



# Assessment of the Spatial Organisation of Rural Areas with Emphasis on Land Consolidation and Exchange Works: A Case Study of Zagnańsk Municipality

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**Abstract:** This study examines the spatial structure of rural areas to evaluate the demand for land consolidation and exchange, using the Zagnańsk commune in Świętokrzyskie Voivodeship, Poland, as a case study. The commune's land use is dominated by forested areas (60.16%), followed by arable land (20.15%), highlighting both its natural resources and agricultural significance. The analysis identifies substantial land fragmentation, with 40.12% of private parcels under 0.10 ha, and a lack of road access to 39% of parcels, especially in districts like Kaniów and Gruszka. Land tenure is primarily divided between state-owned (59%) and privately owned (36.41%) lands, with significant variations across cadastral districts. Soil quality assessments reveal productivity indices ranging from 21.47 to 45.90 for arable land and 26.25 to 43.13 for grasslands, underscoring regional disparities. The study develops a ranking of consolidation needs, identifying Kaniów, Gruszka, and Kajetanów as priorities due to high fragmentation and accessibility issues, while Długojów is deemed least urgent. Findings emphasize the necessity of targeted land management strategies to optimize agricultural efficiency and spatial organization. Prioritizing consolidation efforts can address key challenges, including parcel geometry and accessibility, to enhance rural development.

**Keywords:** accessibility analysis, land consolidation, land fragmentation, rural development

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## 1. Introduction

The spatial structure of rural areas in Poland has evolved over centuries due to human activity, socio-economic changes, and natural conditions. A crucial part of this transformation is land consolidation and exchange, processes essential in areas affected by land fragmentation [3, 21, 23, 24]. Before initiating such projects, a detailed analysis of the spatial structure is necessary to provide the information needed for effective planning and prioritisation of consolidation efforts [9]. The history of land consolidation in Poland dates to the medieval period, with early efforts by ecclesiastical institutions to consolidate land, a practice that continued during the partitions [18].

After Poland regained independence in 1918, the government faced the challenge of integrating regions with varying levels of economic development. In 1923 the Land Consolidation Act was passed, consolidating over 5.4 million hectares of land [10, 8]. Post-WWII consolidation efforts were slower due to political changes and the state's agricultural policy, which focused on allocating land for agricultural cooperatives [13]. Poland's accession to the European Union in 2004 initiated a broad restructuring of rural areas, with land



consolidation aimed at improving spatial organisation, reducing the number of farms, and increasing their size while also preserving the environment and shaping the agricultural landscape [16].

The main objective of the Common Agricultural Policy of the European Union (EU) is to improve the quality of life in rural areas and to make the best use of their diverse resources. Socio-economic differences in the EU Member States persist despite numerous actions taken within the framework of the broadly understood EU policy. Many authors of scientific publications indicate that these projects do not fully bring the expected results [1,9,10]. This state of affairs is confirmed by the report of the European Commission for Economic and Social Cohesion [15].

The 1982 Land Consolidation and Exchange Act regulates land consolidation in Poland. This key legal framework governs the procedures for consolidation, including the initiation process, the steps involved, and the protection of participants' interests. This act ensures that land consolidation efforts are consistent with national regulations and facilitate the transfer of ownership rights [20]. The consolidation process in Poland shares similarities with other European countries, such as Lithuania and Norway, and is based on principles set by international bodies like the United Nations [17].

An overview of the current legal regulations helps to understand the legal framework directly influencing the discussed issue. This is crucial for ensuring compliance with applicable laws. In Poland, land consolidation and exchange activities are governed by the Land Consolidation and Exchange Act of March 26, 1982 (Journal of Laws 2023, item 1197). This document is a key legal act containing essential information about consolidation processes, such as the objectives and areas of land consolidation, the initiation procedure, the course of land consolidation and exchange, and the protection of participants' interests.

## **2. Materials and Methods**

This study aims to analyse the spatial structure of rural areas in the context of the demand for land consolidation and exchange, using the Zagnańsk commune in Kielce County, Świętokrzyskie Voivodeship, as a case study.

The Zagnańsk commune comprises five types of land use: agricultural land, forested and wooded areas, built-up and urbanised areas, water bodies, and various other areas. The dominant land use is forested and wooded areas, primarily forests covering 7,491.22 ha (60.16% of the total area), highlighting the region's natural resources and recreational potential. Agricultural land also constitutes a significant portion, with arable land covering 2,508.78 ha (20.15% of the commune), indicating the importance of agriculture in the local economy. Other agricultural areas include meadows, pastures, orchards, and fallow land.

The built-up and urbanised areas include roads (175.71 ha), railway land (160.72 ha), and residential regions (91.52 ha), which facilitate communication and urban development. Water bodies occupy a small portion of the land, with areas under flowing (19.77 ha) and standing (10.55 ha) surface waters. The smallest group, other regions, constitutes just 0.06% of the total area, covering 7.85 ha.

Arable land dominates in the cadastral districts of Bartków (57.93%), Jasiów (65.04%), Kajetanów (56.60%), Kaniów (65.68%), and Umer (53.84%), where it occupies more than half of the total area, indicating their agricultural character. Permanent meadows cover the largest areas in Kajetanów (20%) and Umer (17.48%), while permanent pastures near Samsonów account for nearly 14% of the district's total area, suggesting their importance for livestock



farming. The highest percentages of orchards are found in the Bartków and Jasiów districts, at 2.05% and 3%, respectively.

Forests and wooded areas dominate in 9 out of 15 cadastral districts of Zagnańsk, including Belno (approx. 81%), Długojów (approx. 86%), Gruszka (approx. 75%), Jaworze (approx. 75%), Kołomań (approx. 73%), Samsonów (approx. 53%), Szałas (approx. 58%), Tumlin (approx. 61%), and Zachełmie (approx. 67%). Residential areas in the Zagnańsk district account for 11.36%, likely correlated with the highest population of the commune (1,944 residents). Railway land is found in five districts: Bartków, Gruszka, Tumlin, Zachełmie, and Zagnańsk (Fig. 1.).



Figure 1. Usage structure of the Zagnańsk municipality

In the Zagnańsk commune, state-owned land, which does not overlap with perpetual leaseholders, comprises the largest percentage, covering 7,358 ha (59% of the total area). This is due to the commune's extensive forested areas. The second-largest group comprises privately owned land, 4,543.33 ha (36.41%). These two groups dominate the property structure of the commune. The smallest group is state-owned enterprises and other public legal entities, covering only 0.04 ha. Additionally, no land is registered under specific legal categories, such as municipalities, counties, or voivodeships, in combination with perpetual leaseholders.

The land tenure structure in the Zagnańsk commune provides a detailed overview of land division among different registration groups across 15 cadastral districts. It includes the land area and the percentage share of each district registration group, enabling a precise assessment of land ownership in the studied area.

State-owned lands, which do not overlap with perpetual leaseholders, dominate in the Długojów district, constituting nearly 90% of the total area of 1,151.19 ha. This represents the highest percentage of state-owned land among all districts. Conversely, the lowest share of



state-owned land is found in the Jasiów district, which accounts for only 0.85%. Lands belonging to the third registration group are found exclusively in the Zagnańsk district, covering just 0.04 ha (0.01% of the commune's total area).

Group 7, consisting of privately owned lands, is the second most prevalent form of land ownership in the commune. The largest share of this group is found in the districts of Jasiów (94.57%), Kaniów (89.47%), and Umer (87.08%). The smallest share of private land is in Długojów (9.69%). The remaining groups (2, 4, 5, 8, 9, 10, 11, 13, 15, and 16) marginalise the overall land tenure structure, as their land areas are minimal, and their percentage share is negligible (Fig. 2).

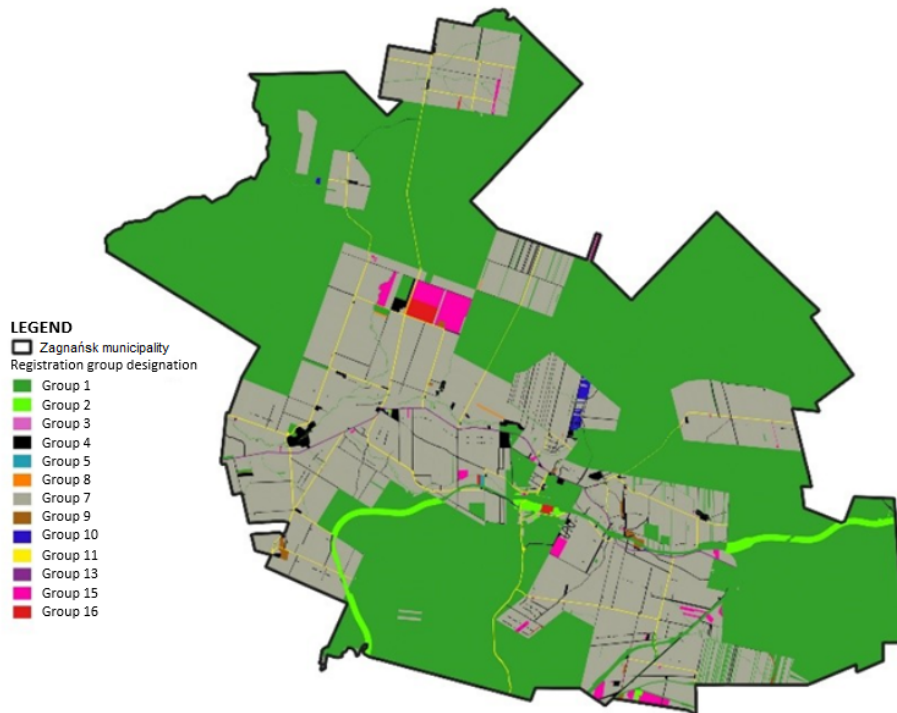


Figure 2. Ownership structure of the Zagnańsk municipality

### 2.1. Evaluation of Agricultural Land Quality

Soil classification based on quality can be based on attributes such as fertility, productivity, and yield. While these terms were once synonymous, they are now distinguished with different meanings. The term "productivity" refers to the soil's ability to produce biomass, typically measured by the amount of dry organic matter produced per unit area.

This study includes calculations of the productivity index for arable lands and permanent grasslands across the 15 cadastral districts of the Zagnańsk commune. The point values assigned to the individual soil classes for both arable and grasslands were taken from Table 1.

Table 1. Point values of quality classes of arable land and grassland

Land class	Arable land	Grassland
I	100	90
II	92	80
IIIa	83	65
IIIb	70	



IVa	57	45
IVb	40	
V	30	35
VI	18	15

The productivity value index for individual cadastral districts was calculated using the following formula (1) [8]:

$$W_{wp} = \frac{\sum_{1}^n (x_n \cdot W_p)}{P} \quad (1)$$

$x_n$  – the area of soil quality classes for arable land or grasslands;

$W_p$  – point values for specific soil quality classes for arable land and grasslands;

$P$  – total area of soil quality classes for arable land or grasslands.

These indicators reflect the productive value of individual soil classes within a given cadastral district, allowing for the comparison of their quality and suitability for agricultural production (Fig. 3.).

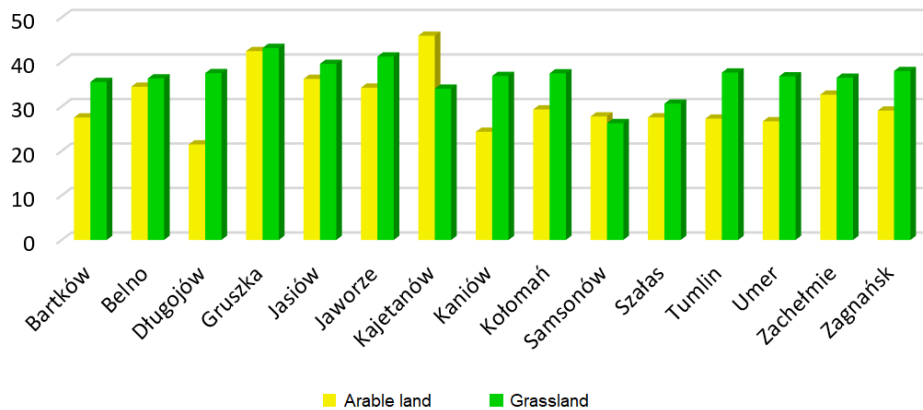


Figure 3. Comparison of the values of productivity indicators of arable land and grassland

The productivity index for arable land ranges from 21.47 to 45.90 points. The highest values are found in the cadastral districts of Kajetanów (45.90) and Gruszka (42.42), while the lowest value is recorded in the Długojów district (21.47) (Fig. 3).

For permanent grasslands, the productivity index ranges from 26.25 to 43.13 points. The highest values are observed in the districts of Gruszka (43.14) and Jaworze (41.20), while the lowest is in Samsonów (26.25) (Fig. 4).

The quality assessment revealed that the Gruszka cadastral district is the most valuable regarding soil quality, as evidenced by high productivity index values for both arable land and grasslands.

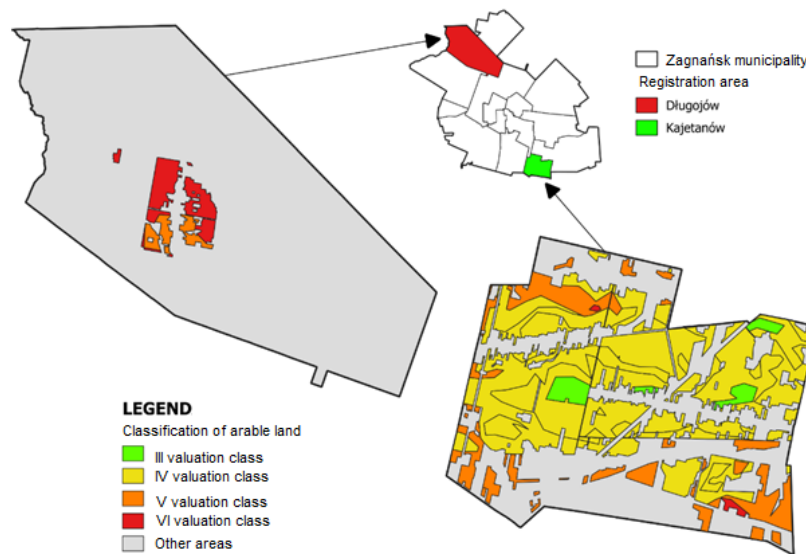


Figure 4. Classification of arable land in the Długojów and Zagnańsk districts

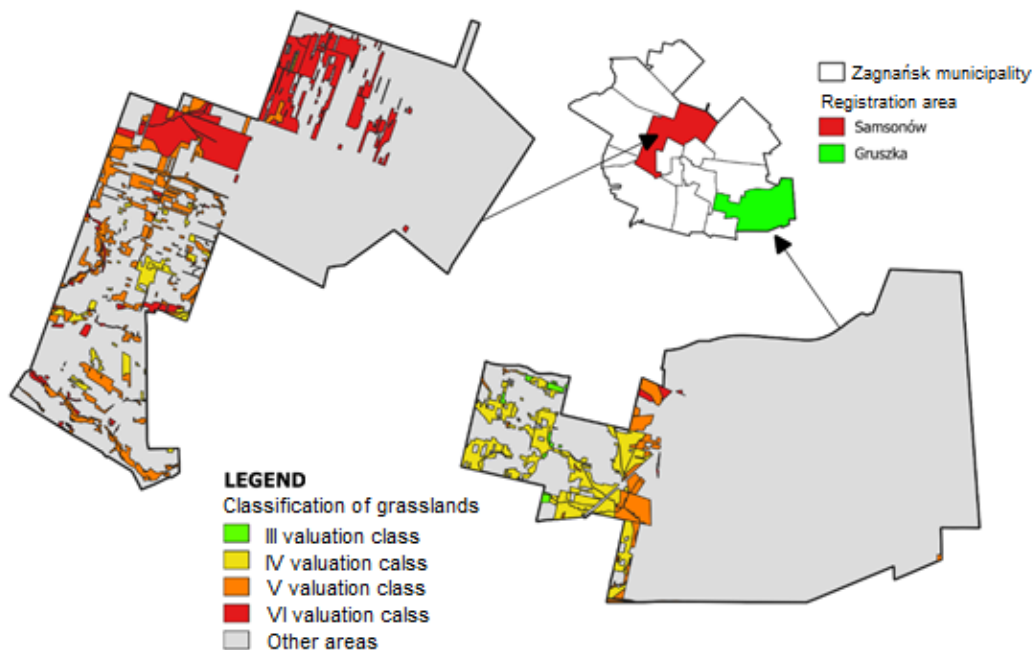


Figure 5. Classification of grasslands in the Samsonów and Gruszka districts

## 2.2. Parcel Fragmentation

The analysis of land fragmentation among private owners (Group 7) clearly shows that the largest group of plots consists of those smaller than 0.10 ha, which account for 40.12% of all parcels owned by individual farms. In the size range between 0.11 and 0.30 ha, there are 4,593 plots, making up 29.94% of private lands. The next group consists of parcels ranging from 0.31 to 0.60 ha, representing 16.05% of the total, with 2,462 plots. The fourth group, with plots between 0.61 and 1.00 ha, includes 1,254 parcels, or 8.17% of all private plots. The



smallest proportion of plots is above 1.00 ha, accounting for 5.72% of all land owned by private individuals.

The dominance of small plots indicates a high degree of land fragmentation in the Zagnańsk municipality, which may result from factors such as inheritance practices across generations or the division of land into smaller parcels for economic purposes. The relatively low percentage of plots larger than 0.61 ha suggests that there are few large farms in the area, which may limit the potential for intensive agriculture but could also promote a more sustainable development of the local economy (Fig. 5).

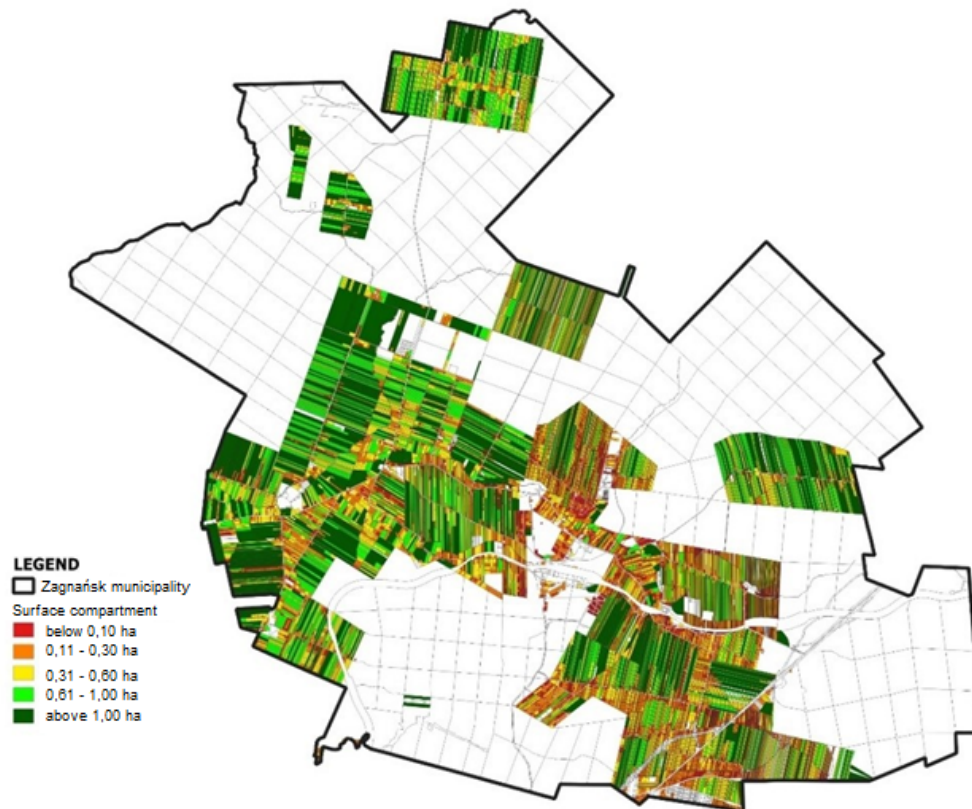


Figure 6. Fragmentation structure of cadastral plots in the private sector of the Zagnańsk commune

The highest number of parcels in the size range below 0.10 ha is found in the Zagnańsk district (1,035 parcels), constituting 59.52% of all private parcels in this district, while the smallest number is in Długojów (12 parcels), making up 7.84% of the total number of parcels. The second size category, between 0.11 and 0.30 ha, shows the most balanced distribution, with the percentage of parcels in this range varying from 17.40% to 37.53% across districts, the smallest value being in Kołomań and the largest in Kajetanów. In the third size range (0.31 – 0.60 ha), the highest percentage of parcels is in the Szalas district (34.18%), while the lowest is in Zagnańsk (7.53%). The most significant percentage of parcels in the fourth size category (0.61 – 1.00 ha) is found in the Kołomań district (27.47%), while the smallest percentage, 2.13%, is in Zagnańsk, the lowest value across all districts. The final size category (above 1.00 ha) contains the fewest parcels. The highest percentage of these parcels is in the Długojów district (26.80%), while the lowest is in Zachełmie (0.52%). The Belno district exhibits the most balanced land fragmentation, with a relatively even distribution of parcels across all size categories: 95 parcels in the first category, 94 in the second, 126 in the third, 110 in the



fourth, and 78 in the fifth, translating to percentage shares between 15.51% and 25.05% (Fig. 6). The most significant disparities in percentage values are observed in the Zagnańsk district, where 59.52% of all parcels fall into the first size category, while only 2.13% fall into the fourth category (0.61 – 1.00 ha) (Fig. 7).

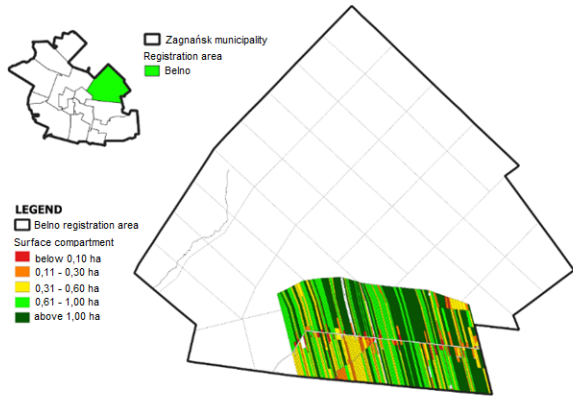


Figure 7. Fragmentation structure of cadastral plots of the private sector in the Belno area

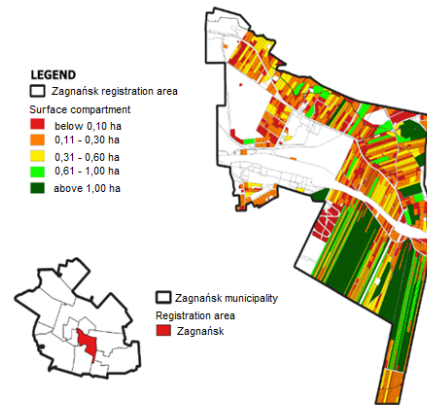


Figure 8. Fragmentation structure of cadastral plots of the private sector in the Zagnańsk area

To better assess the extent of land fragmentation in the private sector cadastral parcels, a fragmentation index was calculated for 15 municipal cadastral. The index was calculated in five surface area categories, with the following weights assigned:

- 1 for the category below 0.10 ha;
- 2 for the category 0.11 – 0.30 ha;
- 3 for the category 0.31 – 0.60 ha;
- 4 for the category 0.61 – 1.00 ha;
- 5 for the category above 1.00 ha.

The fragmentation index for private sector land was calculated using the following formula (2) [7]:

$$w_R = \frac{\sum_1^n (x_n \cdot l_n)}{P} \quad (2)$$

$x_n$  – the area of cadastral parcels in the respective surface area categories;

$l_n$  – the weight assigned to each of the five surface area categories;

$P$  – the total area of private sector land in the municipality.

The average parcel size and the land fragmentation index for the private sector are presented below in a boundary format (Fig 9., Fig. 10.).



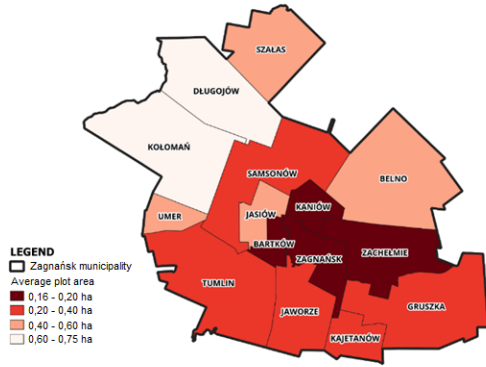


Figure 9. Average plot area in individual areas of the Zagnańsk commune

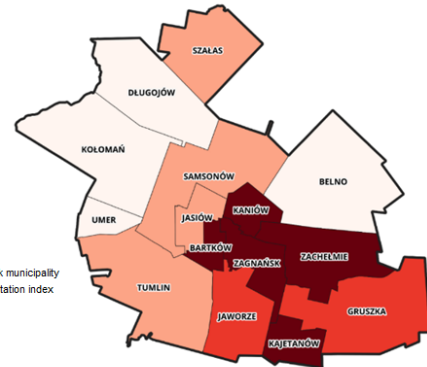


Figure 10. Land fragmentation index in individual areas of the Zagnańsk commune

The analysis revealed that some regions of the Zagnańsk commune are characterised by land fragmentation and faulty geometry. The presence of narrow and elongated parcels causes difficulties in fieldwork, resulting in increased financial costs and labour intensity, directly impacting agricultural production's profitability. The most optimal ratio for parcel elongation parameters, which would help reduce costs and increase work efficiency, is 1:5 [11].

The elongation index for cadastral parcels was calculated using the following formula (3), and is presented in both tabular and graphical (Figure 11) formats:

$$w_k = 40 \cdot \pi \cdot \frac{P}{O^2} \quad (3)$$

$P$  – area of the cadastral parcel;

$O$  – perimeter of the cadastral parcel.

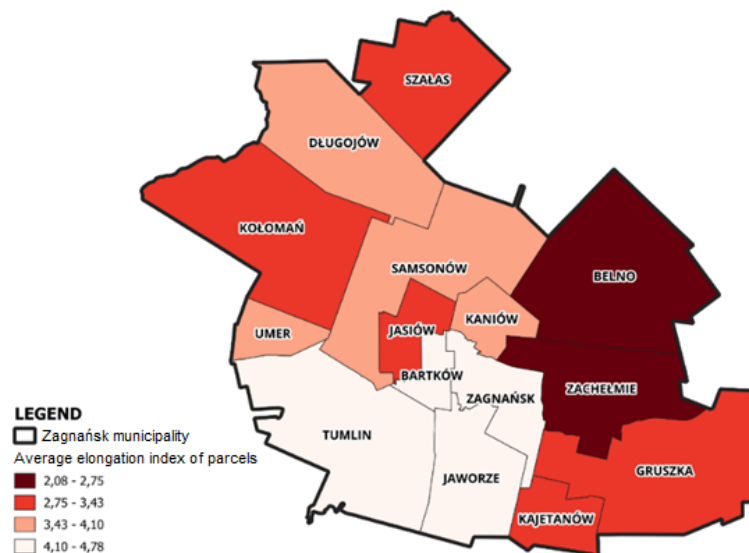


Figure. 11. Average elongation index of parcels in individual cadastral areas of the Zagnańsk commune



Analysis of the Accessibility of Cadastral Parcels to Roads Roads are a fundamental element of technical infrastructure, and improving the road network is a key task in land consolidation and exchange projects. Accessibility of parcels to public roads enables communication between individual farms and the land they cultivate. The presence of parcels without direct access to public roads generates several issues, including increased cultivation costs and the need to negotiate passage through parcels owned by others. As previously mentioned, land consolidation and exchange projects aim to eliminate the problem of lack of direct access to public roads, thus improving the spatial structure of the area [4, 14].

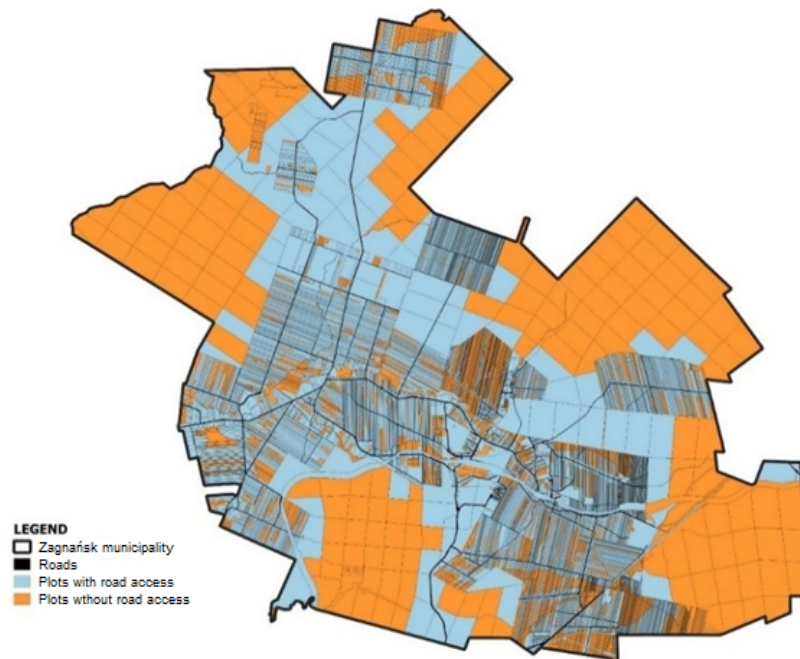


Figure 12. Map of cadastral parcel accessibility to roads in the Zagnańsk commune

The analysis and Figure 12 provides a comprehensive overview of cadastral parcel accessibility to roads in the Zagnańsk commune. It identified areas with significant accessibility issues and those with relatively good road access.

The total of 7,518 parcels (39% of all parcels) lack road access, covering 6,030.26 hectares. The most parcels without road access are in Kajetanów (1,001), while the fewest are in Długojów (84). However, the highest percentage of parcels without road access is in Kaniów (56.17%), while the lowest is in Samsonów (22.55%).

The Belno area has the largest area without road access (1,115.77 ha), representing 74.12% of the total area in that cadastral unit (Fig. 13). The smallest area without road access is in Bartków (50.42 ha), while the lowest percentage is in Zagnańsk (19.86%) (Fig. 14).

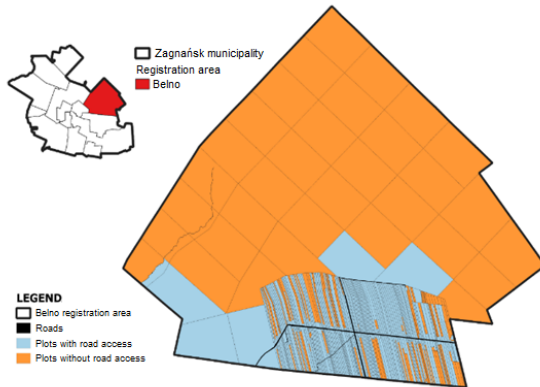


Figure 13. Map of accessibility of cadastral plots to roads in the Belno area

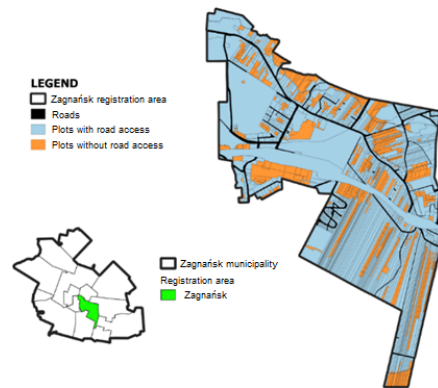


Figure 14. Map of cadastral parcel accessibility to roads in the Zagnańsk cadastral unit

### 2.3. Ranking of land consolidation needs

Multivariate statistical methods for determining a synthetic measure are valuable in research on the urgency of land consolidation and exchange, especially in spatial comparative analyses [6]. To build a ranking of objects based on quantitative characteristics, it is essential to standardise the values of the variables to ensure comparability. This is achieved by eliminating measurement units and standardising the range of values [19, 7].

Characteristics of the Selected Factors to determine the need for land consolidation and exchange in the Zagnańsk commune, 18 factors characterising the analysed cadastral units were selected. These were grouped into 6 categories, as shown in Table 8.

Tab.8. Factors selected for determination of the need for land consolidation and exchange at Zagnańsk area

Group	No	Factor
General information	x1	area
	x2	number of plots
	x3	number of inhabitants
	x4	population density
	x5	average plot area
	x6	% share of the number of private sector plots
	x7	% share of the area of private sector plots
Structure of ownership	x8	share of State Treasury land (1st and 2nd registration groups)
	x9	% share of Municipal land (4th and 5th registration groups)
Assessment of the quality of agricultural land	x10	arable land productivity index
	x11	grassland productivity index
Accessibility of plots to roads	x12	% share of the number of plots without road access
	x13	% share of the area of plots without road access
Fragmentation of cadastral plots	x14	average private sector plot area
	x15	fragmentation index
	x16	average value of the elongation index
Structure of use	x17	% share of forests
	x18	% share of orchards

Before proceeding with the ranking process, a preliminary selection of factors must be conducted. This involves eliminating variables for which the coefficient of variation (V) is below 20%. According to Table 8, 3 of the 18 factors do not meet this criterion in the analysed area.



These are the percentage share of private sector parcels, the productivity index of grasslands, and the fragmentation index. However, due to the importance of these variables, they were included in the further analysis.

### 3. Method for Determining the Order of Municipal Units for Land Consolidation

The zeroed unitary method was used to develop the ranking of land consolidation, and exchange needs in the cadastral units of Zagnańsk municipality. This method allows the ordering of diagnostic variables describing the analysed area by dividing them into three distinct subsets - types of variables [22]:

Stimuli: Variables for which an increase in value indicates an improvement in the analysed object's characteristics. They are normalised according to the following formula (4):

$$Z = \frac{(x-x_{min})}{(x_{max}-x_{min})} \quad (4)$$

Detractors: Variables for which an increase in value indicates a decrease in the analysed object's characteristics. They are normalised according to the following formula (5):

$$Z = \frac{(x_{max}-x)}{(x_{max}-x_{min})} \quad (5)$$

$Z$  – normalised variable

$x$  – variable before normalisation

$x_{max}$  – maximum value of the variable in the set

$x_{min}$  – minimum value of the variable in the set

Nominants: Variables that achieve the highest score (optimum) only for a specific value or range of values.

A comprehensive multi-criteria assessment of each analysed object can be conducted thanks to standardising diagnostic features. The synthetic measure, obtained through aggregation, is calculated using the following formula (6) [6]:

$$z_i = \frac{1}{p} \sum_{j=1}^p x_{ij} (i = 1, \dots, m) \quad (6)$$

The range of values for the normalised measures lies between <0; 1>, with higher values of the synthetic measure indicating a higher rank for the object [5].

#### Ranking of the Need for Land Consolidation Works

The need for land consolidation and exchange works was ranked using the zeroed unitary method. A total of 18 variables were used, creating a ranking of the urgency of consolidation works (Figure 15, Table 9).



**LEGEND**

- ☐ Zagnańsk municipality
- Ranking of the need for land consolidation and exchange works
- 1. Kaniów
- 2. Gruszka
- 3. Kajetanów
- 4. Zagnańsk
- 5. Belno
- 6. Tumlin
- 7. Kołomań
- 8. Zachelmie
- 9. Szalas
- 10. Bartków
- 11. Samsonów
- 12. Jaworze
- 13. Jasiów
- 14. Umer
- 15. Długojów

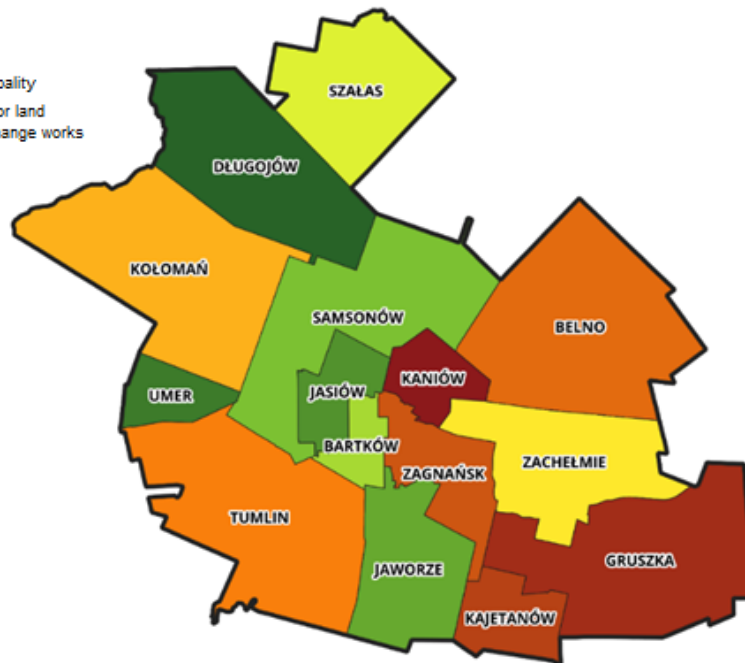


Figure 15. Ranking of the Need for Land Consolidation and Exchange Works in the Municipality of Zagnańsk

Table 9. Ranking of the Need for Land Consolidation and Exchange Works in the Municipal Units of Zagnańsk

ZERO UNITARYZATION METHOD		
No	District	Value of synthetic measure
1	KANIÓW	0,584
2	GRUSZKA	0,559
3	KAJETANÓW	0,545
4	ZAGNAŃSK	0,538
5	BELNO	0,498
6	TUMLIN	0,483
7	KOŁOMAŃ	0,468
8	ZACHEŁMIE	0,451
9	SZAŁAS	0,430
10	BARTKÓW	0,421
11	SAMSONÓW	0,419
12	JAWORZE	0,418
13	JASIÓW	0,387
14	UMER	0,380
15	DŁUGOJÓW	0,377

The analysis revealed that the area with the greatest need for land consolidation and exchange works is Kaniów. This area is characterised by a high percentage of private sector parcels with a high land fragmentation index and frequent lack of access to public roads. At the opposite end of the ranking is the Długojów area, with a synthetic measure value of 0.377. Its low ranking is due to the significant proportion of state-owned land, mainly large, forested areas, resulting in a higher average parcel size.



A detailed analysis of the ranking shows four groups of cadastral units with similar synthetic measure values (Figure 16). The first group includes the cadastral units of Kaniów, Gruszka, Kajetanów, and Zagnańsk, located in the central and southeastern parts of the municipality. These units require the most urgent land management work, characterised by a high degree of land fragmentation, small parcel sizes, and many parcels lacking access to roads.

The second group consists of Belno, Tumlin, Kołomań, and Zachelmie, located in the eastern and western parts of the municipality. The synthetic measure values range from 0.451 to 0.498. These areas require consolidation works as the second priority, driven by a high percentage of private sector parcels and unfavourable geometry.

The third group, comprising Szalas, Bartków, Samsonów, and Jaworze, has a lower priority for consolidation works due to more favourable land fragmentation and elongation indices. These areas also have low productivity indicators for both arable land and grassland.

The lowest demand for consolidation and exchange works is found in the last group, consisting of Jasiów, Umer, and Długojów. Their ranking is due to favourable conditions, including optimal average parcel sizes and a low percentage of parcels without access to public roads. These make them the last areas to undergo consolidation.

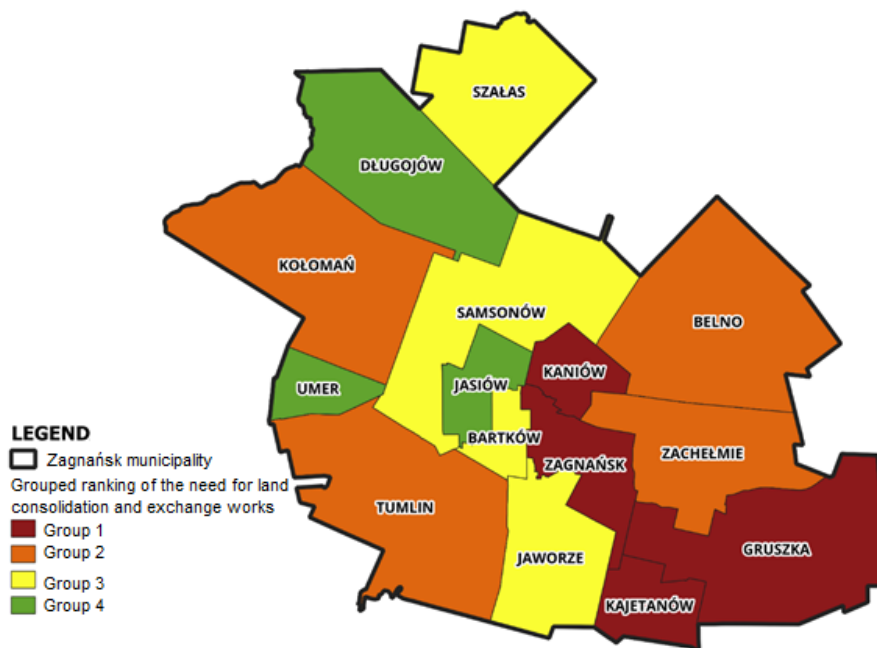


Figure 16. Grouped Ranking of the Need for Land Consolidation and Exchange Works

#### 4. Results and Conclusions

The spatial structure of rural areas in Poland varies significantly across regions due to historical, environmental, social, and economic factors. In northern and western Poland, large agricultural holdings dominate, requiring urgent regulation of land ownership. In the eastern and central regions, medium-sized farms prevail, with slow structural changes. In contrast, southern and southeastern Poland (e.g., Małopolska, Podkarpacie, Silesia, and Świętokrzyskie) exhibit extensive land fragmentation.



An analysis of the Zagnańsk municipality, covering land use, ownership structure, fragmentation, and access to roads, revealed issues common in southern and southeastern Poland. The area has 23 land use types, with forests covering over 60% and arable land making up 20%. Private land ownership accounts for over 36% of the municipality's area, with most private parcels being small (under 0.10 ha, 40.12%, and 0.10-0.30 ha, 30%). This indicates significant land fragmentation.

The analysis also revealed that many parcels have unfavourable shapes (long and narrow), and 39% lack access to public roads, particularly in Gruszka and Kaniów, where half of the parcels lack road access.

These findings highlight the flawed spatial structure of the municipality, but improvements are possible through land consolidation and exchange. Given administrative, social, temporal, and financial constraints, consolidation efforts should be prioritised. The Kaniów area is identified as the highest priority, while Długojów has the most favourable conditions. The analysis ranks areas into four groups based on synthetic measure values, with rankings depending on the selected factors.

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