

# The Role of the Land Layout Parameters and Production Efficiency in the Evaluation and Shaping of the Spatial Structure of Land

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**Abstract.** The article contains the results of the plots layout research in the farms of the selected object in the southern Poland. The basic surface element adopted for the research, were continuous parts of the registry plots covered by one form of use. To carry out tests on such a large number of plots specialized computer programs used, which use data from the digital cadastral map and the descriptive part of the land and buildings registry documentation kept in digital system. The applied technology allowed obtaining more than 70 features, characterizing each analyzed plot. Detailed studies included the 15 basic features of plots layout, first four of which determine the spatial parameters of the plot, three features relate to the estimated costs of cultivation dependent on its layout, the next two describe the location of the plot in the village and in the farm, and the last five characterize the farm, that owns the plot. The obtained result allowed the identification of positive and negative aspects of the tested ground system indicating the necessary changes in terms of its improvement.

**Keywords:** farm land layout, spatial structure of land, land consolidation.

**Conference topic:** Technologies of Geodesy and Cadastre.

## Introduction

Land belonging to the farm should be optimally shaped and located as close as possible to the farm centre. This solution streamlines the organization of the entire process of agricultural production and also reduces the expenditure incurred on transport, which can significantly limit the profitability of the whole farm. The results of research contained in a number of scientific studies have shown that incorrectly shaped and excessively fragmented plots, make that their agricultural use is not as effective, as in the case of plots with the correct shape and optimum area (Hopfer 1991; Harasimowicz 2000; Mielewczyk 2010). The disadvantages occurring in the spatial structure of land force the implementation of arrangement-agricultural works, with the aim of the reconstruction of a defective ground layout in such a way that its future agricultural development could be more effective and could bring real financial benefits (Pijanowski 2014). The works correcting defects in rural land systems should be preceded by an assessment of the actual condition of the land, which is based on an analysis of the basic spatial and technical parameters for plots belonging to the particular farms (Harasimowicz 2002; González *et al.* 2004; Gniadek *et al.* 2013). In the available literature it is possible to find many methods allowing to perform such tasks (Zandonadi *et al.* 2013; Demetriou *et al.* 2013). It seems that among the available solutions the most accurate results can be obtained through the automated method applying a synthetic configuration index in the form of the cultivation costs dependent on the spatial shape of the plot (Gniadek *et al.* 2013). Using this solution it should be remembered that the assessment of the efficiency of the production process should be related not to the borders of the registry plots within which there may be a variety of arable land use, but to the mentioned parts of the plots covered by a separate cultivation process.

## The purpose, scope and method of the elaboration

The aim of the article was to make the analysis of farm land for the needs of reconstruction of the existing system of land. The village Koźlice with the area of 604.01 hectares situated in the south western part of Poland, in the Lower Silesian Voivodeship was selected for the study. In the process of assessing farm land specialised computer software was used, which allowed both, to specify the spatial and technical parameters necessary to evaluate the analyzed plots and farms (MK, SWORG, STATISTICA), and preparation of documentation illustrating the state of arrangement and shape of studied surface elements (QGIS). The basic surface elements adopted for testing, were continuous parts of the plots covered by a separate form of use (arable land and permanent grassland) – conventionally identified in the study as “plots”. A full assessment of the shape of plots was carried out using a synthetic of their shape in the form of so-

called cost of cultivation dependent on the shape and location of plots. All plots existing in the village belonging to the existing farms were included into studies.

### Basic spatial and technical parameters of plots

The parameters determined in the process of calculation, characterizing the spatial shape of plots and farms in the studied village, enabled the use of statistical tools to support the implementation of a detailed assessment of the existing system of land. Certain basic descriptive statistics for the analyzed parameters are shown in Table 1. From the obtained research material results that in the analyzed area there are plots with an average area of 1.07 ha, which according to research (Harasimowicz 2002) can be considered as suitable for the mechanical cultivation. The high kurtosis of this parameter, equal 278.26 testifies the fact that a large part of plots has a similar value as the calculated average. The largest plot has the area of 69.37 hectares and the smallest only 0.03 hectares, therefore the range, which is the difference between the maximum and minimum area of a plot is wide and is equal 69.34 ha.

Table 1. Basic descriptive statistics of considered features of plots land configuration in Koźlice (source: own elaboration)

Variable name	Statistic								
	Mean	Median	Minimum	Maximum	Interval	Standard deviation	Mean standard error	Skewness	Kurtosis
Plot area [ha]	1.07	0.65	0.03	69.37	69.34	4.02	0.23	16.37	278.26
Plot length [hm]	1.69	1.53	0.17	5.63	5.46	1.12	0.06	0.43	-0.78
Plot width [hm]	0.54	0.40	0.10	12.32	12.22	0.78	0.05	11.73	170.68
Plot elongation	4.42	3.00	0.09	25.91	25.81	4.01	0.23	1.89	5.09
Land configuration costs without driving to the plot [cereal units per ha]	7.65	4.58	1.08	56.61	55.53	8.43	0.49	2.88	9.26
Land configuration costs with driving to the plot (bad roads) [cereal units per ha]	14.46	13.05	1.59	64.90	63.31	8.28	0.48	1.78	5.87
Land configuration costs with driving to the plot (good roads) [cereal units per ha]	10.37	8.56	1.59	59.93	58.34	7.81	0.45	2.93	10.64
Distance of the plot from the farmers habitat	8.50	7.35	0.07	32.27	32.20	7.88	0.47	0.81	-0.15
Distance of the plot from the village center	9.17	7.83	0.13	31.04	30.91	7.10	0.41	1.06	0.41
Number of plots at the farm	32.94	16.50	1.00	79.00	78.00	28.67	1.65	0.63	-1.25
Number of arable plots	20.53	10.00	0.00	54.00	54.00	20.08	1.16	0.73	-1.10
Number grassland plots	3.81	3.00	0.00	10.00	10.00	3.60	0.21	0.87	-0.80
Area of the farm [ha]	33.84	10.33	0.25	112.24	111.99	38.44	2.21	0.97	-0.49

Shown in Figure 1 distribution of the number of plots in individual class intervals, presents the real picture of the area structure. According to (Woch 2001) as the minimum area enabling the full mechanization of field work is assumed size of not less than 1–2 hectares. The results indicate that, despite the average area (1.07 ha) the analyzed plots are highly diverse in terms of the area they occupy. About 37% of the parcels is characterized by a correct area. However, most of the studied population (63% of the plots) has very small areas, less than 1 ha, of which nearly half did not exceed 0.3 ha. Due to the changes in the agricultural sector in terms of its current modernization and the implementation of modern systems of precision farming, the result indicates faulty structure of plots in the study area, pointing to the need for changes to improve their area.

The average length of cultivation for the tested plots is 169 m (Table 1). This parameter has a wide range from 17 to 563 m. According to research, the lengths of the plots, which are below the range of 100 to 150 m generate high costs associated with cultivation reducing the income of the production (Harasimowicz 2000). As it is apparent from

Figure 2, the plots of the length less than 50 m (app. 21%) constitute the largest group, and in the range from 50 m to 100 m there are app. 15% of plots.

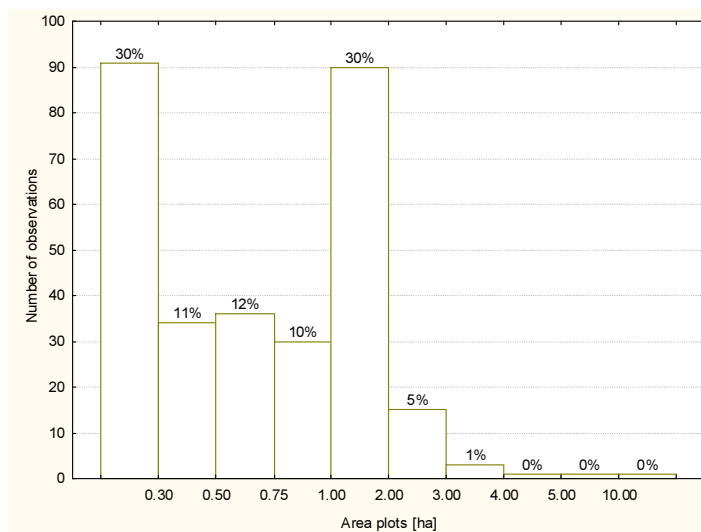


Fig. 1. Number distribution of plots depending on their area (source: own elaboration)

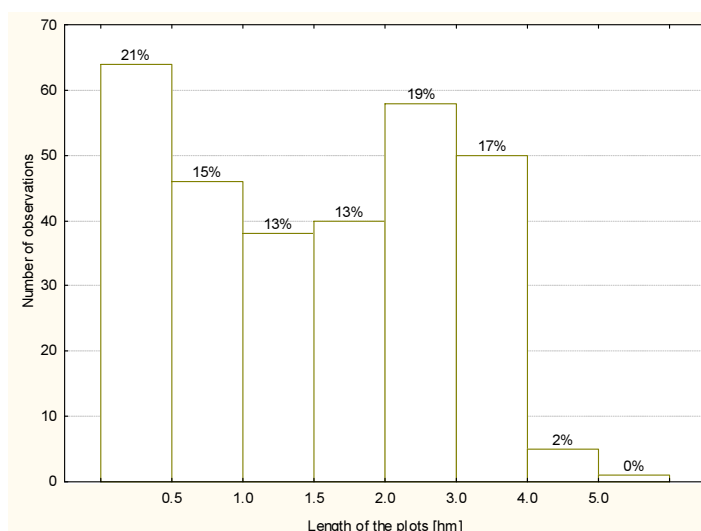


Fig. 2. Number distribution of plots depending on their length (source: own elaboration)

In the area of Koźlice there are about 13% of plots within the range of minimum length considered valid. A similar number of plots occurs in the next range of size from 150 m to 200 m. The remaining plots, about 38% have lengths that are considered valid for the use of mechanical cultivation. The aforementioned result about 38% of the parcels with the correct lengths presumably concerns almost identical population of plots, which as described previously is characterized by the correct areas.

As shown in Table 1, the average width of the plot for this area is 54 m. Although the range reflects rather considerable diversity in the shape of plots in Koźlice the kurtosis (170.68) shows that a lot of plots is similar to the width of each other and thus may indicate the similar shape. According to researches (Harasimowicz, Ostrągowska 1996), the correct width of the the plot for the tractor cultivation should be not less than 30 to 50 m. This means that the average value of this parameter in the study area extends slightly beyond mentioned above interval. However, the plots of smaller widths, below the mentioned range constitute up to 29% (Fig. 3).

The community is characterized by a significant decrease in the production income, because on the plots with small widths a significant decrease in the yield observed along their lengths takes place. The remaining group of plots with the widths over 50 m constitutes 30% of the entire population. Among the mentioned population there are isolated

cases of parcels of widths greater than 200 m. Such large widths occur on the few plots, which are parts of several farms dominating in terms of area in the analyzed area.

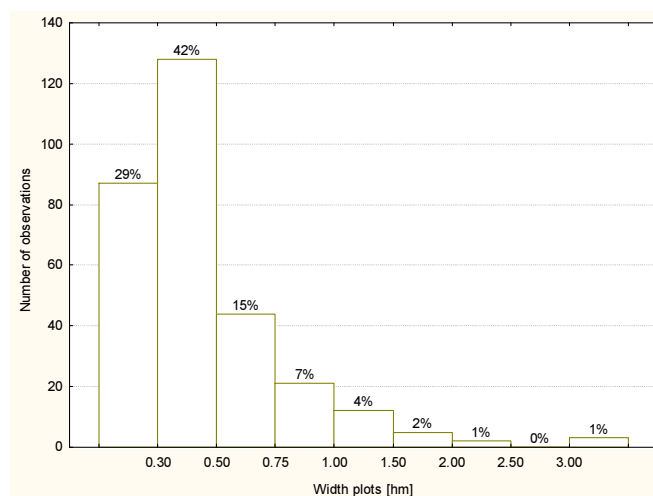


Fig. 3. Number distribution of plots depending on their width (source: own elaboration)

The average elongation of the parcels under consideration is about 1: 4 (Table 1). The correct elongation of plots, larger than 1 ha, should be 1: 5 (Harasimowicz, Ostrągowska 1996). In the case of the analyzed index of plots elongation a correlation between the number of tested plots and the value of index elongation can be observed (Fig. 4).

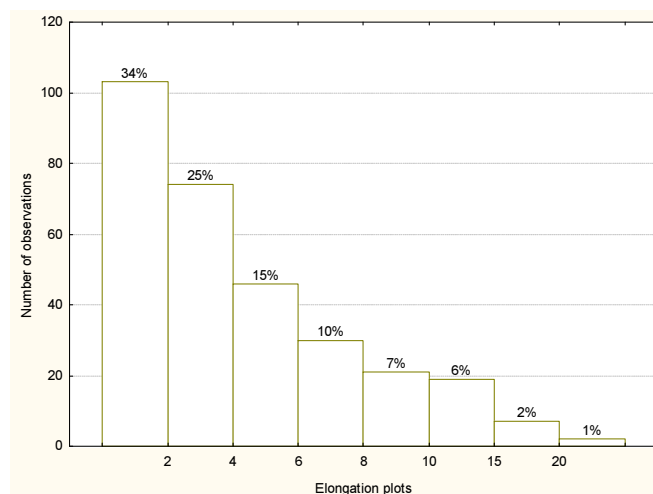


Fig. 4. Number distribution of plots depending on their elongation (source: own elaboration)

With the increase of the elongation decreases the number of observations. Therefore, the largest group of plots, constitute those which elongation is smallest. From the analyzed distribution of the number of plots depending on their elongation it is apparent, that about 59% of the parcels have elongation less than 1: 4, which is not sufficient and may indicate a reduced level of income derived from farm production. Only about 15% of the parcels is close to the correct elongation between 1:4 and 1:6. The remaining 26% of the parcels have too high elongation, which may cause an increase of costs associated with the cultivation.

### The location of plots in the farm and in the village

The characteristics of the parcels location within particular farms, was made basing on the distance from the nearest corner of the homestead plot. To determine the location of the plot in the village the distance between the center of the village and the nearest corner of the plot was used.

The average distance of the homestead from the nearest corner of the plot on the farm is 850 m (Table 1) and it is smaller by about 60 meters from the average distance of plots from the village center. Similar sizes of the averages confirm a compact development area in the studied terrain, however, the distributions of number for the distances;

plot – homestead and plot – the center of the village, are different. From the distribution of distances of plots from homesteads (Fig. 5) results that 41% of the studied population of plots are located within 500 m, what according to research (Dembowska, Lachert 1974) can be considered as the value of the least influencing the increase in incurred costs related to transport.

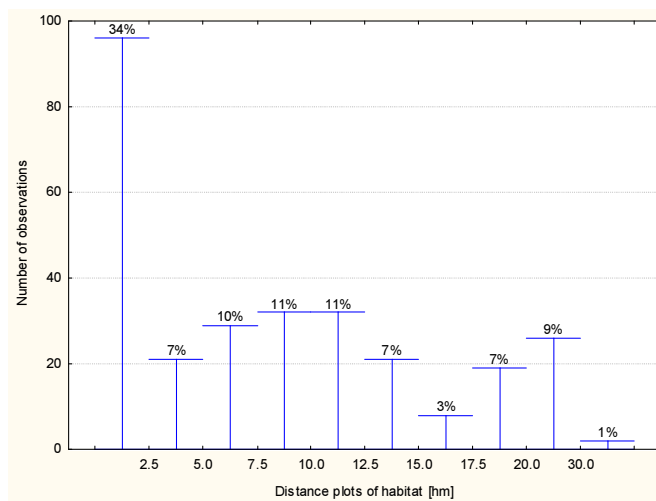


Fig. 5. Number distribution of plots depending on their distance from the farmer's habitat (source: own elaboration)

Proximity proves the proper location of plots in relation to farm buildings and little possibilities of bringing the plots closer to homesteads in the event of reconstruction of the land layout. From the presented in Figure 6 land configuration it results, however, that the majority of this population are plots of small areas, where cultivation is not as profitable as in the case of large and properly shaped.

Approximately 39% of the plots are located at distances from 500 to 1500 m from homesteads, what can be considered as suitable for large farms (Przybyłowski 1989). In the surveyed village there are just a few of such production units the others are family farms ranging in size from a few to several dozen hectares. A similar percentage in the analyzed interval was also noticed for the distance plot – village center (Fig. 7). However, percentage differences can be seen here in the internal intervals of the population for the distance plot – homestead and plot – the center of village.

In the interval of plots distance from homesteads above 1500 m the decrease in their quantities can be observed. The exception is the range from 2000 to 3000 m, with visible increase in the quantity to about 9% (Fig. 5) and 10% (Fig. 7), of the entire population. This increase is due to the large quantity of plots, with the grassland, which are mostly concentrated in the most distant from the homesteads, southern part of the object. A large number of them in this region is probably due to the occurring in the past need for a grassland in each farm.

The compact settlement of farm buildings located in the central part of the village can provide some kind of limitation on the reduction of the distance of plots from homesteads in the case of agricultural arrangements works. Presumably, if the system of homesteads was more fragmented, correction of the existing borders could bring better results in the reduction of costs associated with transport.

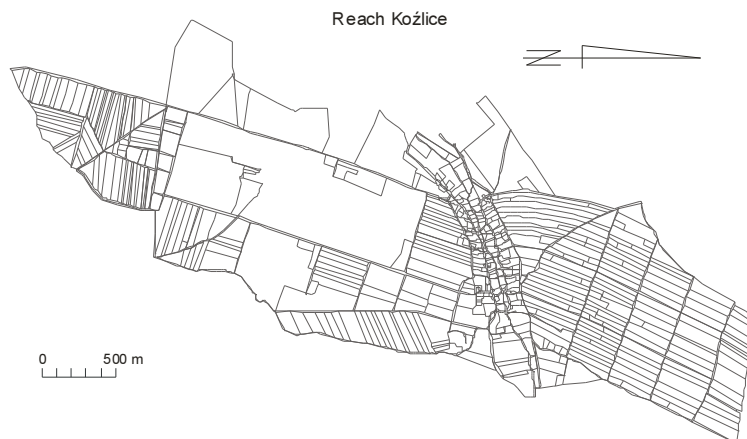


Fig. 6. The system of borders of the registry plots in the village Koźlice (source: own elaboration)

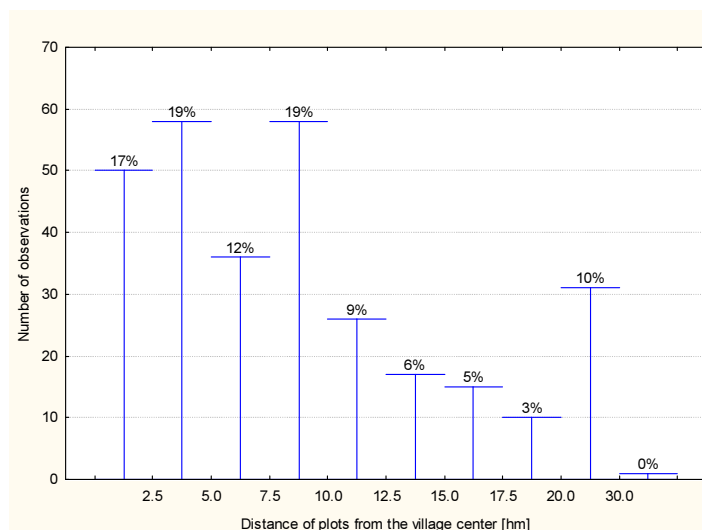


Fig. 7. Number distribution of plots depending on their distance from the village center (source: own elaboration)

### Estimation of the shape of plots using synthetic index of the cost of cultivation

The analysis of the basic parameters of spatial configuration and distribution of plots in the studied farms made possible a preliminary assessment of the existing state of the spatial configuration of the land. Values of the analyzed parameters obtained through a calculation were compared to the optimal values and the interpretation of results was conducted separately for each of them. Such model of studies may in practice result in some discrepancies between estimated and actual participation of plots which shape is faulty. For this reason, it is better to conduct research using a synthetic index of the spatial configuration of land, covering all technical and spatial parameters including the location of plots.

Detailed analysis of the shape of the plots was carried out using the index of their configuration in the form of the cost of cultivation dependent on the layout of the plot. The index adopted in the study was estimated for each of the tested plots assuming full mechanization of field works using medium power tractors and cereal yielding at 5 t / ha. According to (Harasimowicz 2002) the correct size of the index for the plots, which have an optimal area and the correct shape should not exceed 4 cereal units / 1ha.

In the Koźlice village average cost of layout with good access roads is 10.37 cereal units/ ha (Table 1). This value is incorrect, as it far exceeds the permissible limit of optimal costs. Only 8% of all parcels is characterized by costs of layout below this limit, (Fig. 8).

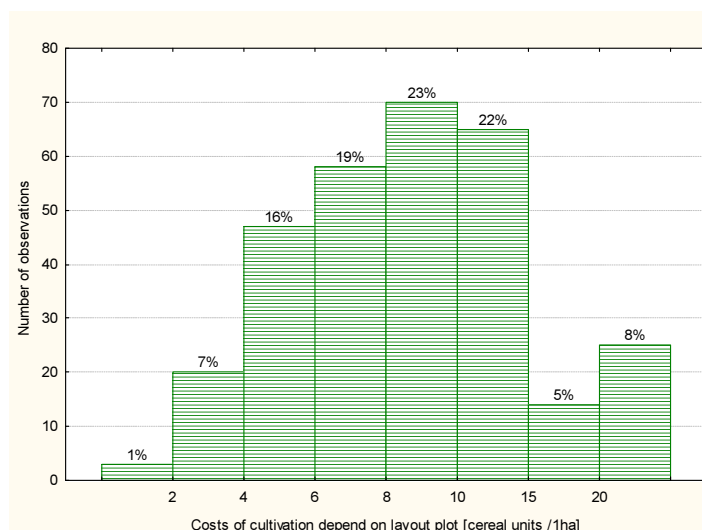


Fig. 8. Number distribution of plots depending on their exploitation costs connected with land configuration (source: own elaboration)

Comparing this values to the results of the previous analysis of the shape parameters large discrepancies can be seen between the mentioned above set of plots having the correct synthetic index of shape and the total participation

of plots with optimal area, length and width (Fig. 1, 2, 3). Using therefore the proposed solution more reliable test results can be obtained demonstrating the production capacity resulting from both the shape and location of plots.

Analyzing the rest of the set of plots using adopted cost index can be stated that 92% of plots generate costs in excess of the permissible limit of 4 cereal units / 1ha. A significant part of the plots is concentrated around a medium value of the layout costs, which is confirmed by the value of kurtosis, equal 10,64. The largest group of plots (23%) is characterized by the costs of layout from 8 to 10 cereal units / ha. The set containing a similar number (22% of all plots), is characterized by costs from 10 to 15 cereal units / ha. The third group in size has 19% of plots, where costs are incurred from 6 to 8 cereal units / ha. The highest costs observed on the plots of the worst shaping represent 13% and are successively in the ranges: from 15 to 20 cereal units / ha – 5% and beyond 20 cereal units / ha – 8%.

## Conclusion

The issue of the assessment of the land configuration in the village Kozłice on the basis of the parameters of spatial shaping discussed in the work made it possible to obtain results which enabled confirmation of the correctness and defects in the tested land system. The adopted methodological solution allowing for a comprehensive study of all farms in the village, forces using data regarding the digital cadastral map and the descriptive part of the registry documentation kept in a digital system.

Detailed analysis of the obtained values of the basic spatial and technical parameters of plots and farms showed a high inadequacy of the existing spatial structure of the land. Inadequate surfaces, lengths or widths of the plots are the cause of the impossibility of obtaining an adequate income from farm production and indicate the need for changes in the existing ground system. The disadvantage of the tested ground system is also concentrated building zone, which in the case land system reconstruction, will be an important element limiting the ability to bring land closer to home-steads.

An important observation are large discrepancies arising from a separate interpretation of the parameters of spatial configuration of plots and the synthetic shape index in the form of the estimated costs of cultivation dependent on the shape and location of the plot relative to the farm center. These discrepancies indicate clearly that a separate interpretation of each of the tested parameters can contain not fully accurate information. Reported in the paper discrepancy between the population of plots of the proper shape obtained on basis of the aforementioned, separate interpretation of the shaping parameters and population determined on the basis of the ratio of costs of cultivation constitutes about 20 to 30% of the entire population. Such a large difference gives rise to the conclusion, that detailed studies related to the assessment of rural land system should be carried out using synthetic instrument in the form of the estimated costs of cultivation, and not, as in many cases, a separate interpretation of the selected spatial and technical parameters.

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