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OPTIMISATION OF SPATIAL STRUCTURE EXEMPLIFIED BY THE VILLAGE OF FILIPOWICE

Summary

The developed method of optimising a farmland arrangement system considers two basic directions when improving the layout of plots and farms: the aim of bringing farmlands closer to a farmstead site and the aim to improve the size and shape of plots. The basis for constructing this optimisation model comprises the division of consolidated land complexes into small elementary strips and the determination of distances between those strips and farmstead sites. The final result of the entire optimisation procedure is a complete digital map of a new farmland arrangement system. With this map, it is possible to compile all the documents necessary to create a cadastre. The time- and labour consuming processes of preparing data, constructing the model and solving it have been automated through the application of relevant software programs, thus, the method developed can be used in practice. The optimisation principles of farmland arrangement system were exemplified in the case of the village of Filipowice located near the city of Cracow. The optimisation performed resulted in, among other things, enlarging the mean plot area by four times and in bringing it 30% closer to a farmstead site.

Key words: plots layout, optimisation of farmland arrangement system, consolidated lands complex

INTRODUCTION

Usually, transformations in spatial structure of a village aim at improving plots layout and at decreasing distances between plots and farmstead sites. The developed optimisation method of farmland arrangement system takes into consideration the two basic improvement directions of layout of plots and farms, and the optimisation range of the directions considered is diversified. The optimisation of the location of farmlands in relation to farmstead sites is also included; its intention is to minimize the distances between the farmland plots and

farm buildings. The location of farmlands in relation to the farmstead sites is defined using small elementary strips (having an area of a few ares) that have been allocated within the project complexes according to the direction the plots have been designed. Owing to the optimisation process performed based on this rule, it is possible to allocate elementary strips to farms so as to obtain the smallest average distances to farmstead sites.

A correct layout of plots is created in two phases. The first phase comprises preparatory work focused on preparing a general farmlands consolidation design; this preparatory work precedes the practical application of the method discussed. Whilst designing a new road network and fixing borders of project complexes, the areas of plots to be allocated and the potential to shape them properly are taken into account. In particular, this refers to the distances between those neighbouring roads, which denote the borders of the project complexes and which should be adjusted to the desired length of plots. With a road network, designed in this manner, it is possible to get correct lengths of plots, and their correct shape is, then, conditioned, mainly, by the procedure of sectioning off sufficiently large plots pursuant to the design assumptions.

The target of the second phase of shaping the layout of farmland plots is to guarantee the correctness of their areas. The allocation of elementary strips to particular farms performed while minimizing distances between farmlands and farmstead sites can be repeated in many other project complexes in the form of small shares in the farmland area. The developed software program contains several correction procedures to be used when allocating the shares of farms within the consolidated land complexes. Those corrections make the allocated shares larger than the area assumed (provided it is possible).

The method developed refers to the former studies and papers on the optimisation of farmland arrangement system within a village, such as [Stelmach 1975, Żebrowski and Hopfer 1979, Banat et al. 1982, Harasimowicz 1986, Cay and Iscan 2006, Harasimowicz et al. 2006, 2007, 2008], made from the point of view of the farmland location towards farmstead sites. A new component added to the method under discussion is an attempt to include the size and shape of plots and to finalize the entire optimisation process using an automated map compilation procedure for new farmland arrangement system.

The procedures connected with the optimisation of farmland arrangement system are exemplified by the village of Filipowice situated near the city of Kraków, a on the southern slopes of the Kraków-Częstochowa Jurassic Highland Chain. This ca. 1000 ha village is characterized by a considerable farmland fragmentation. More than 400 farms registered here are in possession of over 9 thousand plots of a 10-a area on average.

**OPTIMISATION MODEL OF THE FARMLAND ARRANGEMENT SYSTEM
IN THE VILLAGE OF FILIPOWICE**

A digital map and a cadastre constitute the major source of data for the optimisation of the farmland arrangement system. The process of acquiring data has been automated through appropriate software programs; thus, the labour intensity required for the necessary information to be compiled has been essentially reduced.

Prior to optimising the allocation of farmlands to farms, a preliminary plot consolidation system has to be accomplished. The preliminary design should include: the determination of 'invariants', i.e. of territories excluded from the consolidation project and the determination of borders of project complexes and of directions for designing plots. The preparatory activities should also cover additional analyses and calculations required for the village's spatial structure optimisation model to be constructed. They are: compiling a map showing the division of consolidation complexes into elementary strips, and constructing a matrix of distances between the elementary strips created and the farmstead sites.

The software programs [Harasimowicz and Janus 2006] developed can be applied when dividing the consolidation complexes into elementary strips and constructing a matrix as indicated above. With those computer programs, the realization of the labour consuming tasks will be highly facilitated.

Based on the data preparation process developed, 4 initial files are created (fig. 1); they comprise:

1. a matrix of distances between the elementary strips and farmstead sites;
2. a set of elementary strips under the land consolidation project including their allotment to farms and consolidated land complexes;
3. a list of farms referred to;
4. a list of consolidated land complexes.

With the materials prepared, it is possible to optimise the arrangement of elementary strips in relation to farmstead sites. The elementary strips allocated have identical surface areas or identical values. Therefore, it is possible to formulate a variation model of distances to farmlands using binary variables. The decision-making variables in this model refer to small elementary strips of surface areas ranging from several to twenty ares, and sectioned off within the project complexes, for which the distances to farmstead sites have been determined. The model described includes those basic farmland consolidation conditions, which refer to the surface area or to the value of farms, as well as their probable extension as regards the land use structure and soils quality. The objective function is an average distance between farmlands and farmstead sites in the village, i.e. an average distance to the elementary strips that have been marked off.

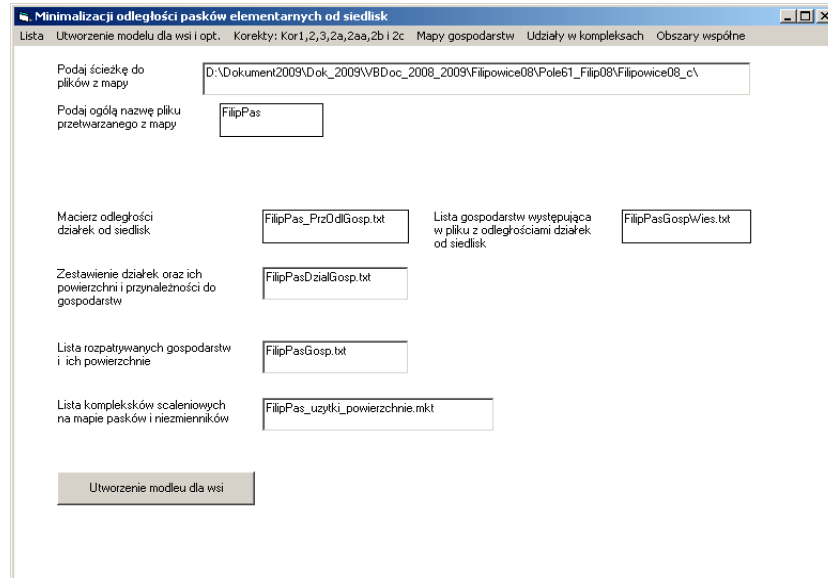


Fig. 1. Specimen of Worksheet, element of „OptGospPaski” software program, to be used when optimising farmland arrangement system in a village

The simplest form of the model under consideration can be expressed as:

$$\begin{aligned} \sum_{i=1}^m x_{ij} &= g_{pj}, \quad j = 1, 2, \dots, n \quad (n - \text{number of farms}) \\ \sum_{j=1}^n x_{ij} &= 1, \quad i = 1, 2, \dots, m \quad (m - \text{number of elementary strips}) \\ \sum_{i=1}^m \sum_{j=1}^n l_{ij} x_{ij} &= \min, \end{aligned} \quad (1)$$

where:

- x_{ij} – decision-making variable to determine the allocation of an i -th elementary strip do to a i -th farm;
- $x_{ij} = 1$ provided an elementary strip belongs to a given farm;
- $x_{ij} = 0$ provided an elementary strip does not belong to a given farm;
- l_{ij} – distance between an i -th elementary strip and a i -th farmstead site as determined for a given plot comprising the element under consideration;
- g_{pj} – surface area of a i -th farm expressed by a given number of elementary strips.

The assumed optimisation model of farmland arrangement systems in a village is relative unsophisticated, however, for its simplicity, the model paid with its large size. In an average village, the number of elementary strips can be as much as ten to twenty thousands. This number multiplied by a number of farms results in several millions of decision-making variables. However, the simplicity of this model allows solving it by an effective algorithm reduced to a few reviews (table 1) of elementary strips exchanged among the farms using displacement assessment matrices [Harasimowicz 1986]. With this algorithm used, it is possible to solve even highly extensive models with relatively unsophisticated computers.

Table 1. Corrections to the optimisation of the farmland arrangement system in the village of Filipowice

Optimisation Phase	Average distance between farmstead site and farmland [m]	Parameters of Corrections		Number of plots and elementary strips covered by the optimisation process		Number of farms' shares in consolidation complexes					Number of farms with increases in distances to their farmlands exceeding 100 m
		Maximal change in the objective function	Number of Re-views	Plots	Strips	All	Up to 1 ha	Up to 0.5 ha	Up to 20 a	Up to 10 a	
Prior to optimisation	1190.78	-	-	3381	5128	1185	1078	824	492	239	-
Optimisation of distances to farmstead sites											
Phase 1	936.22	100	1	-	5128	1101	974	713	468	270	-
Phase 2	932.12	100	1	-	5128	1009	868	624	402	229	-
Phase 3	930.67	100	1	-	5128	1004	862	618	394	227	-
Phase 4	929.93	100	1	-	5128	1004	862	618	394	227	-
Final optimisation	929.99	100	some	-	5128	1004	862	618	394	227	-
Corrections comprising restrictions as regards the excessive increase in distances to farmlands											
Correction 2aa: grouping of shares in complexes	959.95	150	up to 200	-	5128	573	379	87	35	11	80
Correction 2b: allocating large plots	960.10	150	1	573	5557*	573	379	87	35	11	87
Correction 2c: reducing the decreases in distances	958.84	100	1	-	5128	678	520	204	36	11	17
Correction 2b_po2c: allocating large plots	961.06	150	1	678	5557*	678	520	204	36	11	18

* number of all elementary strips; this number also includes elementary strips disregarded in the optimisation process

Upon solving the model as described above, a new allocation of elementary strips to farms is determined. This new allocation guarantees the smallest distances between the farmlands and farmstead sites. Yet, the new shares in the consolidated land complexes acquired by individual farms are often too much fragmented. This fragmentation negatively impacts the layout of the plots allotted. Therefore, the solution obtained has to be modified using the correction procedures developed. The correction procedures performed allow for changes in the allotments of elementary strips to individual farms, under the indeterminacy of optimal solution or under a small increase in distance. Owing to those changes, a relevant increase in their surface area takes place.

The allotment corrections of elementary strips should cause the farms to win an adequately large number of such strips in individual consolidated land complexes, so that the plots sectioned off on the basis of those shares have an adequately large surface area. Two major correction procedures have been developed. The one procedure makes it possible that the farms win adequately large shares in the consolidated land complexes (Correction 2aa), whereas the second procedure allows for the elimination of excessively increased distances to farmlands (Correction 2c, Table 2). Those two correction procedures end the procedures of grouping the elementary strips allocated to farms into compact plots under the consolidated land complexes (Corrections 2b and 2b after 2c).

Table 2. Changes in the number and sizes of plots resulting from the optimisation of the farmland arrangement system in the village of Filipowice

No.	Groups of Plots	Surface Area [ha]	Number of Plots			Average surface area of Plot [ha]		
			Prior to optimisation	After Optimisation		Prior to Optimisation	After Optimisation	
				Correction 2bpo2aa	Correction 2bpo2c		Correction 2bpo2aa	Correction 2bpo2c
1	Whole Village including 2 and 3:	979.90	9395	6527	6632	0.10	0.15	0.15
2	- Design Invariables	424.65	5954	5954	5954	0.07	0.07	0.07
3	- Other Plots being optimised, Including 3 and 5	555.25	3381	727	842	0.16	0.76	0.66
4	- Estranged Landowners	95.12	655	66	73	0.15	1.44	1.3
5	- Local Farms	460.13	2726	661	769	0.17	0.70	0.6

* The number of plots after the optimisation is larger than the quantity of farms' shares in the consolidation complexes because the additional plots might belong to the omitted farms without the identified farmsteads or can be attributed to the division of elementary strips by terrain obstructions

The accomplishment of the 2aa and 2b correction procedures makes it possible to create a new allocation of farmlands to farms; this new allocation is characterized by a small distance to the agriculturally cultivated plots and their correct layout. The 2c correction procedure allows for the reduction of excessive increases in the distances to farmlands that can appear in some farms. In fact, the farms should accept farmlands allocated to them and situated at large distances from their farmstead sites since this feature is included in the comparative assessment. In practice, such solutions are avoided; this fact is covered by the 2c correction procedure, though it is connected with the increased fragmentation to a certain degree.

SOFTWARE PROGRAM TO OPTIMISE A FARMLAND ARRANGEMENT SYSTEM

The software program developed makes it possible to construct an optimisation model of a farmland arrangement system, to solve it, and to graphically represent the solution, among other things, in the form of a complete cadastre-referred map showing new allocations of farmlands to farms. In fig. 1, a list of options contained in this software program is represented. The first two push-buttons in fig. 1 („Creating a model for village” and „Corrections: Cor1, 2, 3, 2a, 2aa, 2b”) activate procedures to construct a model selected, to solve it, and to carry out all the required corrections.

In order to perform the optimisation procedure, 4 initial files as named in the worksheet referred to have to be placed in a proper directory (denoted by a given access path) (fig. 1). The accomplished optimisation process results in the allocations of elementary strips to farms. The new allocations with the minimized distances between farmlands and farmstead sites have to undergo seven correction procedures. Those corrections are carried out under the indeterminacy of the solution obtained or under a small increase in the mean distance to the farmlands; thus, their results (for the adequately large farms) are plots sizes as assumed in the consolidation project.

The next push-button in the list of options: „Maps of farms” activates a separate worksheet and makes it possible to get further files. With those files, a digital map of a new, optimised division of farmlands can be plotted, as can a representation of plot layouts in individual farms in the selected optimisation phases and after the accomplishment of the entire optimisation process.

Two last push-buttons in the list of options are auxiliary for the optimisation process in progress. They are used to determine the number and size of farms' shares in the consolidated land complexes, as well as the span size of multiparty sites, where a given plot can be exchanged by another one without impacting the mean distance to farmlands.

Nazwa	Rozmiar	Typ	Data modyfikacji
FilipPas_uzytki_powierzchnie.mkt	58 KB	Plik MKT	2008-11-12 12:19
FilipPas_DzialPas.txt	308 KB	Dokument tekstowy	2008-11-12 15:40
FilipPas_PrzOdGosp.txt	23 251 KB	Dokument tekstowy	2008-12-16 17:14
FilipPasDzialGosp.txt	286 KB	Dokument tekstowy	2008-12-16 17:25
FilipPasGosp.txt	11 KB	Dokument tekstowy	2008-12-16 17:25
FilipPasGospWies.txt	11 KB	Dokument tekstowy	2008-12-16 17:25
_Zred_FilipPasDzialGosp.txt	152 KB	Dokument tekstowy	2008-12-17 12:35
_ZredUzup_FilipPasDzialGosp.txt	163 KB	Dokument tekstowy	2008-12-17 12:35
FilipPas_ListKomPas.txt	2 KB	Dokument tekstowy	2008-12-17 12:35
FilipPas_PasKomW_Zred.txt	275 KB	Dokument tekstowy	2008-12-17 12:35
ElemPow.txt	277 KB	Dokument tekstowy	2008-12-17 12:36
ELisGos.txt	14 KB	Dokument tekstowy	2008-12-17 12:36
ElemPowOpt1.txt	277 KB	Dokument tekstowy	2008-12-17 12:41
ElemPowOpt2.txt	277 KB	Dokument tekstowy	2008-12-17 12:43
ElemPowOpt3.txt	277 KB	Dokument tekstowy	2008-12-17 12:44
ElemPowOpt4.txt	277 KB	Dokument tekstowy	2008-12-17 12:46
ElemPowOptKon.txt	277 KB	Dokument tekstowy	2008-12-17 12:47
FilipPasGospOptKon.txt	20 KB	Dokument tekstowy	2008-12-17 12:47
FilipPasDzialGospOptKon.txt	197 KB	Dokument tekstowy	2008-12-17 15:41
ElemPowOptKonKor1.txt	277 KB	Dokument tekstowy	2008-12-17 16:00
FilipPasGospOptKonKor1.txt	20 KB	Dokument tekstowy	2008-12-17 16:00
ElemPowOptKonKor2.txt	294 KB	Dokument tekstowy	2008-12-17 16:02
FilipPasGospOptKonKor2.txt	20 KB	Dokument tekstowy	2008-12-17 16:02
ElemPowOptKonKor3.txt	294 KB	Dokument tekstowy	2008-12-17 16:03
FilipPasGospOptKonKor3.txt	20 KB	Dokument tekstowy	2008-12-17 16:03
ElemPowKom_OptKonKor2aa.txt	415 KB	Dokument tekstowy	2009-01-14 11:28
ElemPowOptKonKor2aa.txt	282 KB	Dokument tekstowy	2009-01-14 11:28
FilipPasGospOptKonKor2aa.txt	20 KB	Dokument tekstowy	2009-01-14 11:28
FilipPasDzialGospOptKonKor2aa.txt	192 KB	Dokument tekstowy	2009-01-26 13:54
FilipPasDzialGosp1Uzup.txt	459 KB	Dokument tekstowy	2009-02-05 16:47
FilipPas_PasKomWCAk.txt	416 KB	Dokument tekstowy	2009-02-05 16:55
FilipPas_PasKomWCOst.txt	456 KB	Dokument tekstowy	2009-02-05 16:58
FilipPas_PasKomWCOst_Zred.txt	275 KB	Dokument tekstowy	2009-02-05 16:58
FilipPasGospOptKonKor2b_Akt.txt	20 KB	Dokument tekstowy	2009-02-05 16:58
ElemPowOptKonKor2b.txt	311 KB	Dokument tekstowy	2009-02-05 16:58
FilipPasGospOptKonKor2b.txt	20 KB	Dokument tekstowy	2009-02-05 16:58
FilipPasGospOptKonKor2c_Akt.txt	20 KB	Dokument tekstowy	2009-02-05 17:03
ElemPowKom_OptKonKor2c.txt	384 KB	Dokument tekstowy	2009-02-05 17:03
ElemPowOptKonKor2c.txt	305 KB	Dokument tekstowy	2009-02-05 17:03
FilipPasGospOptKonKor2c.txt	20 KB	Dokument tekstowy	2009-02-05 17:03
FilipPas_PasKomWCAk_Po2c.txt	416 KB	Dokument tekstowy	2009-02-07 10:56
FilipPas_PasKomWCOst_Po2c.txt	456 KB	Dokument tekstowy	2009-02-07 10:58
FilipPasGospOptKonKor2b_po2c_Akt.txt	20 KB	Dokument tekstowy	2009-02-07 10:58
FilipPas_PasKomWCOst_Zred_Po2c.txt	275 KB	Dokument tekstowy	2009-02-07 10:58
ElemPowOptKonKor2b_Po2c.txt	307 KB	Dokument tekstowy	2009-02-07 10:58
FilipPasGospOptKonKor2b_Po2c.txt	20 KB	Dokument tekstowy	2009-02-07 10:58
FilipPasDzialGospOptKonKor2b_Po2c.txt	207 KB	Dokument tekstowy	2009-02-10 03:12
FilipPas_ObwDzZwKom_Kor2b_po2c.txt	1 466 KB	Dokument tekstowy	2009-04-03 14:12
FilipPas_OpisDzialZw_Kor2b_po2c.txt	34 KB	Dokument tekstowy	2009-04-03 14:12
FilipPas_SkorDzZwKom_Kor2b_Kor2b_po2c.txt	50 KB	Dokument tekstowy	2009-04-03 14:12
FilipPasLukiDzKomPas_Zred_Kor2b_po2c.txt	790 KB	Dokument tekstowy	2009-04-03 14:42
FilipPas_OpisDzialZw.txt	30 KB	Dokument tekstowy	2009-04-03 15:55

Fig. 2. Specimen of File: „Rides” after the corrections have been incorporated into the optimal allocation of elementary strips to farms (10 groups of files have been arranged, they refer to: initial data for optimisation; construction of a model and phases necessary to obtain an optimal solution; seven correction procedures to be applied to the optimisation model; plotting a resulting digital map)

Figure 2 represents the content of a directory with initial files and with files obtained in individual optimisation phases. In this directory, there are 10 file groups: initial files, files to construct a model, files referring to the optimisation phases of the model constructed, files obtained after the seven required corrections accomplished, and files used to plot a digital map. The final result of the software program discussed constitutes files with: coordinates of the sections forming the digital map (FilipPas_LukiDzKomPas_Zred_kor2b_po2c.txt), plot numbers and points, where they are entered on the map (FilipPas_OpisDzZw_kor2b_po2c.txt), and index of plots, i.e. a list of plots and farms they belong to (FilipPas_SkorDzZwKom_kor2b_po2c.txt). The two first plots are used to plot a digital map of a new farmland arrangement system, and with the third file, a land register of a given village can be made.

OPTIMISATION OF THE FARMLAND ARRANGEMENT SYSTEM IN THE VILLAGE OF FILIPOWICE

Optimising the location of farmlands towards farmstead sites

The village of Filipowice has an area of 979.96 ha; its characteristic feature is a considerable fragmentation of farmlands. A little more than 400 farms are located here; their average area is a little more than 2 ha. On average, one farm has ten to twenty agricultural plots of a surface area of ca. 15 a.

In the village of Filipowice, the process of optimising the farmland arrangement system covered an agricultural acreage of 555.25 ha, what constituted ca. 90% of the total agricultural acreage and almost 60% of the total area of this village (fig. 3). The optimisation model included agricultural lands as they are the key areas for consolidation and did not include other grounds, such as building lands, waters, forests, and small agricultural lands situated in the vicinity to farmstead buildings and closely connected with them. The non-included grounds were regarded as consolidation invariables. The agricultural acreage to be optimised was divided into 81 project complexes (fig. 3) with regard to a new road network. Next, the 81 project complexes were divided into elementary strips of 10 a each according to the assumed directions of designing plots (fig. 4). 5557 elementary strips in total were sectioned off, and 5128 thereof were optimised. The elementary strips omitted (429 strips) were owned by small farms the sites of which had not been identified on the cadastre-related map.

The distance matrix computed refers to 10792 plots constituting elementary strips and to 454 farms, for which the location of the plots with farmstead sites were established. The location of the farmstead sites of estranged landown-

ers living in the neighbouring villages were established on the border of the village of Filipowice, close to the access roads from those villages. The farmstead site referring to the farmlands of other estranged landowners was established in a central point of the development zone. The distance matrix made for the village of Filipowice comprises over 4 million elements; to calculate it, a computer with mediocre operational parameters had to continuously work for two weeks.

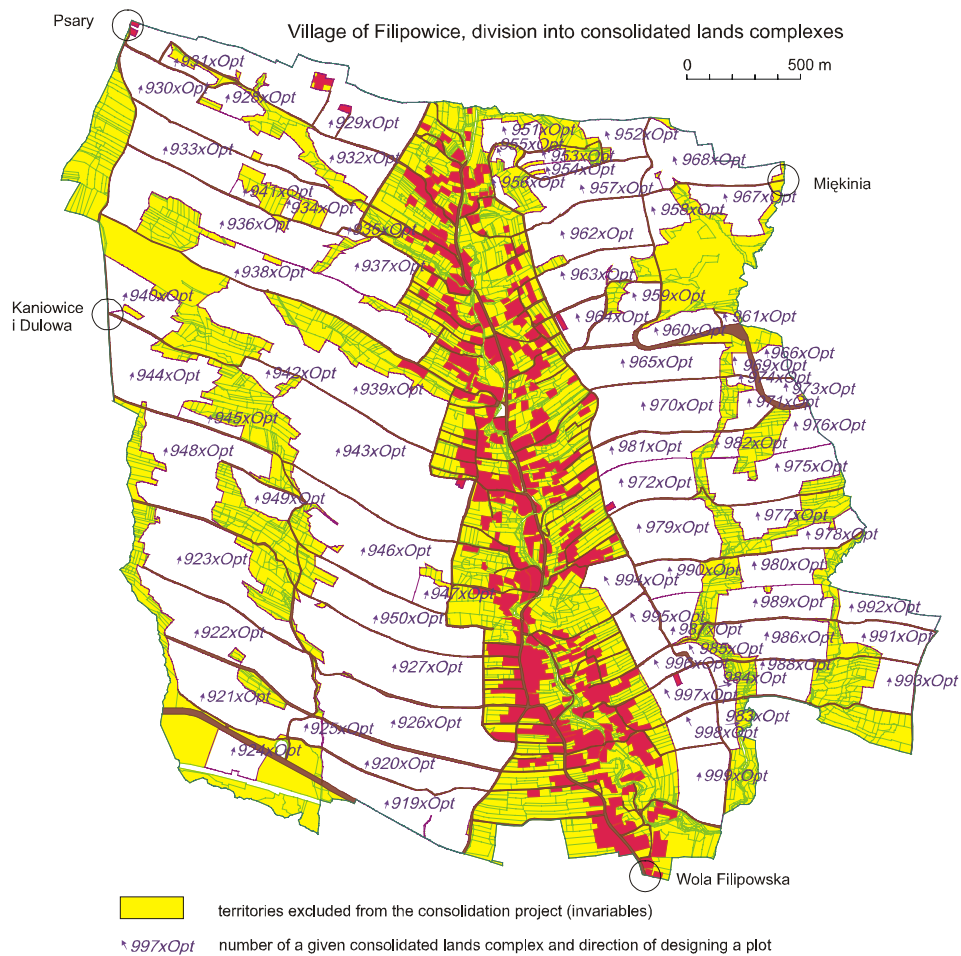


Figure 3. Division of the total area of village of Filipowice into consolidated lands complexes with building sites marked and territories excluded from the consolidation process

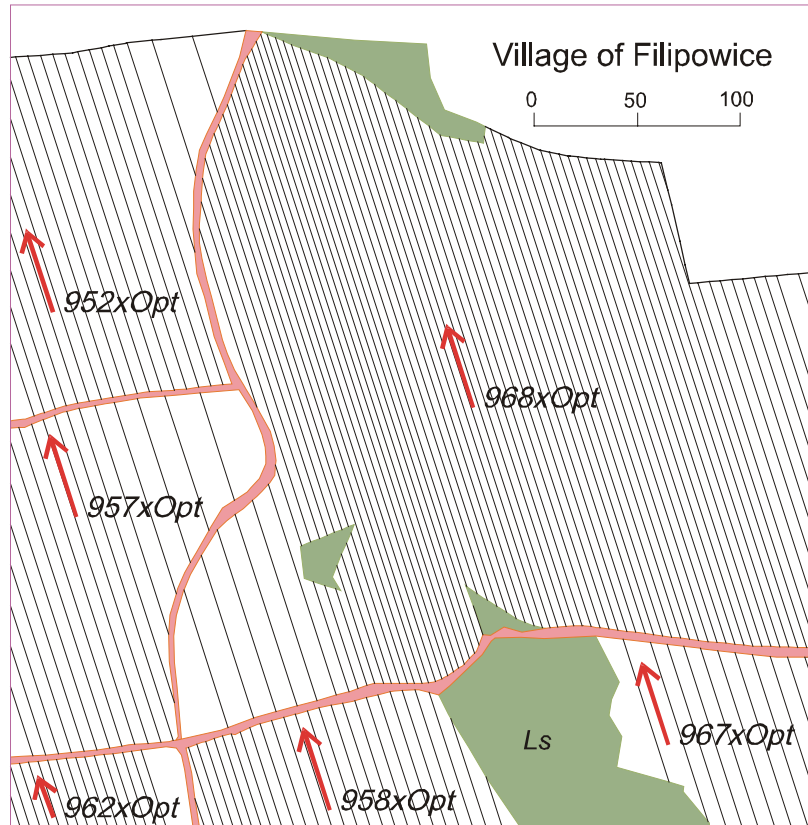


Figure 4. Division of a selected complex covering consolidated lands named as „968xOpt” into elementary strips of an area of 10 a

An average distance between farmlands covered by the optimisation model and the farmstead sites in the village of Filipowice in the initial phase is 1190.78 m (table 1). The farmlands of the farms studied comprise 1185 participation shares of those farms in the consolidated land complexes. The number of those shares is almost three times smaller than the number of optimised plots and of plots belonging to farms situated in the given village, i.e. 3381 plots (table 2). The majority of those participation shares (1078) is not larger than 1 ha, and almost 250 participation shares are smaller than 10 a (table 1).

The optimisation process accomplished had 4 phases connected with a complete review of all the elementary strips (table 1). The average distance to farmlands basically reduced to 255 m was obtained already after the first review of the elementary strips, i.e. in the first phase. However, this reduction in the average distance to farmlands did not cause any significant change in the quan-

tity of participation shares of farms in the consolidated land complexes. This fact is to be attributed to the considerable fragmentation of farmlands in this village. As a result of optimising the belonging of elementary strips to farms, the average distance between farmstead sites and farmlands was reduced by 261 m and amounted to 929.49 m (table 1), i.e. by almost 20%. This new allocation of the elementary strips to farms, which guarantees that the farmlands are brought closer to farmstead sites, means, however, a substantial fragmentation of the participation shares of farms in the consolidated land complexes, since the fragmentation level has been only insignificantly improved if compared with the level prior to optimisation (table 1).

The improperly shaped layout of farms in the optimal solution resulting from the optimisation is, to a high extent, a consequence of the indeterminacy of this solution. There are relatively large quantities of allocations of elementary strips to farms, which make it possible to get the smallest distance to farmlands, and the optimal solution considered is one of such allocations selected, practically, at random. The described disadvantages of the optimal solution result from the fact that the model assumed did not include conditions ensuring the correct size of the plots being sectioned off. Presently, it is impossible to enlarge the optimisation model by adding such conditions just because there are too many difficulties when solving the task enlarged in this way. Those disadvantages can be eliminated either partially or entirely through the developed correction procedures performed under the indeterminacy of the solution or under the small increase in the objective function.

The final optimisation result of the farmland arrangement system in the village referred to are 3 files with allocations of all elementary strips to farms, a list of farms including changes in the average distance to farmlands, and a list of plots and elementary strips including farms to which they belong. It lasted ca. 12 minutes to construct the model optimising the allocations of elementary strips to farms in Filipowice and to solve it. It is a really short time if considering the fairly large size of this model (over 4 million of decision-making variables).

Two correction procedures to decrease the quantity of participation shares of farms in the consolidated land complexes (Correction 2aa) and to form compact plots in those complexes (Correction 2b)

The 2aa correction procedure reduces the number of small participation shares in the consolidated land complexes; it refers to too overly fragmented allocations of farmlands to farms after the location optimisation of the elementary strips. More than 400 farms participating in the optimisation process had 1004 shares in the complexes with an average area equalling 5.1 elementary strips, i.e. of 0.51 ha (Table 2). The majority of shares (862) have an area smaller than 1 ha, and 227 shares do not exceed 10 a.

In this case, the main objective of 2aa correction was to eliminate the participation shares of farms in the complexes smaller than 0.5 ha with a plan to design sufficiently large plots for the farms with an average area, scheduled for optimisation, of a little more than 1 ha. To do this, special correction parameters were adopted. Among other things, it was assumed that the area of 0.5 ha should be the farm's minimal share, and this figure should determine the required size of the plot to be allocated to this farm. Thus, in this village, the objective of eliminating shares smaller than 0.5 ha has been achieved in its entirety. Upon the accomplishment of the corrections discussed, only 87 out of 932 shares smaller than 0.5 ha remained. Those left over shares could not be eliminated because either the farmstead area or the complex area they belonged to were too small. In the village of Filipowice, 85 farms comprise less than 5 elementary strips, 34 farms are smaller than 20 a, and 11 farms – smaller than 10 a.

The 2aa correction procedure, reducing the quantity of small shares of farms, caused the number of all the shares to be substantially decreased, and the areas of the shares to be increased. The average area of one farm's participation share in the consolidated land complex in the village of Filipowice increased to ca. 9 elementary strips after the above correction procedure had been carried out. This share is more than twice higher if compared to the share after the preliminary corrections (5.1 of elementary strips). The total farms' share decreased in a similar proportion. The execution of the 2aa correction procedure resulted in the decrease in the number of all the farms' shares in the complexes by ca. half as much; the number of shares after the 2aa correction was 573.

Upon the 2aa correction completed, the resulting advantageous changes in the number of farms' shares in the complexes, as well as the sizes thereof were connected with an inconsequential increase in the distances to farmlands. The average distance to farmlands in Filipowice was 960 m after the 2aa correction that had reduced the number of small shares. This average distance of 960 m is larger by about 30 m than the average distance obtained after the arrangement of plots had been optimised. A relatively slight increase in the distance after the correction procedures performed results from the restrictions applied to the increase in this distance. The elementary strips exchanged among the farms could not cause the distances to increase by more than 100 to 150 m.

The next 2b correction is related with the 2aa correction as above. The 2b correction procedure groups the farms' shares in the compact plots. It does not cause the number and size of farms' shares in the project complexes to change; however, it can result in slight changes in the distances to farmlands. This is attributed to the dislocations of farms' shares within the project complexes. The performance of the 2b correction results in a new division of farmlands in this village. Under this new division, the farms' shares in the project complexes are sectioned off in single plots. The 2b correction procedure performed in Filipowice caused the number of plots to decrease from 3381 to 573 and the

average distance to farmlands under optimisation to amount to 960.10 m, which is was about 230 m less than the initial distance, and only by less than 30 m larger than the minimum distance (Table 2). Yet, this apparent decrease in the average distance to farmlands in this village is not spread out equally amidst all the farms concerned. In the village of Filipowice, the substantial increase in the distances to farmlands occurred in 87 farms (about 20%) and exceeded 100 m, and, in several cases, it was even 700 m. In some farms, those increases in the distances can be removed without changing the average distance to farmlands through the additional correction procedures.

Correction procedure to decrease excessive gains in distances to farmlands (Correction 2c)

Removing the excessive increases in distances to farms is, principally, possible under the indeterminacy of the optimal solution. Therefore, it does not produce any substantial increase in the average distance between farmlands and farmstead sites. After the increases in distances had been corrected through the 2c correction procedure, the number of farms in Filipowice with a gain in the distances exceeding 100 m was reduced from 87 to 17, but, at the same time, a slight decrease in the average distance to farmlands was reported (table 2).

Then again, the 2c correction procedure completed causes the layout of farms to worsen to a certain degree, especially of the farms consisting of a small number of plots, and this case happens in the village studied. In the village of Filipowice, in order to remove excessive increases in the distances required over 100 additional plots of a relatively small area of 0.5 ha at the very most to be created. The exchange of the whole plots amidst the farms usually results in a changed layout of those farms where excessive increases in the distances occur. Those increases can be removed only when a particular plot is divided and, then, when only one part from all other parts of the plot produced after the division is exchanged.

The changes in allocations to farms connected with the 2c correction procedure force their being grouped in compact plots; this is carried out under the final correction procedure (the 2b correction after the 2c correction). The completion of this corrections produces a slight increase in distances, and, as for the village of Filipowice, this increase was merely a few metres.

Changes in the farmland arrangement system after its optimisation

Fig. Fig. 5, 6, and 7 show maps, which depict overall changes in the farmland division generated by the optimisation and correction procedures accomplished in the village of Filipowice. In Fig. 5, the borders of registered lots prior to the optimisation of the farmland arrangement system are shown. Figure 5

contains 9395 plots of an average area of 0.10 ha (table 2). The design invariables shown in this Figure comprise 5954 plots with development terrains, forests, waters, roads, etc. included therein. The average area of plots assumed as design variables and consisting, mostly, of building plots, is small and amounts to 0.07 ha. 3381 plots lying within the project complexes and having an average area of 6.85 ha were incorporated into the optimisation procedure of the farmland arrangement system.



Figure 5. Farmland arrangement system in the village of Filipowice prior to optimisation

Fig. 6 shows the farmland arrangement system in the village of Filipowice after the optimisation completed and prior to the elimination of excessive increases in the distances, i.e. after the 2b and 2aa correction procedures performed. The arrangement system studied is characterized by the most advantageous fragmentation level of farmlands. Compared to the state prior to optimisation, it is very clear that the borders are now less densely arranged; this means that the layout of plots is improved and the number of plots is reduced. The optimisation of the farmland arrangement system resulted in a fivefold decrease in the number of plots (to 727 plots) and in an increase in their average area to 0.76 ha (table 2).

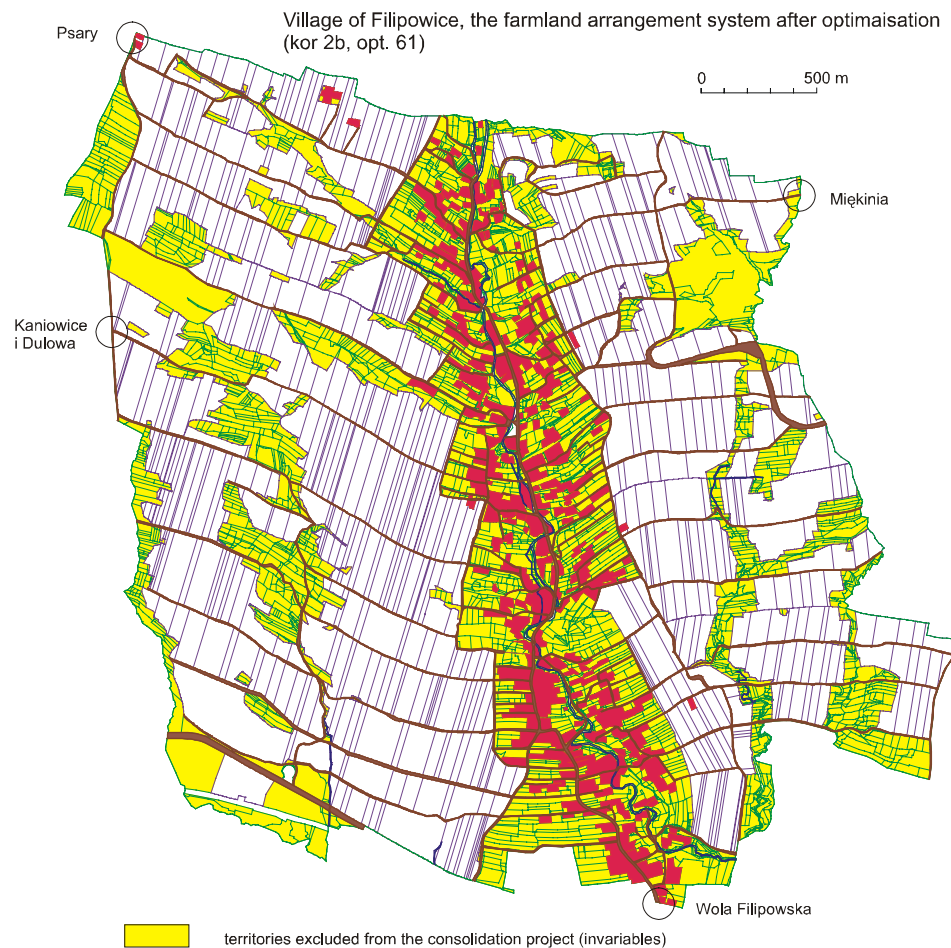


Figure 6. Farmland arrangement system in the village of Filipowice after the optimisation

The eliminated increases in the distances caused the number of plots to rise to 842 (ca. 10%) and the average area to go down to 0.66 ha (table 2, fig. 7). Despite this decrease, the average area of plot in the village of Filipowice after the optimisation of the farmland arrangement system is now more than 4 times larger than at the beginning. The farmland arrangement in this village appears more advantageous since the distances to farmstead sites have become smaller by 200 m on average.

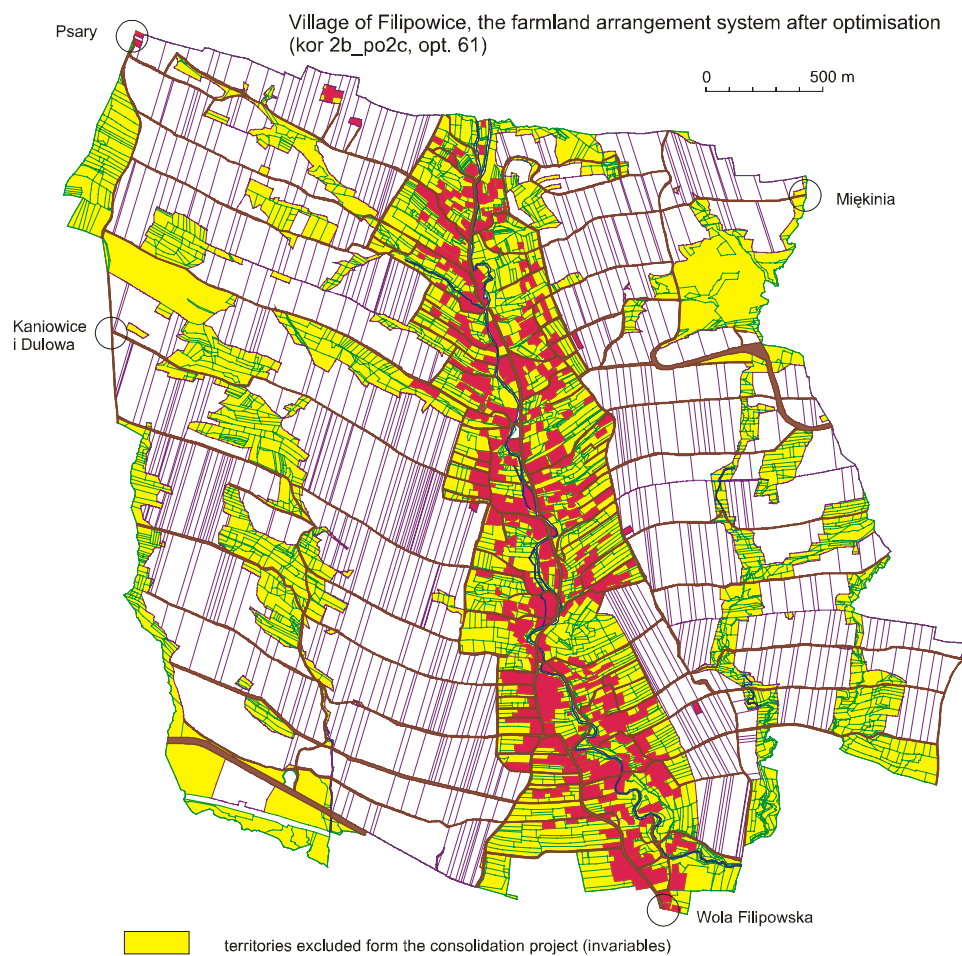


Fig. 7. Farmland arrangement system in the village of Filipowice after optimisation with correction procedures made to reduce the increases in distances

The comparison of the two-farmland arrangement systems in the village of Filipowice, i.e. the system prior to the optimisation and the same system after the optimisation completed, does not absolutely correctly represent the changes in the system. The reason thereof is the number of estranged landowners, i.e. of persons living in another village and possessing shares in lands in the village studied. The estranged landowners in the village of Filipowice were classified into several groups according to the place of their permanent residence. During the optimisation process, individual groups of the estranged landowners won large joint farmland shares, which would be allocated amidst individual farms only later. The reduced number of plots belonging to local farms should be interpreted as a real optimisation effect of the farmland arrangement system. The number of those plots is reduced less than four times and amounts now to 769 plots of a 0.60 ha area on average. As soon as the farmland arrangement system is optimised, the standard farm will consist of slightly less than 2 plots. It will be rather difficult to improve this result since the number of project complexes is considerably large (81 complexes) and excessive increases in the distances need to be eliminated.

CONCLUSIONS

The optimisation method of farmland arrangement system in a village as presented in this paper makes it possible to comprehensively assess the existing spatial structure and to modernize it so as to establish new, possibly small distances between farmlands and farmstead sites and to set improved layouts of farm plots. The process of preparing data necessary for the optimisation of farmland arrangement system consists of two phases: dividing the plot complexes into small elementary strips; and calculating a matrix of distances between those strips and farmstead sites. Those phases are highly time- and labour-consuming. In the method developed, this process has been automated through appropriate software programs. Therefore, this method can be applied in practice.

The version of this method, described in this paper, has two main assumptions: only farmlands of equal areas can be exchanged among farms; the wishes of consolidation participants have to be disregarded. Consequently, this version cannot be applied in practice in its full scope. Assuming that farmlands of equal values are to be exchanged does not produce new theoretical problems, but, in this case, the number of the complexes studied should be considerably increased; as the consequence thereof, the software program should also be significantly extended along with the calculation time. Wishes of the consolidation participants can be easily entered into the software program; however, in practice, this causes most usually a conflict of the optimisation model. The explicitly formulated wishes are typically connected with the elimination of land pieces they

refer to from the optimisation process; they are then regarded as invariables. Therefore, it seems pointless to include particular wishes of the consolidation participants into the model when dealing with the consolidations of farmlands of a larger scale.

Despite deficiencies, this version of the developed method can be applied in the process of consolidating farmlands. The new allocation of farmlands to farms, obtained owing to the optimisation, and presented in the form of a register and cadastre-related map, can be a functional and handy study showing the possible consolidation effects, facilitating the collection of wishes and the development of the consolidation design.

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