

The Use Of Statistical Methods in Creation of the Urgency Ranking of the Land Consolidation and Land Exchange Works

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Abstract. In the analyzes of the urgency of the land consolidation and land exchange works, and particularly in the spatial comparative analyzes it is helpful to use methods of multivariate statistics, which allows the determination of synthetic measure. Synthetic measures substitute the large set of attributes of the object with one aggregate variable, allowing ordering the analyzed objects (villages) in terms of the phenomenon in question of the urgency of carrying out the work of consolidation and exchange of land. The aim of the paper is to determine measures for the urgency of carrying out the works of consolidation and exchange of land according to the method proposed by Z. Hellwig and comparison of the obtained results with the results obtained using the zero unitarisation method (ZUM). The aim of the analyzes is to verify (check), how the use of different methods of aggregation of the same diagnostic variables affects the results of research. The subject of the research consists of 14 precincts located in the municipality Białaczów, in the Łódzkie voivodship region. To construct the synthetic measure for the urgency of carrying out the works of consolidation and exchange of land 5 groups of features characterizing the works related to consolidation and exchange of land were adopted.

Keywords: land consolidation, spatial structure of land use, land fragmentation, ranking the work of consolidation and exchange land.

Conference topic: Technologies of geodesy and cadastre.

Introduction

With regard to land use, the picture of the contemporary village has been shaped by many years of human activity. The negative effects of that activity follow from the fact that the natural environment has been transformed according to the individual needs of society. A significant role in that process has been played by settlement, with location of villages influencing the arrangement of various forms of land use including agricultural land, systems of transportation and residential areas. One of the biggest land use issues is a high level of fragmentation of land holdings. Fragmentation is mainly due to the enforcement of inheritance law, as discussed by (Noga 1977; King, Burton 1982; Bentley 1987; Tan *et al.* 2006; Hung *et al.* 2007), and depends, first and foremost, on historical, cultural and social factors. Research conducted in Poland (Leń, Noga 2010; Leń *et al.* 2015; Leń, Mika 2016a; Janus *et al.* 2016) has demonstrated a very high level of fragmentation of individual land holdings, especially in south-eastern Poland.

The factors mentioned above generate a range of similar problems, related to excessive land fragmentation, in numerous countries of central Europe (van Dijk 2003; Sonnenberg 2002), and the negative effects of land scattering are also felt in other parts of Europe and the world (Latruffe, Piet 2013).

The flaws in the land use structure of rural areas could be eliminated by land consolidation and land exchange interventions. Land fragmentation has a direct effect on the state of cadastre in Poland, as described, among others, by (Buśko, Meusz 2014; Mika, Leń 2016). Faulty land use structure poses a threat not only to rural areas (Sobolewska-Mikulska *et al.* 2014), but also to suburban areas, thus endangering the spatial order of these areas (Sobolewska-Mikulska 2015; Mika, Salata 2015). One chance to improve this situation in rural areas is to carry out land management and land readjustment operations aimed at introducing complex changes in the agricultural space such as consolidation of parcels. From the moment Poland joined the European Union, the processes of land consolidation and land exchange have been targeted at economic development as a factor in increasing the attractiveness of rural areas to their inhabitants, and at fostering economically and environmentally sustainable development of the agriculture sector (Dudzińska, Kocur-Bera 2014, 2015).

Land management and readjustment operations are an investment which pays off by removing defects in the spatial structure of lands. It is estimated that there are around 3 million ha of such poorly structured agricultural space in Poland. This means that even with subsidies from the European Union, it is impossible, both financially and human-resource-wise, to carry out such intervention everywhere. Effective management of finance and effective land consolidation and exchange require that priorities be established for performing these tasks. This issue has been dis-

cussed in the studies by (Leń 2011, 2013; Dudzińska *et al.* 2014; Leń, Mika 2016b). In this connection, ranking methods are becoming increasingly useful in empirical research on human activity, including research on the land use structure of rural areas. The use of statistical methods in scientific research has been broadly discussed by (Jasińska 2012) and (Preweda 2013). The advantage of using synthetic measures in this field of study is that they provide means for multi-criteria analysis of very complex phenomena, such as the spatial structure of villages (Leń *et al.* 2016).

The aim of this study was to establish the priority schemes for land consolidation in the villages of the commune of Białaczów by using two independent statistical methods. The study encompassed 14 villages located in the district of Opoczno, Łódź Voivodeship. The ranking of villages was established using zero unitarization and Hellwig's ordering method. Calculations were based on twenty factors representing five groups of parameters characterizing the land use structure of the villages studied. The results in the form of two independently calculated synthetic measures for each village, allowed us to determine two separate priority hierarchies for consolidation interventions.

The factors

The research area encompassed 14 localities in the commune of Białaczów, district of Opoczno, Łódź Voivodeship (Fig.1), with a total area of 11483.62 ha. The ranking of urgency of land consolidation and exchange in the commune of Białaczów was prepared on the basis of twenty factors characterizing the individual localities.

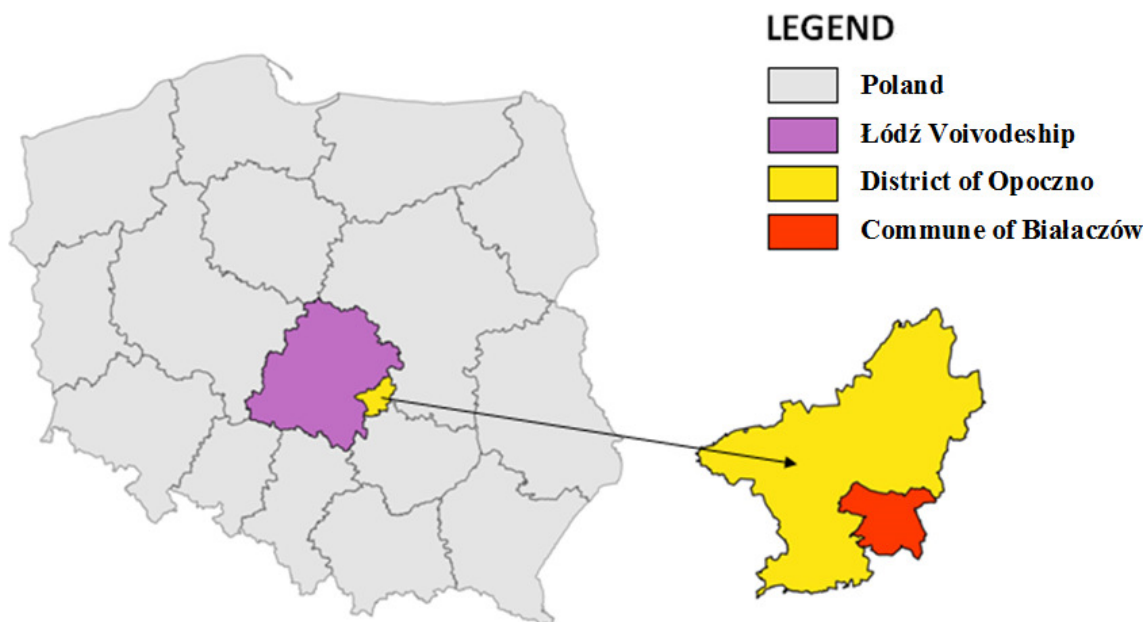


Fig. 1. The location of the commune of Białaczów
(Source: own elaboration)

A first group of factors included those which described the land tenure structure: x1 – percentage share of lands belonging to the State Treasury, x2 – percentage share of lands belonging to the commune, x3 – percentage share of lands belonging to individual agricultural holdings, x4 – percentage share of lands belonging to the district. A second group of factors were related to land use: x5 – percentage share of arable land, x6 – percentage share of grasslands, x7 – percentage share of pastures, x8 – percentage share of agricultural built-up land, x9 – percentage share of forests, x10 – percentage share of transportation areas. The factors, expressed as a percentage, were calculated on the basis of data obtained from the Land and Building Register, in relation to the total area occupied by each particular locality. A third group consisted of factors associated with the demographic conditions of the investigated district: x11 – number of inhabitants and x12 – number of inhabitants per km². The demographic data were obtained from the Commune Office in Białaczów. A fourth group of factors, regarding land fragmentation, included six indicators determined on the basis of data obtained from the Land and Building Register: x13 – total area of a village, x14 – total number of plots, x15 – average area of a plot in the village, x16 – number of privately owned parcels, x17 – average area of privately owned parcels and x18 – land fragmentation coefficient. The last group of factors were: x19 – percentage of plots without road access and x20 – percentage of plot area without road access. In this part of the study, tools available in “QGIS” software were used to calculate, in a fast and easy way, numerical results as well as their graphical representation. A list of the twenty factors characterizing the investigated localities is shown in Table 1.

Table 1. Numerical values determined for the investigated factors characterizing the area under study (Source: Calculations done by the present author on the basis of data obtained from the Land and Building Register)

No.	Name of village	Land tenure structure					Land use structure					Demographic conditions		Land fragmentation					Plots without road access		
		x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15	x16	x17	x18	x19	x20
		Percentage share of lands belonging to the State Treasury	Percentage share of lands belonging to the commune	Percentage share of lands of individual agricultural holdings	Percentage share of lands belonging to the district	Percentage share of agricultural lands	Percentage share of grasslands	Percentage share of pastures	Percentage share of agricultural built-up lands	Percentage share of forests	Percentage share of transportation areas	Number of inhabitants	Number of inhabitants per km ²	Total area	Total number of plots	Average plot area in the village	Number of privately owned parcels	Average area of privately owned parcels	Land fragmentation coefficient	Percentage of plots without road access	Percentage of plot area without road access
1	Białaczów	41.82	2.01	54.16	1.67	35.00	2.52	0.73	1.82	53.97	2.19	1143	52	2214.93	2083	1.0633	1833	0.6544	4.21	16.37	30.40
2	Kuraszków	14.52	2.58	81.66	0.69	46.29	6.59	9.65	1.96	30.26	2.99	169	30	570.511	516	1.1056	443	1.0516	4.53	7.75	4.41
3	Miedzna DREWNIANA	49.36	1.95	48.41	0.21	31.20	2.00	2.46	2.60	58.37	2.32	577	55	1057.5	1716	0.6163	1538	0.3329	3.49	1.40	10.84
4	Pareczów	22.84	1.49	72.29	0.64	53.93	4.69	3.84	2.22	30.26	3.10	369	46	804.578	1047	0.7685	913	0.6371	4.07	3.53	6.80
5	Pareczówek	10.73	2.62	78.44	0.53	43.95	7.62	9.17	2.53	28.43	4.70	440	61	725.853	2537	0.2861	2015	0.2826	3.12	4.26	2.18
6	Petrykozy	10.26	2.62	83.93	1.41	58.89	7.04	6.16	4.58	10.34	5.60	517	100	518.724	736	0.7048	637	0.6835	4.13	9.92	6.46
7	Radwan	5.62	1.79	92.56	0.03	64.85	3.03	6.27	2.26	14.31	5.30	237	65	364.676	761	0.4792	654	0.5161	4.06	28.25	14.93
8	Skronina	36.73	3.95	58.53	0.75	36.28	8.92	5.15	1.54	42.30	3.76	844	73	1161.85	1664	0.6982	1418	0.4796	3.65	8.05	14.41
9	Sobień	15.73	2.25	79.62	0.42	36.40	10.97	3.63	1.47	41.60	2.41	261	26	1022.31	1593	0.6418	1231	0.6612	4.18	4.39	2.88
10	Sędów	0.75	3.26	94.14	1.08	48.83	19.78	4.60	2.39	18.13	4.04	341	78	437.354	1002	0.4365	803	0.5128	3.67	3.09	3.46
11	Wąglany	4.76	3.31	90.5	0.0	47.29	6.87	4.74	4.96	30.15	3.60	382	79	480.669	1581	0.3040	1433	0.3036	3.28	2.40	0.98
12	Zakrzów	16.51	3.49	82.07	0.92	51.84	14.02	1.64	2.89	28.83	2.48	192	41	469.153	729	0.6436	655	0.5878	4.04	2.47	1.09
13	Żelazowice	2.79	1.61	94.28	0.4	51.63	4.55	5.26	2.74	30.63	1.77	338	45	746.701	1774	0.4209	1634	0.4308	3.72	14.60	11.01
14	Ossa	80.97	1.43	17.52	0.0	10.19	0.03	3.23	0.96	75.80	1.20	76	8	908.809	654	1.3896	578	0.2754	3.34	14.07	18.90

Prioritization of land consolidation and land exchange interventions

To perform a prioritization analysis, it is necessary to first characterize the values of the investigated variables, expressing them in the form of descriptive statistics. The variables, considered from the point of view of how urgent land consolidation was, were divided into stimulants and destimulants. Seventeen factors were treated as stimulants, and the remaining three factors were regarded as destimulants.

Table 2. Factors selected as stimulants and destimulants of land consolidation (Source: own elaboration)

Selected factors		Mean	Median	Min	Max.	Coefficient of variation V
Stimulants	x2 – percentage share of lands belonging to the commune	1.01	2.42	1.43	3.95	79.49
	x3 – percentage share of lands of individual agricultural holdings	30.24	80.64	17.52	94.28	72.13
	x4 – percentage share of lands belonging to the district	0.26	0.59	0.00	1.67	199.64
	x5 – percentage share of arable lands	18.13	46.79	10.19	64.85	75.23
	x6 – percentage share of grasslands	2.90	6.73	0.03	19.78	179.72
	x7 – percentage share of pastures	1.96	4.67	0.73	9.65	129.72
	x8 – percentage share of agricultural built-up lands	1.03	2.33	0.96	4.96	107.52
	x10 – percentage share of transportation areas	1.34	3.05	1.20	5.60	98.62
	x11 – number of inhabitants	173.12	355.0	76.0	1143.0	163.86
	x12 – number of inhabitants per km ²	22.27	53.08	8.36	99.67	108.78
	x13 – total area of village	337.75	736.28	364.68	2214.93	140.50
	x14 – total number of plots	540.97	1314.0	516.0	2537.0	114.12
	x15 – average area of a plot in a village	0.28	0.64	0.29	1.39	112.94
	x16 – number of privately owned parcels	464.26	1072.0	443.0	2015.0	111.90
	x17 – average area of privately owned parcels	0.22	0.51	0.28	1.05	96.27
	x19 – percentage of plots without road access	3.55	6.07	1.40	28.25	212.17
	x20 – percentage of plot area without road access	3.79	6.63	0.98	30.40	219.87
Destimulants	x1 – percentage share of lands belonging to the State Treasury	9.22	15.13	0.75	80.97	244.65
	x9 – percentage share of forests	14.51	30.26	10.34	75.80	123.22
	x18 – land fragmentation coefficient	1.57	3.88	3.12	4.53	26.40

Often, before a synthetic ranking is determined, the values of diagnostic features are screened for inclusion. One criterion which is very often used excludes from analysis those variables whose coefficient of variation V is smaller than 20%. This, however, did not apply to the factors used in this study as all of them exceeded 20%. Another, equally popular criterion, excludes features which are highly correlated with each other, since they provide similar information on the order of the items that are being ranked. However, because all the investigated variables were highly relevant to the ranking, they were all included in the analysis irrespective of their degree of correlation (Leň *et al.* 2016).

The ranking of villages for the purposes of land consolidation and land exchange was established on the basis of zero unitarization and Hellwig's ordering method, by creating synthetic measures of urgency of consolidation. Syn-

thetic measures allow one to classify objects with respect to the magnitude of multi-faceted and multifactorial phenomena such as land use structure.

The zero unitarization method is used to normalize the diagnostic variables characterizing an object. These variables are divided into two groups (Kukuła 2000):

- stimulants – variables whose increase leads to an increase in the value of a diagnostic feature of the object under consideration; in this case standardized variables are calculated from the following formula:

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

- destimulants – variables whose increase leads to a decrease in the value of a diagnostic feature of the object under consideration; in this case standardized variables are calculated from the following formula:

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

where: z – standardized variable; x – variable before standardization; x_{\max} – maximum value of variable in a given set; x_{\min} – minimum value of variable in a given set.

Standardization of diagnostic features allows one to obtain a consolidated multi-criteria evaluation of each object. The consolidated evaluation is obtained by aggregation. In order to obtain a synthetic measure, average values of sets characterizing respective features are calculated using the following formula (Pluta 1986):

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

Standardized measures are in the range $<0;1>$. Results are interpreted as an average of the optimal features of each object. Therefore, the higher the value of the synthetic measure, the higher the position of the object in the ranking.

In the case of Hellwig's method, information is synthesized from a number of diagnostic variables, and one aggregated measure is assigned to the phenomenon under consideration. In the present study, synthetic measures concerning the urgency of land consolidation and land exchange were determined using the factors defined in the previous section. Synthetic measures of the urgency of land consolidation were calculated using Hellwig's method from the following formula:

$$W_k = \sum_{k=1}^5 (Czn_k w_k),$$

where: Czn_k – standardization of features, which facilitates comparison of values between categories, calculated from the formula:

$$Czn_k = (s_j / s_{\max})_k,$$

where: k – k -th factor describing the phenomenon under consideration ($k=1, 2, 3, 4, 5$).

Values of weighted means of features (s_j) in a range are calculated by the following formula:

$$s_j = \frac{1}{\sum w_i} \sum c_i w_i, \quad (j = 1, 2, 3, 4),$$

where: c_i – value of a given feature in the j -th range; w_i – weight of a feature.

The weights of the particular features affecting the final evaluation of the land use structure in the localities of the commune of Białaczów are given in Table 3. These weights were assigned on the basis of principle $\sum w_i = 1$.

Table 3. Weights of the individual factors (Source: own elaboration)

No.	Category	Weights of factors
1	Land tenure structure	0.1
2	Land use structure	0.1
3	Demographic conditions	0.2
4	Land fragmentation	0.4
5	Plots without road access	0.2

Next, partial weights were assigned to the individual features c_i (Table 4) comprising each of the five categories of factors under consideration.

Table 4. Partial weights of factors by category (Source: own elaboration)

Category	Factors	Partial weights c_i
Land tenure structure	x1	0.2
	x2	0.2
	x3	0.5
	x4	0.1
Land use structure	x5	0.5
	x6	0.1
	x7	0.1
	x8	0.05
	x9	0.2
	x10	0.05
Demographic conditions	x11	0.5
	x12	0.5
Land fragmentation	x13	0.2
	x14	0.2
	x15	0.2
	x16	0.2
	x17	0.2
	x18	0.2
Plots without road access	x19	0.5
	x20	0.5

Calculations done using Hellwig's method and zero unitarization yielded values of synthetic measures in the range $\langle 0;1 \rangle$. The values of the synthetic measures were used to identify localities with the most urgent need for land consolidation. The ranking of localities by urgency of land consolidation and land exchange is presented in Table 5 and Figure 1. A map showing the urgency of land consolidation and land exchange by commune is given in Figures 3 and 4.

Table 5. Ranking of urgency of land readjustment determined by calculating synthetic measures using the zero unitarization and Hellwig's methods (Source: own elaboration)

Position in the ranking	Zero unitarisation method		Hellwig's method	
	Value of synthetic measure	Name of area	Value of synthetic measure	Name of area
1	0.56	Petrykozy	0.86	Białaczów
2	0.53	Białaczów	0.63	Skronina
3	0.53	Parczówek	0.62	Żelazowice
4	0.51	Skronina	0.60	Parczówek
5	0.51	Sędów	0.58	Petrykozy
6	0.48	Wąglany	0.53	Miedzna Drewniana
7	0.45	Żelazowice	0.52	Radwan
8	0.43	Radwan	0.48	Wąglany
9	0.42	Kuraszków	0.48	Sobień
10	0.40	Zakrzów	0.46	Parczów
11	0.38	Parczów	0.44	Sędów
12	0.37	Sobień	0.40	Ossa
13	0.34	Miedzna Drewniana	0.36	Zakrzów
14	0.18	Ossa	0.35	Kuraszków

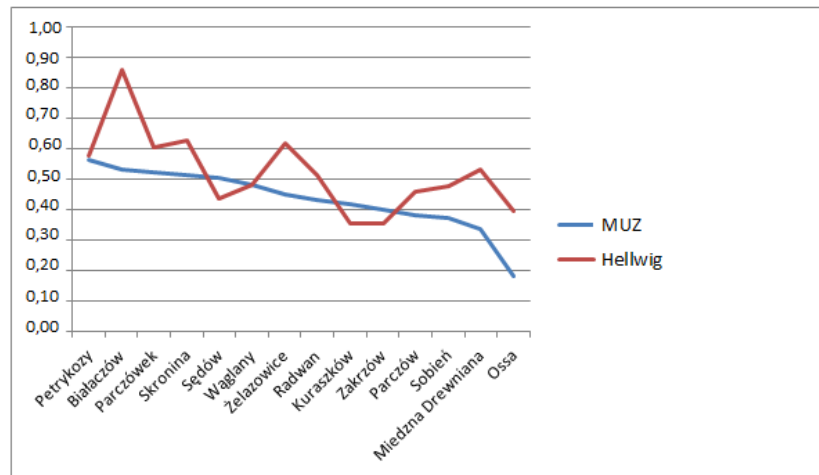


Fig. 2. Comparison of results obtained using zero unitarization vs. Hellwig's method (Source: own elaboration)

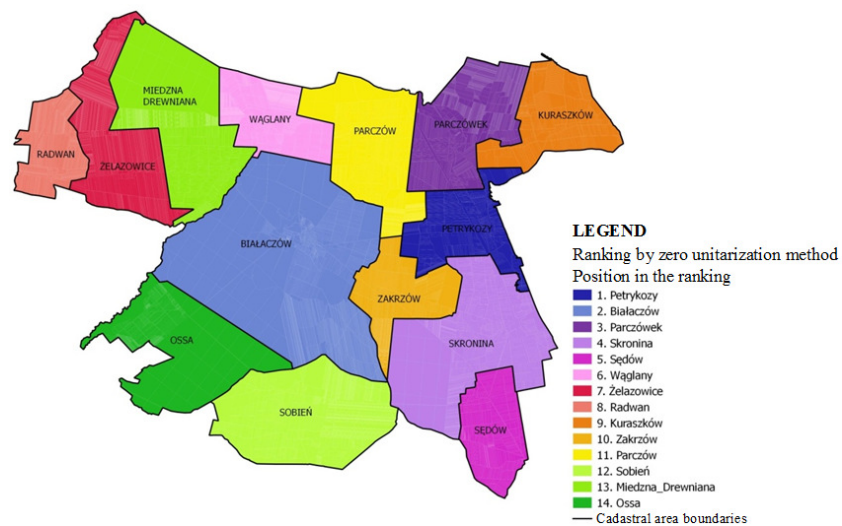


Fig. 3. Ranking of localities determined by zero unitarisation method. Spatial data were mapped using QGIS software (Source: own elaboration)

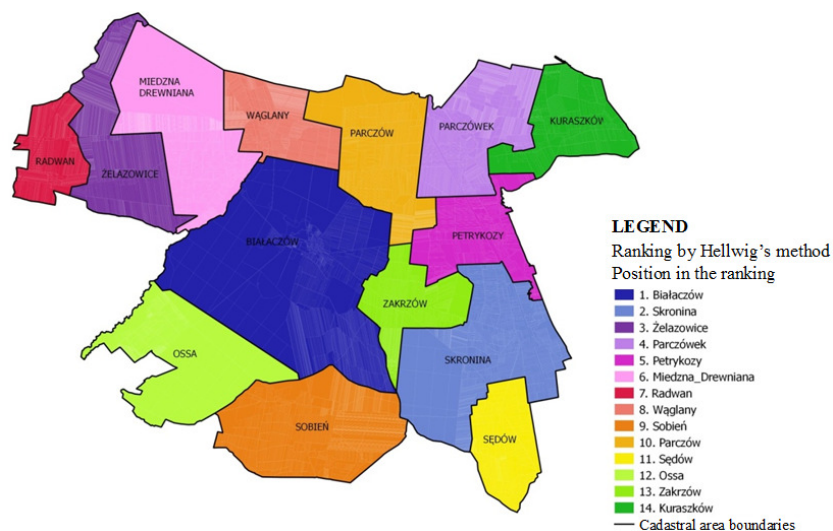


Fig. 4. Ranking of localities determined by Hellwig's method. Spatial data were mapped using QGIS software (Source: own elaboration)

Conclusions

The use of two different prioritization methods enabled us to create two separate rankings of urgency of land consolidation and land exchange. Fifty percent of the villages (7 localities) held nearly the same positions in both rankings at a tolerance of ± 2 positions. The priority ranks of four of those localities (29%) differed by one position and the remaining three localities (21%) differed by two positions when the two rankings were compared. Among the localities for which the differences in land consolidation urgency were greater than two positions, two (14% of all localities) differed by three positions and another two differed by four positions in the rankings. The priority ranks of the remaining three localities differed by five to seven positions. The greatest difference (7 positions) was found for Miedzna Drewniana. The greatest convergence of positions in the two rankings was observed for Białaczów, Parczówek, Radwan and Parczów (a difference of 1 position). The results obtained in the present study show that consolidation should be first performed in the following localities: Białaczów, Petrykozy, Parczówek and Skronina. These localities are characterized by a large share of privately owned parcels: Białaczów – 88%, Parczówek – 79%, Petrykozy – 87%, Skronina – 85%. The areas of Białaczów and Skronina are the largest in the commune, and, therefore, the percentage of plot area without road access in those localities is much higher than in the other villages (Białaczów – 30.4%, Skronina – 14.4%).

What deserves special attention is the fact that those localities have the largest populations, with Petrykozy having a population density of 100 inhabitants per km². Among the investigated villages, Parczówek stands out as having the largest number of parcels (2015 privately owned plots) and the smallest average plot area of 0.2826 ha. Our analysis shows that consolidation should be carried out primarily in those localities which have the largest populations and a high share of privately owned parcels.

Among Polish provinces, Łódź Voivodeship is characterized by worse-than-average natural conditions for the development of agriculture, which, besides industry is, paradoxically, the main economic specialty of this region. In Łódź Voivodeship, there prevail small and very small agricultural holdings whose productivity is low. Rural areas are characterized by insufficient economic activity and poor social involvement and community participation, as well as poor access to utilities and social services. This is why it is so important to restructure agricultural production in rural areas and increase its quality as a way of boosting economic efficiency and improving the living conditions of the inhabitants. The specific character of the agricultural holdings and the environmental conditions of Łódź Voivodeship indicate that a strong agricultural sector oriented towards ecological farming could be created in this area, which would improve the environmental conditions of the region.

Agrarian restructuring is a must for sustainable rural development. Land consolidation, which is an instrument for improving land use structure, must be performed in a systematic way and should be a permanent element of long-term rural land use policies of local governments.

In conclusion, the results obtained in this study provide a reliable source of information on the priority of land consolidation and land exchange interventions in the investigated area. The results are representative as they apply to the whole study area characterized by faulty land use structure.

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