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ASSESSMENT OF LAND FRAGMENTATION FOR THE PURPOSE OF LAND CONSOLIDATION WORKS AS EXEMPLIFIED BY THE PASYM COMMUNE

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Summary

In Poland there are no uniform regulations and legal norms establishing the principles of space assessment aimed at determining the demand for land consolidation works. The article is an attempt to answer the following question: what factors are important today in determining the demand for this kind of works?

The factors were set on the basis of professional literature and on a questionnaire conducted on a group of specialists in land consolidation and on farmers. The aim of the questionnaire was to examine the preferences of chosen land fragmentation factors. The survey was carried out in the Pasym commune, situated in the Warmia and Mazury Voivodeship.

The results of the research show that the land fragmentation mostly depends on the number of land plots (parcels) in a farm, their distance to a settlement and the size of a land plot. The least significant factors in this respect proved: a size of a farm and its irregular shape. The research has confirmed a general tendency in spatial changes of small farms in the Warmia and Mazury Voivodeship.

Keywords

land consolidation • land fragmentation • land plot • farm

1. Introduction

Many researchers indicate areas where consolidation procedures should be carried out. Their recommendations are aimed at improving agricultural production environment in a village. This environment is confronted with many problems, such as: high land fragmentation (patchwork of fields), unfavourable land layout of farms, maladjustment of spatial parameters of land plots to a current mechanized cultivation, landscape impoverishment (disappearance of such elements as: between-fields afforestation, forests, water holes, beauty spots), deficient transport network of access roads to rural areas and forests (not adjusted to the use of modern agricultural machinery), in many cases lack of road access to rural areas resulting from a high land fragmentation, unregulated water relations and lack of important land reclamation structures, fallowing of

lands or arable areas that are not used for what they were intended, existence of lands belonging to land communities, which in fact means that they are now "no-man's" lands [Błaż et al. 2010]. In Poland there are no uniform regulations and legal norms establishing the principles of space assessment aimed at determining the advisability of land consolidation works. In a document containing directives on preparation of guidelines for land consolidation project [Wytyczne do opracowania... 2011] the basic factors considered in determining the demand for such works in Lower Silesian Voivodeship have been established. These factors are: analysis of a state of land ownership, a level of interest in consolidation works among land owners, a level of interest in arrangement and investment works that accompany a land consolidation process. Additional factors that decide the order of consolidation works are: unfavourable land patchwork, occurrence of high class of soils, relatively high mean size of a farm, extended land patchwork between villages, linear investments disruptive to agricultural production and a possibility of a farm enlargement thanks to consolidation.

2. Objectives and methods

The article is an attempt to answer the question as to what factors (parameters) are important today in determining the demand for land consolidation works, as exemplified by the Pasym commune.

Presentation of essential factors and description of demand for consolidation works was preceded by three research tasks that were logically interrelated. The research tasks were completed in the following stages:

1. Finding current land fragmentation factors used in determining the demand for consolidation works.
2. The choice of authors' factors for assessing land fragmentation in a selected area.
3. A case study – determining the demand for consolidation works in the Pasym commune.

Qualitative methods, in particular analytical, logical topology and identification methods were used in the above research tasks [Dawidowicz 2012]. The deployed methods support a comprehensive approach to the analysed problem and the formulation of optimal solutions. Other research methods involved comparative analysis as well as analyses of literature, documents and legal regulations related to the discussed issues [Dudzińska 2011].

3. Finding current land fragmentation factors used in determining the demand for consolidation works

Land fragmentation, alternatively named by Bentley as pulverization, parcellization or scattering [Bentley 1987], is defined as a situation where a farm possesses several non-contiguous land plots (parcels), often scattered over a wide area. It is an observed phenomenon in many countries around the world, and is generally viewed as an obsta-

cle to agricultural productivity and modernization [European Commission 2005, FAO 2003, Gąsiorowski and Bielecka 2014].

According to findings of King and Burton [1982] land fragmentation is associated with six factors:

- the landholding size,
- the number of parcels belonging to the holding,
- the size of each parcel,
- the shape of each parcel,
- the spatial distribution of parcels,
- the size distribution of the parcels.

Simmons [1964] suggested an index of land fragmentation that takes into account the number of parcels in a farm and a relative size of each parcel. He calculated the index by devising the following formula:

$$FI = \frac{\sum_{i=1}^{n} a_i^2}{\mathrm{A}^2}, \tag{1}$$

where:

FI – fragmentation index,
n – number of parcels in a farm,
a – size of a parcel,
A – total size of a farm.

If *FI* equals 1, it means that a farm consists of only one parcel, if the value is close to 0, it indicates higher degree of fragmentation.

Dovrin [1965] assumed that a fragmentation is defined by a distance that a farmer has to cover to get to each of his parcel and to get back to his farmstead after each visit to a parcel. This method however does not take into account the number of real annual number of his visits to his parcels nor a situation when each parcel can be visited without the necessity of going back to a farmstead.

Januszewski [1968] devised a similar index to the one used by Simmons, by combining the number of parcels in a farm with their spatial layout and he obtained a coefficient *K*:

$$K = \frac{\sqrt{\sum_{i=1}^{n} a_i}}{\sum_{i=1}^{n} \sqrt{a_i}}, \tag{2}$$

where:

n – number of parcels,
a – size of parcels.

The value of *K* stays between 0 and 1. The value of *K* index closer to 0 means a high degree of fragmentation. The index has three main characteristics: the degree of fragmentation increases proportionally with the number of parcels; fragmentation

increases when the range of parcel sizes is small and fragmentation decreases as the area of large parcels increases and that of small parcels decreases.

Igbozurike [1974] proposed an equation based on a mean size of parcels and a distance covered by a farmer on each consecutive trip to all his parcels (in one journey to and from all his parcels). The equation is as follows:

$$P_i = \frac{\frac{1}{S_i}}{\frac{S_i}{100}} \cdot Dt, \tag{3}$$

where:

P_i – index of land fragmentation for of S_i of each parcel,
Dt – total distance to and from all parcels.

According to King and Burton [1982] this method does not determine explicitly the distances nor it takes into account the number of parcels. They gave an example of a farm consisting of two parcels of size S_i located 10 km from each other, which would give an index P_i twice as high as a farm consisting of ten parcels of size S_i located 1 km from each other.

Schmook [1976] defined a fragmentation index as a ratio of surface area of a polygon surrounding all the farm parcels to a surface area of a farm itself. An index value is always higher than 1. The higher the value, the higher the degree of fragmentation. Schmook also suggested other fragmentation quotient obtained as a ratio of mean distance to parcels to their mean size.

Gąsiorowski [2014] defined fragmentation in selected Polish communes by taking into account such factors as: the size of a parcel, index of parcel's shape, a number of border points of a parcel (it shows the degree of border's complexity or irregularity of its shape), a distance of a parcel's centroid to a farm's centre (it is defined as a complex of residential and utility buildings, and distance is not measured in a straight but in the shortest line), a percentage share of agricultural lands in a total size of a parcel, a percentage share of a parcel in a total size of a farm.

Gawroński [2005] included four variables describing the demand for land consolidation and exchange works. The variables are: x_1 – fragmentation of an area structure of single farms, x_2 – mean number of recorded parcels that make one farm, x_3 – mean size of a single farm, and x_4 – share of lands belonging to Agricultural Property Agency in a size of agricultural lands of studied territorial units.

Similar fragmentation factors were used by Van Hung et al. [2007]. They defined two main measures of fragmentation: the number of plots per farm and a measure, based on Simpson's diversification index, which considers the number of plots, plot size and farm size. Blarel et al. [1992] have also used these two indicators to measure land fragmentation in Ghana and Rwanda.

Demetriou [2012] developed a method called LandFragmentS, which can include all recorded and essential measures of land fragmentation. The method is flexible,

because a user can choose which measures should be included in a specific project. In this method a weight is ascribed to each measure, which reflects its importance for the whole project. LandFragmentS compares a current state of land fragmentation to its state in ideal conditions, which in most cases is purely theoretical. Moreover the method takes into account a ratio of current land fragmentation to its worst possible state. First a planner chooses the measures that influence fragmentation and which will be included in a model, and then he ascribes to each of them an appropriate weight. In the next stage he calculates the quantity of these factors.

In Table 1 each line represents a farm or a land plot (parcel), and each column a land fragmentation factor. The results are then standardized (if necessary), by appropriate methods (e.g. by means of a value function), to create a standardized table of land fragmentation. Land fragmentation index (LFI_i) is calculated by multiplying standardized value of each factor (f_{ij}) by appropriate weight of each factor (w_j) and then summing up the value of each line or farm in the following way:

$$LFI_i = \sum_{i=1}^{m} f_{ij} w_j \tag{4}$$

Table 1. Land fragmentation factors in relation to each farm, according to LandFragmentS method

Ownership ID of ownership	Land fragmentation factors (weights)							Index
	F_1 (w_1)	F_2 (w_2)	F_3 (w_3)	…	F_J (w_j)	…	F_m (w_m)	
1	f_{11}	f_{12}	f_{13}	…	f_{1J}	…	f_{1m}	LFI_1
2	f_{21}	f_{22}	f_{23}	…	f_{2J}	…	f_{2m}	LFI_2
…	…	…	…	…		…		
n	f_{n1}	f_{n2}	f_{n3}	…	f_{nJ}	…	f_{nm}	LFI_n
								GLFI

Source: Demetriou 2012

A farm will have a value between 0 (full fragmentation or the worst efficiency of a system) and 1 (no fragmentation or the highest efficiency of a system). General land fragmentation index (GLFI) for a whole research site is calculated as a mean of LFI_i:

$$GLFI = \frac{\sum_{i=1}^{n} LFI_i}{n} \tag{5}$$

The presented method is flexible and in all conditions it represents characteristic factors for local determinants of a researched area.

4. Authors' study

4.1. The choice of factors for assessing land fragmentation in a selected area

From the analysis of professional literature a conclusion can be drawn that factors taken into consideration in estimating land fragmentation are often related to a spatial specificity of an analysed area (e.g. mountain areas), to a possibility of acquiring certain data and to an accessible technology of analyses. Usually the researchers take into account an outcome of three factors influencing the land fragmentation degree in farms (number of land plots, size of each land plot and size of a whole farm).

In an era of modern technologies used for estimation of land fragmentation the researchers take into consideration an increasing number of factors, e.g. Demetriou [2012] and Gąsiorowski [2014] additionally include, among other things, shape of land plots or a road access to a land plot.

In his method LandFragmentS Demetriou [2012] introduces yet another feature: an element of a free choice of factors that are important in estimating the demand for land consolidation works, and besides he determines weight and importance of each factor.

4.2. Authors' choice of factors

For the purpose of this article a research was carried out to determine new factors that would enable accurate assessment of land fragmentation. The kind of factor and weight indexes for each factor were determined based on a questionnaire sent to a group of specialists in land consolidation and to farmers. The aim of the questionnaire was to examine the preferences of chosen patchwork parameters (land fragmentation).

The values of weights were established based on the obtained results to indicate factors influencing the patchwork index (land fragmentation index) and to determine a degree of their influence. The questionnaire was designed to allow the respondents to compare all fragmentation factors presented in lines of a table with the same factors presented in columns. If a feature in a line proved to be more important than a feature in a column, then 1 should be put down. Otherwise a responded was asked to write 0.

The research was carried out in the Pasym commune, in the Warmia and Mazury Voivodeship. As a result of it a percentage value of each factor influencing the degree of land fragmentation factor was calculated (Table 2). The factors are presented in Table 3.

Table 2. Table model used in the presented questionnaire

	Size of a farm	Number of land plots in a farm	Distance of a farm's land plots to a settlement	Land layout index	Size of a land plot	Elongation of a land plot	Irregular shape of a land plot	Access of a land plot to a road
Size of a farm	---							
Number of land plots in a farm		---						
Distance of a farm's land plots to a settlement			---					
Land layout index				---				
Size of a land plot					---			
Elongation of a land plot						---		
Irregular shape of a land plot							---	
Access of a land plot to a road								---

Source: authors' study

Table 3. Assessing weight of particular factors

Factor's name	Mean assessment [*Oi*]	Weight [*Wi*]
Size of a farm	8	9.5%
Number of land plots in a farm	13	15.5%
Distance of farm's land plots to a settlement	12	14.3%
Land layout index	11	13.1%
Size of a farm	12	14.3%
Elongation of a land plot	10	11.9%
Irregular shape of a land plot	8	9.5%
Access of a land plot to a road	10	11.9%
Total	84	100%

Source: authors' study

4.3. Case study – assessing the demand for land consolidation works in the Pasym commune

The commune covers an area of 149.4 km^2, 46% of which are arable lands, 31% – forests, and 11% is under water. The commune has a population of 5156 inhabitants, which means that its population density is 34.5 person per km^2. The analysed area covers in total 31.07 km^2, which for the purpose of the study was divided in the six following precincts: 1 – north, 2 – north-east, 3 – east, 4 – south-east, 5 – south, 6 – west. The boundaries of the precinct are shown in Figure 1. In the north precinct there are 531 land plots of a size from 0.10 ha to 45 ha. The mean size of a land plot in this area is 2.2530 ha and the configuration of land plots there has an irregular patchwork type.

The north-east precinct includes 682 land plots of size from 0.10 ha to 35 ha. The mean size of a land plot in this area is 1.1518 ha. Configuration of land plots suggests an irregular patchwork type. There is 1287 land plots in the area of mean size 1.0263 ha, but a size of the biggest land plot does not exceed 45 ha. The south-east precinct covers 223 land plots. The size of land plots stays within the range from 10 ares to 19 ha. The mean size of a land plot in the area is 2.2953 ha. The south precinct covers 548 land plots of a mean size of 3.8773 ha and none of them is bigger than 15 ha. The west precinct includes 1704 land plots of a mean size of 0.7529 ha. The biggest land plot in the area is of 27 ha.

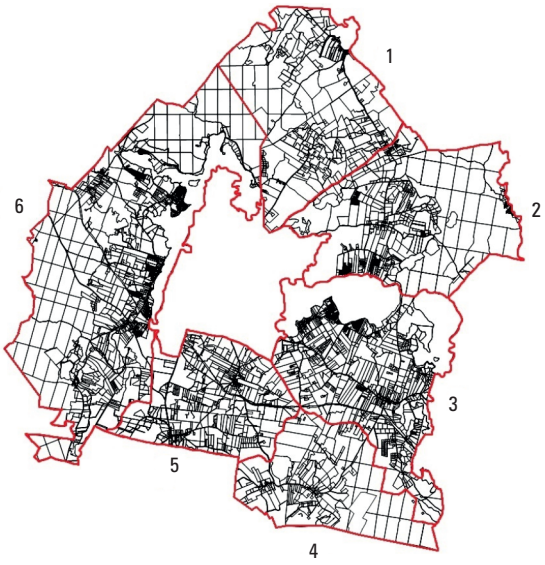
The elongation of an agriculture land plot, that is a ratio of its length to its width, has much influence on a land plot's shape. The elongation can be calculated by a formula (6) that requires value of a factor and a surface area. To derive the formula presented below, a square was used as a basic figure, the elongation of which (marked as *w*) equals 1. In addition, this factor is judged visually [Litwin and Szewczyk 2012].

$$w = \frac{O + \sqrt{O^2 - 16P}}{O - \sqrt{O^2 - 16P}}, \tag{6}$$

where:

O – perimeter of a land plot,

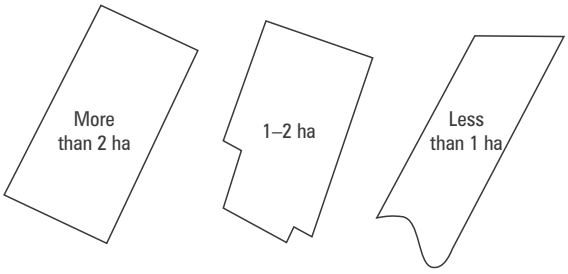
P – surface area of a land plot.



Source: Waluk 2013

Fig. 1. The division of the Pasym commune into studied precincts

The land plot that have a favourable shape are characterized by longer parallel sides and angles that are close to 90°. Preferably a border line should be as short as possible and least varied and meet all the previous requirements. The examples of favourable shapes of land plots are shown in Figure 2.



Source: author's study

Fig. 2. Examples of favourable shapes of land plots

Table 4. Assessment of a degree of land fragmentation in the Pasym commune

Factor's name		Number of land plots and their point value in the adopted scale										Total		Fragmentation degree value	Fragmentation degree
		Very favourable – 1 point		Favourable – 2 points		Satisfactory – 3 points		Unfavourable – 4 points		Very unfavourable – 5 points					
		Number of land plots	Point value	Number of land plots	Point value	Number of land plots	Point value	Number of land plots	Point value	Number of land plots	Point value	Number of land plots	Point value		
Size of a land plot	North precinct	54	54	3.7	170	73	219	57	228	261	1305	530	1976	3.7	unfavourable
	North-east precinct	36	36	61	122	67	201	60	244	457	2285	681	2888	4.2	unfavourable
	East precinct	61	61	113	226	123	369	132	528	858	4290	1287	5474	4.2	unfavourable
	south-east precinct	30	30	45	90	32	96	32	128	84	420	223	764	3.4	satisfactory
	South precinct	65	65	94	188	103	309	67	268	219	1095	548	1925	3.5	satisfactory
	West precinct	62	62	112	224	120	360	117	468	1292	6460	1703	7932	4.6	unfavourable
Elongation index	North precinct	225	225	3.2	350	82	246	18	720	30	150	530	1691	3.2	satisfactory
	North-east precinct	398	36	177	354	43	129	17	68	46	230	681	817	1.2	very favourable
	East precinct	707	707	382	764	118	354	29	116	51	255	1287	2196	1.7	favourable
	South-east precinct	83	83	85	170	33	99	7	28	15	75	223	455	2.0	favourable
	South precinct	190	190	235	470	94	282	10	40	19	95	548	1077	2.0	favourable
	West precinct	907	907	500	1000	146	438	51	204	99	495	1703	3044	1.8	favourable

% of land plots in the irregular shape	North precinct	221	221	2.6	150	64	192	86	344	84	420	530	1327	2.6	satisfactory
	North-east precinct	454	454	93	186	56	168	39	156	40	200	681	1164	1.7	favourable
	East region	892	892	179	358	56	168	38	152	122	610	1287	2180	1.7	favourable
	South-east precinct	91	91	61	122	47	141	5	20	19	95	223	469	2.1	favourable
	South precinct	196	196	177	354	100	300	45	180	30	150	548	1180	2.2	favourable
	West precinct	911	911	291	582	99	297	223	892	179	895	1703	3577	2.1	favourable
% of land plots without road access	North region	499	499	1.2	–	–	–	–	–	31	155	530	654	1.2	very favourable
	North-east precinct	655	655	–	–	–	–	–	–	27	135	681	790	1.2	very favourable
	East	1234	1234	–	–	–	–	–	–	53	265	1287	1499	1.2	very favourable
	South-east precinct	202	202	–	–	–	–	–	–	21	105	223	307	1.4	favourable
	South precinct	530	530	–	–	–	–	–	–	18	90	548	620	1.1	very favourable
	West precinct	1634	1634	–	–	–	–	–	–	69	345	1703	1979	1.2	very favourable
Total	North precinct	999	999	335	670	219	657	161	1292	406	2030		5648	2.7	satisfactory
	North-east precinct	1181	1181	331	662	166	498	116	468	570	2850		5659	2.1	favourable
	East precinct	2984	2894	674	1348	297	891	199	796	1084	5420		11349	2.2	favourable
	South-east precinct	406	406	191	382	112	336	44	176	136	695		1995	2.2	favourable
	South precinct	981	981	506	1012	297	891	122	488	286	1430		4802	2.2	favourable
	West precinct	3514	3514	903	1806	365	1095	391	1564	1639	8195		16174	2.4	favourable

Source: Waluk 2013

The above spatial elements of agriculture lands were confronted with weights obtained from the questionnaire, were classified into five-point scale and presented in a table. The results of calculations of spatial and technical factors of land plots were divided into quality classes, according to the scale: very favourable state – 1 point, favourable state – 2 points, satisfactory state – 3 points, unfavourable state – 4 points, very unfavourable state – 5 points.

Numbers in Table 4 show that mean size of land plots in the north precinct of the Pasym commune is unfavourable, while the elongation index and shape of land plots are satisfactory. There is also a very favourable number of land plots without road access. On the other hand the north-east precinct of a commune has an unfavourable degree of a feature called "the size of a land plot", the elongation index however as well as the shape and number of land plots without road access are very favourable or favourable.

In the west precinct of the commune there are very few land plots without an independent access to a road, which was regarded as a very favourable feature. As favourable were judged such features as: an elongation index and shape of land plots. The mean size of land plots is unfavourable in this precinct.

In the south precinct of the studied area the mean size of a land plot was a feature regarded as only satisfactory, and the best marks were given to the share of land plots without road. The west precinct of the commune is characterized by the unfavourable mean size of land plots and by very favourable number of plots without road access. The remaining features are satisfactory.

5. Conlusions

The main objective of the article was to define a set of factors important in the assessment of land fragmentation. The goal was achieved by the questionnaire survey distributed among farmers living in studied area and specialists in land consolidation. Thanks to it a hierarchy of geometric and technical factors has been established that are taken into account in the assessment of demand for land consolidation works. The results of the study show that the land fragmentation mostly depends on the number of land plots (parcels) in a farm, their distance to a settlement and on the size of a land plot. The land fragmentation is least influenced by such factors as: the size of a farm and an irregular shape of a land plot. The research has confirmed the general tendency in spatial changes taking place in small farms in the Warmia and Mazury Voivedship.

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