that the smaller parcels are the result

of adjustment of the boundary layout to the way land was cultivated in the last century and the interference in the land layout made in the decades following the consolidation. This is confirmed by the distribution of the area of parcels in the post-consolidation state, in which the percentage of areas over 1 ha is higher compared to the present state.

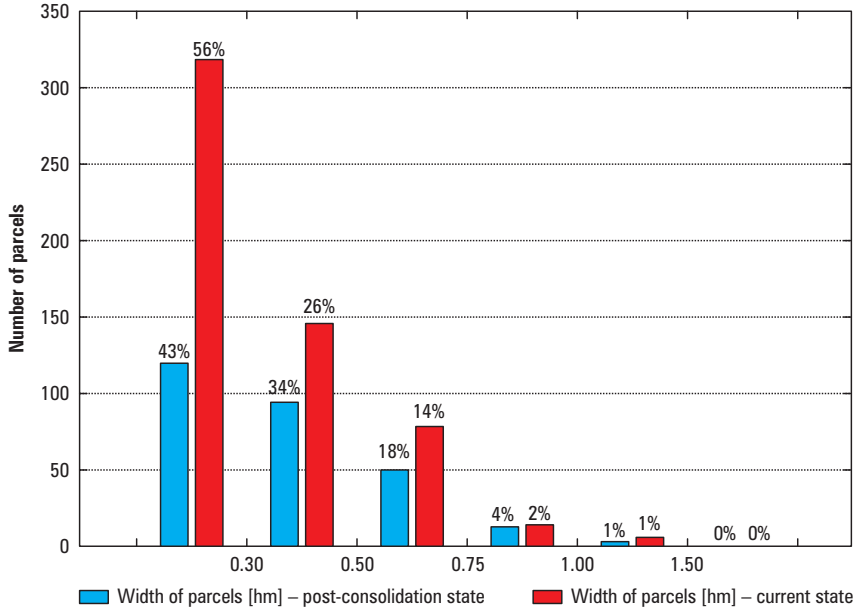
The second parameter analysed is the length of the parcels. Its average value, according to Table 1, is around 290 m (current state) and 280 (post-consolidation state). In both variants, this parameter includes a wide range of parcels, from a few metres to nearly 900 m. According to the available literature, the optimal length of a parcel on which full mechanisation of the agricultural production process can be applied should not be less than 150 m [Harasimowicz and Ostrągowska 1996]. The strength distribution in relation to the length of parcels presented in Figure 5 demonstrates that currently almost 80% of the surveyed land parcels have lengths that enable full mechanisation of field work. In the case of the post-consolidation layout, there are several percent more parcels within such a range. Analysing the layout of parcel boundaries in the study area, one can see the reason for such a state. The high number of parcels with the appropriate length is related to the fact that the new boundaries, resulting from the divisions carried out over the years, mostly coincide with the direction of the longer side of the divided parcel, which, as a consequence of the separation of new elements, does not create shorter parcels. The values of the analysed parameter can be considered correct, but each parcel of land that is divided in this way will be narrower, increasing its cultivation costs as a consequence.



Source: Author's own study

Fig. 5. Strength distribution of parcels by length in post-consolidation and present state

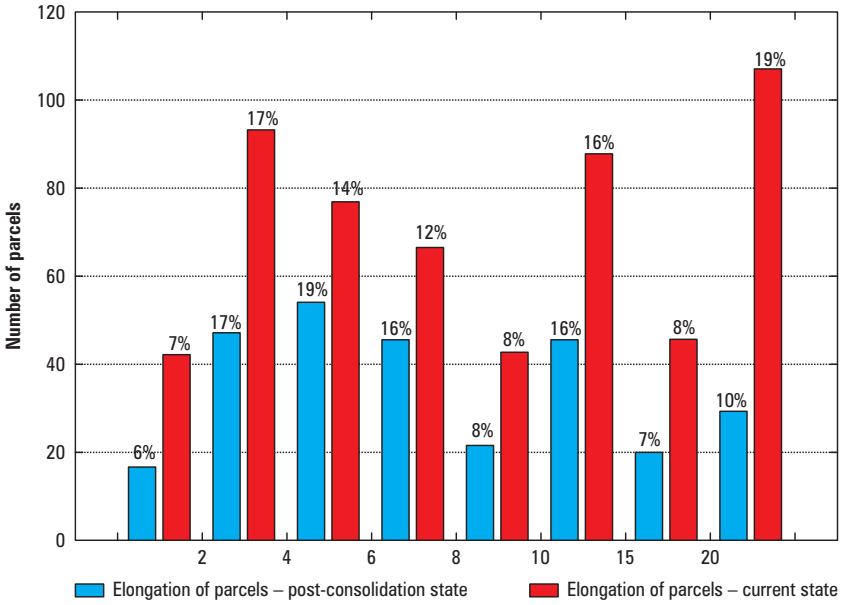
The next parameter analysed is the width of the parcel. The data in Table 1 show that its average value for the current state is 32 m and it can be considered appropriate [Harasimowicz 2002]. For the post-consolidation state, the value of this parameter is several metres higher. Figure 6 accurately represents the whole studied group. The data confirm the initial assumptions about the defectiveness of a significant cluster of this feature, resulting from how divisions have been made over the years and the formation of boundaries in the consolidation process. More than 50% of the parcels in the current state have widths insufficient to carry out fully mechanised field work, but nearly half of the parcels have retained the widths that were designed in the consolidation process. Compared to the post-consolidation state, it can be concluded that there has been an increase in the proportion of parcels with incorrect widths.



Source: Author's own study

Fig. 6. Strength distribution of parcels by width in post-consolidation and present state

The last parameter is the elongation of the parcels. Its average value is the current state is about 1:13, while in the post-consolidation state about 1:11. According to Harasimowicz [2002] appropriate parcel elongation is not a constant property as it depends on the parcel's area, and it should be related precisely to this factor, since it influences the appropriate lengths and widths. Detailed information on the examined parameter in both variants (current and post-consolidation are presented in Figure 7. According to this information, the analysed cluster of parcels is characterised by a wide range, significantly exceeding the extent assumed by the consolidation instruction in Poland [1983]. The reason for this was mainly the way the divisions were made over the years.



Source: Author's own study

Fig. 7. Strength distribution of parcels by elongation in post-consolidation and present state

Source: Author's own study

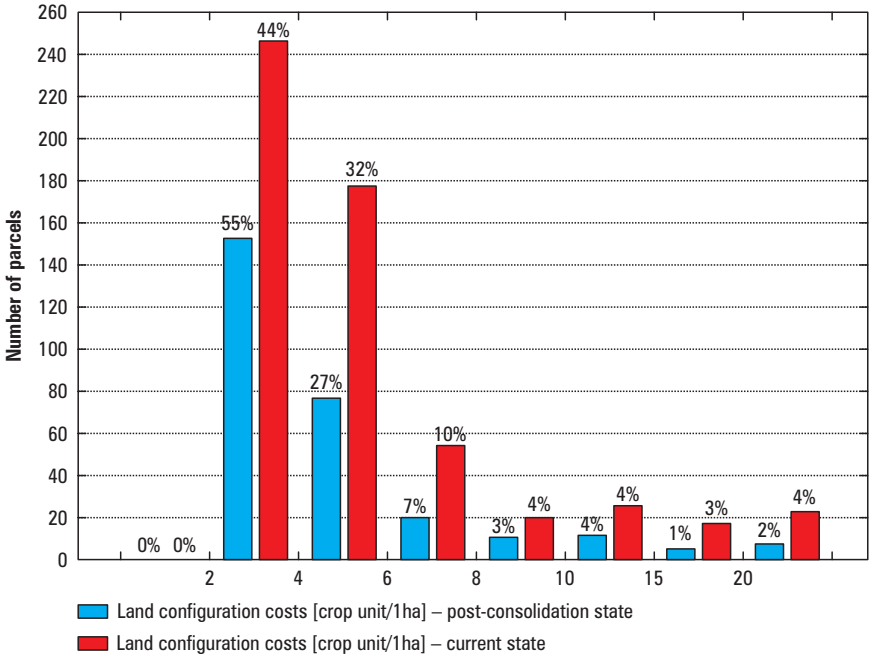
Fig. 8. Layout of boundaries of parcels in Przysieka village and the location of parcels with agricultural land without road access

5. Accessibility to agricultural transport roads

According to the existing regulations, the execution of the consolidation works should provide each planned parcel with direct road access. In order to identify cases of parcels without direct road access, the site was surveyed using 'Qgis' software tools. The result, shown in Figure 8, indicates the current location of parcels without road access. These results confirm flaws in the land layout by identifying 155 cases of parcels with a total area of approximately 105 ha for which no direct road access has been provided in the division process over the years. The area of these parcels reaches 20% of the area covered by the agricultural production process. A different form of access may have been proposed for the divided parcels, which is permitted under current Polish law, but in the case of real estate transactions this may pose a serious problem for potential buyers or tenants.

6. Agricultural production efficiency

According to the adopted methodology, evaluation of the efficiency of agricultural production for a specific set of parcels can be based on a synthetic measure of their layout, such as the so-called cultivation costs depending on the land configuration. The applied solution made it possible to estimate the value of the index of cultivation costs for all the studied parcels under the assumption of full mechanisation of field works with the use of medium power tractors and grain yield at the level of 5 t/ha [Harasimowicz and Kubowicz 1994]. As already mentioned, the correct magnitude of the mentioned index for parcels with optimal area and appropriate shape should not exceed 4 cereal units/1 ha. As the calculations show, its average value for the studied cluster exceeds 6 crop units/1ha in the present state and 5 crop units/1 ha in the post-consolidation state. On the basis of Figure 9, it can be concluded that less than half of the surveyed cluster in the present state has an optimal area and shape. This is undoubtedly a consequence of the initial consolidation procedure and the fact that subsequent land divisions carried out over the years did not include these parcels. The remaining – about 30% of the land parcels – have unsuitable surface and shape parameters, and 25% require radical changes in terms of redevelopment of their boundaries. The data in the analysed figure show that the percentage share of parcels in the post-consolidation state with an index value of up to 4 crop units/1 ha is more than 10 percentage points higher and indicates a decrease in the percentage share of parcels with the correct shape in the current state of the cluster of parcels. Analysing the present layout of the boundaries, it should also be noted that in the village of Przysieka there have been cases of parcels observed which have been divided in a way suggesting their future development. Such arrangements are common in rural areas. The elimination of such a cluster would certainly increase the acreage of parcels with the correct shape, but the identification of use carried out excludes such a possibility, leaving the picture as it results directly from the conducted calculations.



Source: Author's own study

Fig. 9. Strength distribution of parcels by cultivation costs in post-consolidation and present state

7. Summary and conclusions

The issues presented in the paper, which included a study of the spatial layout of parcels belonging to farms in the Przysieka village, made it possible to indicate the existing flaws in the land layout. Based on the results of the research, the type and extent of irregularities resulting from land divisions carried out over several decades could be estimated. The values of the estimated parameters of area, length, width, and elongation for the surveyed parcels indicate that the changes in the layout of the parcels that have been occurring after the land consolidation works have led to a deterioration in the parameters of the parcels, resulting in a decrease in their income from agricultural production. Taking into account the current possibilities of applying modern systems and solutions in the agricultural sector, the obtained result of the research in Przysieka, which included the four analysed parameters, proves that the surveyed boundary layout is partially (about 40%) defective. This is confirmed by the evaluation of the surveyed area with the use of a synthetic measure of layout, i.e. cultivation costs depending on the spatial arrangement of the parcels, the acceptable level of which can be observed in only 44% of the surveyed cluster. The investigation into the accessibility of the parcels to roads has shown that about 20% of the parcels with agricultural land currently have no direct access to any road.

The values obtained for the surveyed parameters indicating the defectiveness of the layout are not entirely caused by the change in the boundaries following the subdivisions. The original layout of the boundaries of the surveyed parcels, adapted to the needs of agriculture at that time, which, as the research indicates, almost half meets the requirements for the needs of today's agriculture, is mainly responsible for the current, defective state of the surveyed layout. When comparing the value of the index of cultivation costs depending on the spatial arrangement of a parcel in particular class ranges for the present arrangement of boundaries and the arrangement after consolidation, the deterioration of production efficiency due to land parcel layout can be approximated at a dozen or so percentage points.

However, to formulate more universal conclusions relating to such post-consolidation sites requires further research.

Funded by the Ministry of Education and Science's subvention to the University of Agriculture in Krakow for 2023.

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