APPLICATION OF GIS TOOLS IN ANALYSING A ROAD NETWORK PROVIDING ACCESS TO CADASTRAL PARCELS IN THE PROJECT CONCERNING LAND CONSOLIDATION AND EXCHANGE*

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Abstract

Issues specified in the study concern evaluating a road network providing access to cadastral parcels in villages divided by a linear investment. The scope of work includes the villages of the Podkarpackie Voivodeship which are crossed by the motorway dividing them into two parts of different sizes- the northern and southern ones located along the motorway. Basing on the data from the descriptive and cartographic part of the Land and Buildings Register, there were made detailed surveys of the spatial structure of land in rural areas. In this regard, a detailed analysis of the road network in villages of the Podkarpackie Voivodship was made using QGIS tools. Detailed examinations have revealed parcels without access to the road. In conducting research in this field, a cartographic method was used to present the distribution of cadastral parcels without access on local registration maps with the application of QGIS tools. On the basis of land register data and the factual assessment, there was made an evaluation of the road network providing direct access to cropland in the examined villages. Poorly developed network of roads providing direct access to cropland, combined with strong fragmentation of plots and other degradation effects resulting from the motorway construction illustrates the scale of this problem. Complex consolidation and exchange of land can play the corrective role in the space degraded by linear investments.

Key words: *motorway, road network, complex tasks of land consolidation and exchange, GIS tools*

Introduction

The area of today's village is the result of human activity. Man, as a human being, has transformed the natural landscape for his own needs, not taking into account the negative effects. The agricultural land has been exposed to continuous divisions resulting from land inheritance or transfer. Listed elements have badly affected the village area. There has been an increase in the number of plots, fragmentation and changes in land formation. Significant problems, however, have turned out to be not very good technical condition and the total lack of roads giving access to parcels (NOGA, 2001). Access to agricultural plots is provided by roads that play an important role in agriculture. Frequently extended plots are located in different areas where there is no access to them. A significant factor is the impact of constructing a motorway passing through the village. The road is an important part of social, economic and cultural life and of interpersonal relationships, but it also blocks access from cadastral parcels to habitats, which hinders functioning between towns. The linear route of the motorway includes hundreds of kilometers, where it crosses cadastral parcels of many owners and badly affects the natural environment and its management (BALAWEJDER, NOGA, 2016). Motorway crossing agricultural land affects the management and investment in agricultural production areas adjacent to the road lane, which results in decreasing the value of farms (BALAWEJDER et al., 2015). One of negative results of this impact on farms is the

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deterioration of the farmstead expanses, where the area of land decreases while the time of getting from the habitat to the cropland is increased (WILKOWSKI, 1995). For agricultural production the worst problem caused by a running motorway lane is cutting off and leaving small fragments of plots on the opposite side of the habitat. It makes access to cadastral parcels of a given host complicated, prolongued or sometimes even impossible (SOBOLEWSKA-MIKULSKA, 2012). Carrying out the project of land consolidation and exchange we can observe that in many villages of the south-eastern Poland the road network is poorly developed. The problem is even more exacerbated since regulating the legal status of roads is not an easy task (BIEDA, STALKA-KRAWCZYK, 2014). What is more, there is a lack of synchronization between the data recorded in the Land and Buildings Register and the factual state (PRZEWIEZLIKOWSKA, BUSKO, 2014; BALAWEJDER, ADAMCZYK, CYGAN, 2016). Among other things, GIS tools were just used for this purpose. GIS tools are widely used (THRALL, 1998). In order to analyze the network of roads providing access to cadastral parcels according to the factual state, QGIS software was used for illustrating the phenomenon and improving the performance of the following analyses.

Characteristics of the research object

Łańcut County lies in the central part of the Podkarpackie Voivodeship, 17 km east of Rzeszów. It has very good transport connections, namely the A4 motorway (graphically presented in Fig. 1), the national road no. 94 and the Kraków - Przemyśl railway, which all run through Łańcut County. It borders with County of Rzeszów and with Counties of Przeworsk and Leżajsk. Łańcut County occupies an area of 452km^2. More than 20% of its area is covered by forests and forest land. It has 79866 inhabitants. The population density is 177 people/km^2. Łańcut County is divided into the town of Łańcut and communes of: Białobrzegi, Czarna, Łańcut, Markowa, Rakszawa and Żołynia.

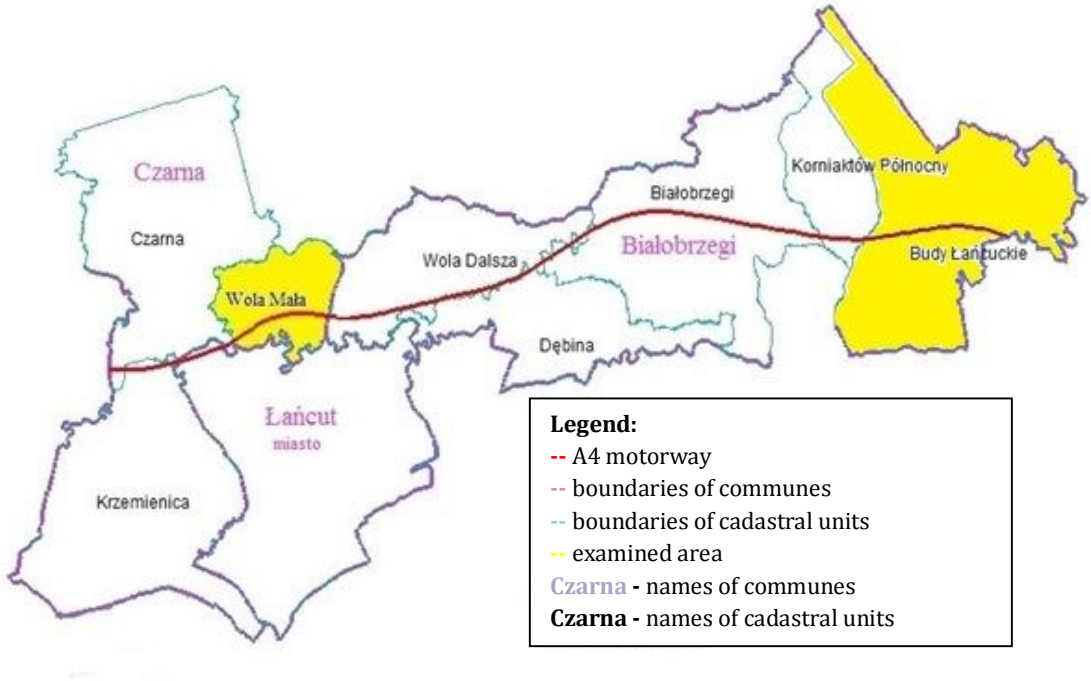

Fig. 1. The A4 motorway route through Łańcut County. *Source: Own study.*

Examined village Wola Mała is one of villages in Czarna Commune. The area of the village is 439.09 ha. The largest area is occupied by individual grounds covering 353.06 ha, which constitutes 80.4% of the total village land, the majority of which (50.9%) are farms (gr.7.1). In the examined village agricultural land prevails, occupying the area of 356.93 ha, which gives 81.3% of the total village area. The largest area of that land is occupied by arable land, which covers 48,7% of the total village area.

Another examined village is Budy Łańcuckie located in the eastern part of Białobrzegi Commune and in the north-eastern part of Łańcut County. The Wisłok River divides the village into and Budy Łańcuckie Lewe and Budy Łańcuckie Prawe. The area of the village is 1640.46 ha. The largest area is also occupied by individual grounds covering 1122.97 ha, which constitutes 68.5% of the total village land, the majority of which (50.9%) are farms as well (gr.7.1). The population of Budy Łańcuckie village is 1894 people and 51.1% of the population are females and 48.9% of the population are males. The village is inhabited by 22.6% of the commune inhabitants. In the examined village of Budy Łańcuckie, the same as in Wola Mała

village, agricultural land prevails, which occupies the area of 1159.60 ha, what gives 70.7% of the total village area. The largest area of that land is also occupied by arable land, which covers 48.1% of the total village area.

Table 1. The study on fragmentation.

No.	Cadastral unit name	Total area		Total number of plots in the cadastral unit	Average plot area in the cadastral unit [ha]	Individual grounds	
		ha	%			ha	%
1.	Budy Łańcuckie	1640.46	78.89	3613	0.45	1122.97	68.5
2.	Wola Mała	439.09	21.11	1162	0.38	353.06	80.4
Total		2079.55	100.0	4775	0.44	1476.03	71.0

Source: Own study.

As shown in Table 1, there is considerable fragmentation in the examined villages. Average plot area in the examined cadastral units is only 0.44 ha. There are 3613 plots in Budy Łańcuckie village, which gives an average area of 0.45 ha. However, there are 1162 plots in Wola Mała village, which gives an average area of only 0.38 ha.

Analysis of a road network providing access to cadastral parcels

Very important part of the agricultural production area is a network of roads for agricultural transport, which improves farming (HOPFER, KOBYŁECKI, ŻEBROWSKI, 1980). The network of such roads is supposed to provide access to the fields and facilitate their utilization in production. An important factor in planning road networks is the best combination of all the points existing in a given area (MATYAS, 1957). Planning and construction of each road have to be carried out in accordance with certain laws specified in the Act on Public Roads (ACT, 1985) and in the Act on Road Traffic (ACT, 1997). When planning road networks, it is necessary to remember that planned roads should occupy the smallest area of land on which they are located, and that areas created by road construction should have a convenient area and shape (BIELSKA, KUPIDURA, 2013). Roads for agricultural transport should also have access to higher tier roads.

Organization of road networks for agricultural transport is one of the three main objectives of land consolidation, which improves the quality of transport in the areas where it is conducted. All these tasks can both decrease and increase the density of road networks and eliminate the creation of cadastral parcels without access to the road network. All project tasks can be supported by GIS tools. In this study, QGIS 2.18.9 software was used for the analysis.

4775 parcels were taken into account in the analysis of road networks in villages of Budy Łańcuckie and Wola Mała. Parcels occupy the total area of 2079.55 ha. They were examined for their access to the road. They were divided into parcels without access to the road, parcels with access to the road and into those accessible through the road located in a neighbouring village. Parcels being roads and parcels set out as ditches and surface waters were excluded from the examination. In the village of Budy Łańcuckie 39 parcels with the total area of 43.17 ha were excluded, while in the village of Wola Mała there were 15 excluded parcels with the total area of 28.08 ha. What is more, the examined villages are crossed by the national road- A4 motorway, dividing them into two parts: the northern and southern ones relatively to the linear object.

The village of Budy Łańcuckie is also crossed by a county road in a westerly direction towards Białobrzegi Commune. Most municipal roads lead from that county road to the north and south creating a network of roads. Boundaries of Budy Łańcuckie and Świętoniowa village to the east of the cadastral unit are set by that county road. Despite that, roads in Budy Łańcuckie constitute a small area, as they occupy 79.32 ha, that is 4.8%. It results from the fact that this region has a poorly developed road network, which makes it difficult for residents to access their properties. The village of Wola Mała is also crossed by a county road in a westerly direction towards Białobrzegi Commune. Most municipal roads lead from that county road to the north and south creating a dense road network. Boundaries of Wola Mała and Wola Dalsza villages to the east of the cadastral unit are set by the provincial road no. 877 of about 2 km long. As for the examined area, roads occupy 45.90 ha constituting 10.5% of the whole cadastral unit of Wola Mała and land under water, of which land under surface waters occupies 28.08 ha, which accounts for 6.4% of the whole unit.

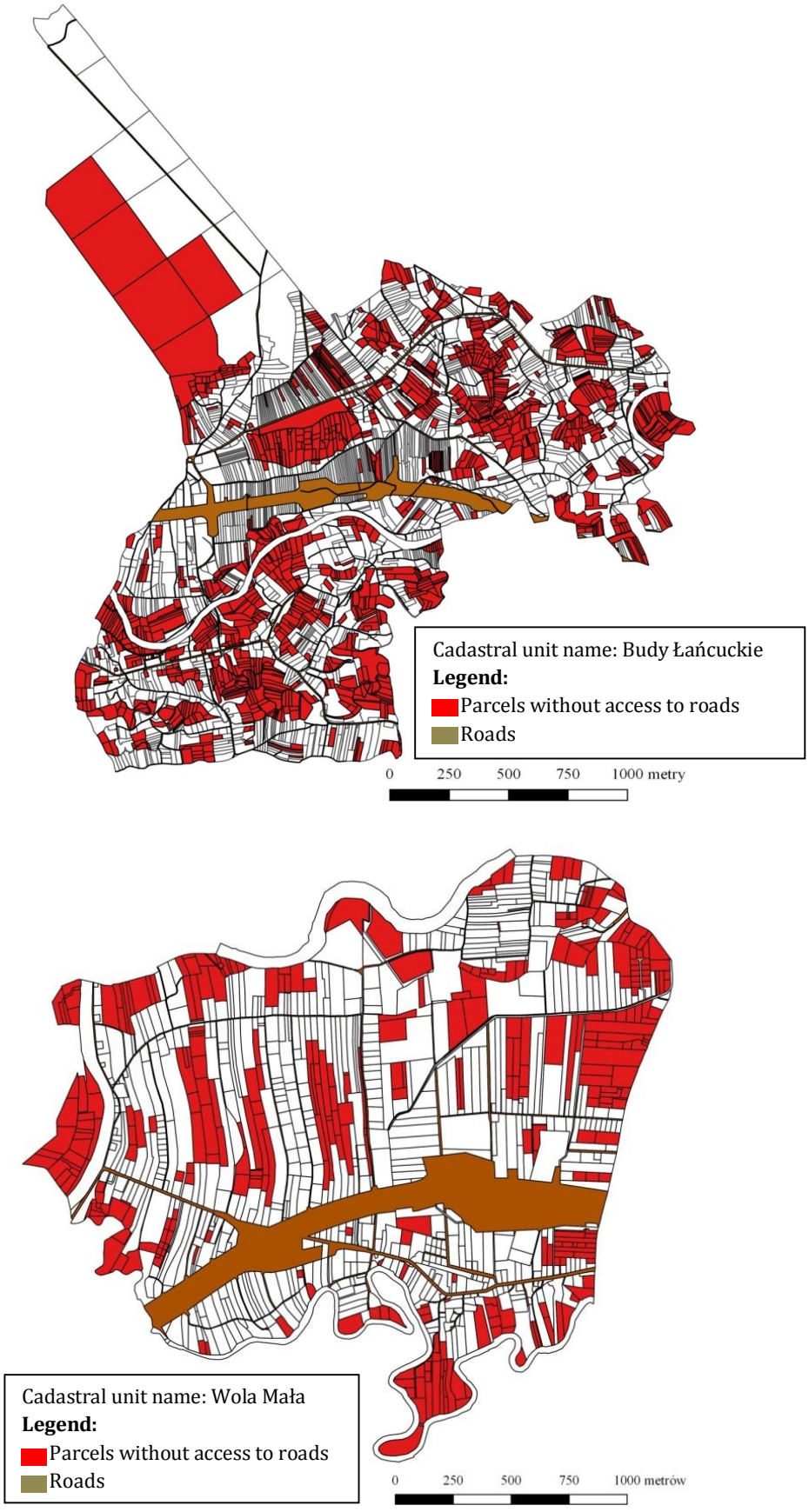

Fig. 2. Access of parcels to roads in the examined cadastral units made with QGIS. *Source: Own study.*

Table 2. Access to roads in the examined cadastral units.

No.	Cadastral unit name	Cadastral parcels	No. of parcels		Area	
				%	ha	%
1	Budy Łańcuckie	Parcels without access to roads	1387	38.4	601.19	36.6
2		Parcels with access to roads recorded in the Land and Buildings Register (EGiB)	2145	59.4	944.49	57.6
3		Parcels being roads	45	1.3	79.32	4.8
4		Ditches	36	0.9	15.46	1.0
5		**Total with roads and ditches**	**3613**	100.0	**1640.46**	100.0
6	Wola Mała	Parcels without access to roads	368	31.7	117.69	26.8
7		Parcels with access to roads recorded in the Land and Buildings Register (EGiB)	767	66.0	247.42	56.3
8		Parcels being roads	12	1.0	45.90	10.5
9		Ditches	15	1.3	28.08	6.4
10		**Total with roads and ditches**	**1162**	100.0	**439.09**	100.0
		Total	**4775**	X	**2079.55**	X

Source: Own study.

As the data included in Table 2 and in Figure 1 illustrate, there are 1387 plots without access in the village of Budy Łańcuckie, which represents 38.4% of all parcels. It gives the total area of 601.19 ha, which accounts for 36.6% of the total land area. In the southern part of the cadastral unit, an impediment to access to a road network is the Wisłok River, along which there is no road providing access to parcels. The Wisłok River also makes it difficult to access fields in the north and in the northwest. In the examined area, there are numerous ditches, which prevent access of parcels to roads. In the cadastral unit of Wola Mała 1162 parcels were examined excluding parcels under ditches or surface waters. There were 27 such parcels of the total area of 73.98 ha. Running strip of the motorway divides the examined area into two parts: the northern and southern one. Along the motorway there are service roads, which provide parcels adjacent to the motorway with access to roads; however; at any place it is not possible to go from the northern part of the village to the south and vice versa. As it can be concluded on the basis of the data shown in Table 2 and graphically presented in Figure 1, there are 368 parcels without access, which constitutes 31.7% of all parcels. It gives the total area of 117.69 ha, which accounts for 26.8% of the total land area. In the southern part of the region the road network is well-developed. An obstacle though is the riverbed of the Old Wisłok, along which there is no road which providing access to the parcels located there, particularly in the eastern part of the cadastral unit. The Wisłok River also makes it difficult to access fields in the north and in the northwest. In the examined area, there are also numerous ditches, which prevent access of fields to roads. In the northwest one can see clusters of plots that are also not served by any road.

Table 3. Access of cadastral parcels to roads after verification.

No.	Cadastral unit name	Cadastral parcels	No. of parcels		Area	
				%	ha	%
1	Budy Łańcuckie	Parcels with access to the road recorded in the Land and Building Register (EGiB)	2145	59.4	944.49	57.6
2		Parcels with access to the road located in a neighbouring village	34	0.9	37.63	2.3
3		Parcels with access to parcels classified as roads	246	6.8	63.61	3.9
4		**All parcels with access to roads**	**2425**	**67.1**	**1045.73**	**63.7**
5		Parcels without access to roads	1104	30.6	472.24	28.8
6		Roads	45	1.2	79.32	4.8
7		Ditches and waters	39	1.1	43.17	2.6
8		**Total**	**3613**	**100.0**	**1640.46**	**100.0**
9	Wola Mała	Parcels with access to the road recorded in the Land and Building Register (EGiB)	767	66.0	247.42	56.3
10		Parcels with access to the road located in a neighbouring village	36	3.1	12,51	2,8
11		Parcels with access to parcels classified as roads	90	7.7	30,98	7.1
12		**All parcels with access to roads**	**893**	**76.9**	**290,91**	**66.3**
13		Parcels without access to roads	242	20.8	74,20	16.9
14		Roads	12	1.0	45.90	10.5
15		Ditches and waters	15	1.3	28.08	6.4
16		**Total**	**1162**	**100.0**	**439.09**	**100.0**
		Total	**4775**	X	**2079.55**	X

Source: Own study.

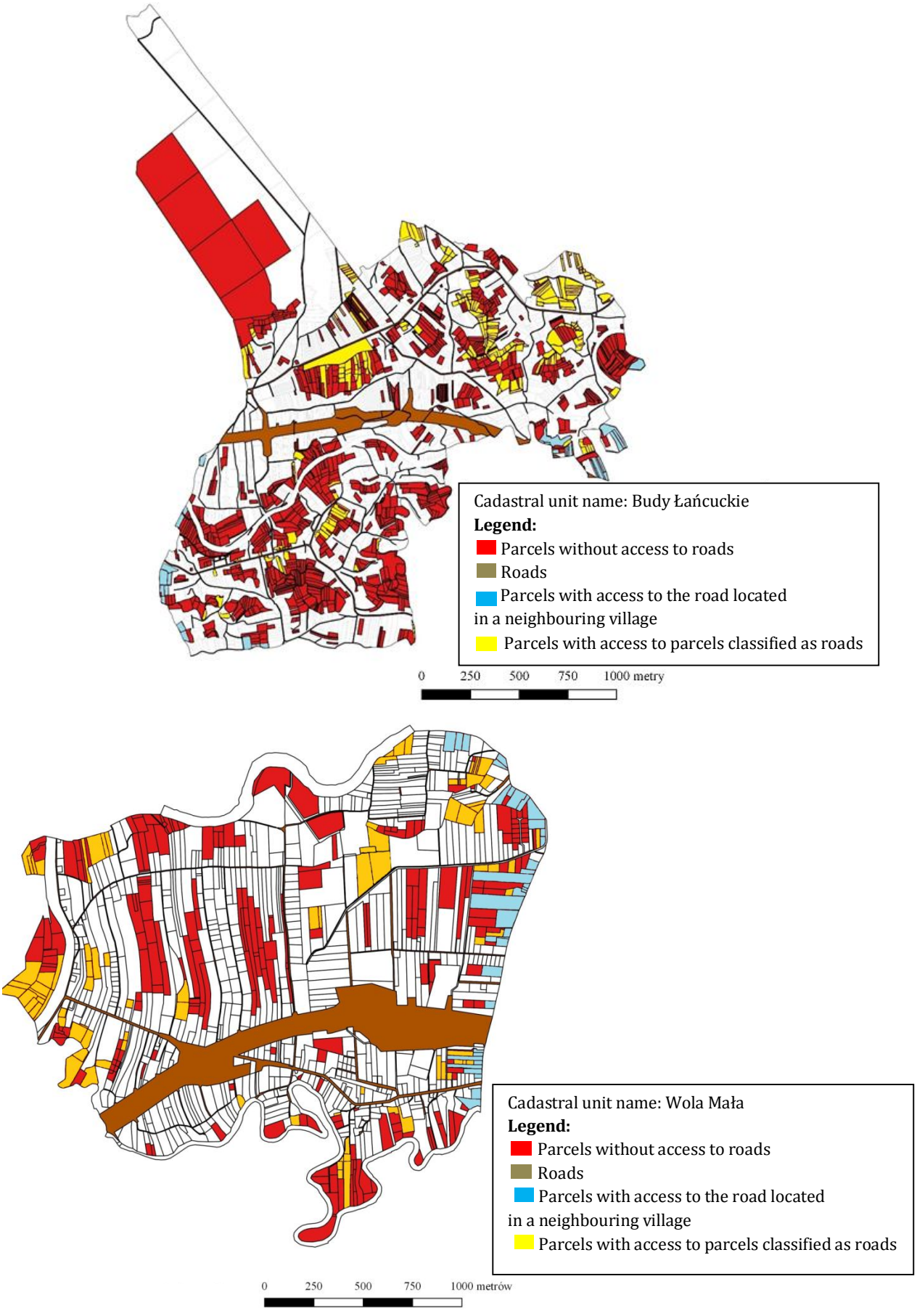

Fig. 3. Access to roads after verification performed with QGIS software. *Source: Own study.*

The next stage of the examination was the verification of existing roads with the factual state. The obtained data are shown in Table 3 and graphically presented in Figure 2. Comparing the obtained results shown in Table 2 with the factual state in Budy Łańcuckie, one can notice changes in areas of the eastern part of the cadastral unit. There are 34 parcels with access to the road located in a neighbouring village occupying an area of 37.63 ha. There are also roads located in the fields, but in the Land and Buildings Register they have not been updated to "dr" ("road") according to the factual state, though they provide parcels with access to roads. There are 246 parcels with access to parcels classified as roads with an area of 63.61 ha. Discussed changes caused that 2425 parcels accounting for 67.1% of all parcels have access to roads. These changes improved access of adjacent cadastral parcels to roads. Comparing the results obtained in Wola Mała, significant changes in areas of the eastern part of the cadastral unit were noticed. The provincial road no. 877 running in the second cadastral unit improved access to roads for parcels located there. There are 36 of them, which gives 3.1% of all parcels accepted for the accessibility analysis with an area of 12.51 ha. One could also note the roads located in the fields, but in the Land and Buildings Register they have not been updated to "dr" ("road") according to the factual state though they provide parcels with access to roads. It is estimated that there are 90 such parcels with the total area of 30.98 ha. These changes caused that still 126 parcels constituting 11.2% of all parcels accepted for the accessibility analysis are provided with access to roads. As a result, 893 parcels representing 76.9% of all analysed parcels have access to roads. This also improved access to roads in case of those parcels, which in the northwest were cut off by the Wisłok River from the remaining cadastral unit and the district road running there.

Conclusions

Analysis conducted with the application of GIS tools revealed large fragmentation and a defective communication network in the examined villages. A4 motorway running through the centre of the village even further exacerbates already defective structure. Conducted examination give the following conclusions:

1. The analysed area occupy 2079.55 ha and includes two villages: Budy Łańcuckie and Wola Mała. It is divided into 4775 cadastral parcels, which gives an average parcel area in a cadastral unit of 0.44 ha.
2. The largest area in analysed villages is occupied by individual grounds, which cover 1476.03 ha constituting 71.0% of the whole land.
3. In both analysed villages the agricultural land prevails, occupying in Budy Łańcuckie 70.7% of the village area and 81.3% in Wola Mała village. In that area there are few forests and little bushland due to the fact that the examined area is an agricultural area, where most of inhabitants work on farms for a living.
4. Roads constitute small area as they occupy 4.8% of the village area in Budy Łańcuckie and 10.5% in Wola Mała. It results from the fact that the examined area has poorly developed road network, which makes it difficult for inhabitants to access their properties.
5. The main objective of this research, i.e. the analysis of the road network providing direct access to cropland in Budy Łańcuckie village, revealed that at the beginning of the analysis 2145 parcels giving 59.4% share in the total number of all analysed parcels had access to roads. It was conducted with the application of QGIS software, which accelerated research work to a great extent. Trenches, surface waters and communication networks were excluded from the analysis. The results were verified with the factual state. Finally, in the cadastral unit of Budy Łańcuckie 2425 parcels accounting for 67.1% of all analysed parcels have access to roads. Verification on the basis of the data recorded in the Land and Buildings Register (EGiB) showed the difference between the obtained results, EGiB data and the factual state. After verification it turned out that some parcels which do not have access to roads, can be accessed through a county road a road located in the neighbouring village. Partial problems with access to roads result from the lack of updated road identification according to the use of the road, which could provide access to a given parcel. The QGIS software has made it possible to quickly present the results of the study.
6. However, the analysis of the road network providing access to cadastral parcels in Wola Mała village showed that in the initial analysis 767 parcels giving 66.0% share in the total number of all analysed parcels had access to roads. Trenches, surface waters and communication networks were excluded from the analysis. It was conducted with the application of QGIS software again, which also in this case improved the examination in this area. The results were verified with the factual state. Finally, in the cadastral unit of Wola Mała 893 cadastral parcels have access to roads, which gives 76.9% of all analysed parcels. It turned out that parcels which initially did not have access to roads, could be accessed through the provincial road no. 877 on the eastern border of

the cadastral unit or through strips set on parcels which are not included in EGiB but are classified as roads providing direct access to fields. On the basis of the conducted analysis of roads providing direct access to fields it was concluded that the road network in that area is well-developed. The vast majority of parcels have access to roads; however; the motorway crossing the examined area affects this system. The motorway divides that village into the northern and southern parts. Inhabitants living on the south side have significantly extended access to plots from their habitats and vice versa.

7. The construction of the motorway in the area of Budy Łańcuckie and Wola Mała villages disturbed the spatial structure due to:
   - the impediment in accessing parcels from habitats,
   - changing the shape and size of parcels, which makes it difficult to manage the farm well,
   - worsening of local communication connections,
   - compulsory transformation of the structure of land use,
   - negative impact on the environment.

In the village of Budy Łańcuckie and Wola Mała there was no consolidation or land exchange. There were made only some assumptions for land consolidation along the motorway. No proceedings for land consolidation along the motorway were started, because there was no consent of this village inhabitants for such a small extent of consolidation.

Examination conducted in the areas of the south-eastern Poland reveal unfavourable conditions caused by the motorway construction disturbing land spatial structure. Unless corrective tools are applied, these problems will become more serious in the course of time. This situation can be improved only by conducting complex tasks of land consolidation and exchange. Land consolidation and exchange in the areas adjacent to the motorway and in other fragments of the villages will improve spatial structure. In the future, complex tasks of land consolidation and exchange should be carried out, which will surely bring the expected benefits.

References

BALAWEJDER M., ADAMCZYK T., CYGAN M. 2016. *The problem of adjusting Polish Spatial Information Resource to the standards of the INSPIRE.* Geographic Information Systems Conference and Exhibition - GIS ODYSSEY 2016, Perugia, Italy, p. 14-24.

BALAWEJDER M., NOGA K. 2016. The *influence of the highway route on the development of patchwork of plots.* Journal of Water and Land Development. No. 30 p. 3–11.

BALAWEJDER M., BUŚKO M., CELLMER R., JUCHNIEWICZ-PIOTROWSKA K., LEŃ P., MIKA M., SZCZEPANKOWSKA K., WÓJCIAK E., WÓJCIK-LEŃ J., ŹRÓBEK S. 2015. *Aktualne problemy gospodarki nieruchomościami w Polsce na tle przemian organizacyjno-prawnych (Current problems of real estate management in Poland against the background of changes of organizational and legal).* Editor of monographs Balawejder M., Mika M. WSI-E, Rzeszów, pp. 144.

BIEDA A., STALKA-KRAWCZYK D. 2014. *Analiza postępowań związanych z regulacją stanu prawnego dróg publicznych na przykładzie Chorzowa (Analysis of proceedings related to the regulation of the legal status of public roads on the example of Chorzów).* Zeszyty Naukowe Uniwersytetu Szczecińskiego. Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania. 36 T. 1, Szczecin, p. 139-151.

BIELSKA A., KUPIDURA A. 2013. *Kształtowanie przestrzeni na obszarach wiejskich (Shaping of space in rural areas).* Oficyna wydawnicza Politechniki Warszawskiej. Warszawa, pp. 174.

HOPFER A., KOBYŁECKI A., ŻEBROWSKI W. 1980. *Kształtowanie sieci dróg na terenach wiejskich. (Shaping the road network in rural areas).* PWRiL, Warszawa, pp. 206.

MATYAS K. 1957. *Lesni doprawni site – Podklady pro planowani. (Planning forest road network)* Praha, pp.316.

NOGA K. 2001. *Metodyka programowania i realizacji prac scalenia i wymiany gruntów w ujęciu kompleksowym (Methodology of programming and implementation of works consolidation and exchange of land in terms of complex).* Szkoła Wiedzy o Terenie. Kraków. AR, pp. 88.

PRZEWIEZLIKOWSKA A., BUSKO M. 2014. *THE ANALYSIS OF THE UPDATING TIME OF SUBJECT AND OBJECT DATA DUE TO THE INFORMATION FLOW BETWEEN THE SYSTEMS OF THE REAL ESTATE CADASTRE AND THE LAND AND MORTGAGE REGISTER.* 114th International Multidisciplinary Scientific GeoConference SGEM 2014, Conference Proceedings, June 19-25, 2014, Book 2, Vol. 3, p. 933-940.

SOBOLEWSKA-MIKULSKA K. 2012. *Możliwości wykorzystania scaleń infrastrukturalnych w procesie przebudowy struktury przestrzennej obszarów wiejskich (Possibilities of using infrastructural consolidations in the process of reconstructing the spatial structure of rural areas).* IiETW nr 1/II 2012, PAN, Kraków, p. 41-51.

THRALL G. I. 1998. *GIS Applications in Real Estate and Related Industries.* Journal of Housing Research,vol. 9, no. 1, pp. 33–59.

THE ACT of 21 March 1985 *on public roads* (Official Jurnal 2016 No. 1440- consolidated text, as amended).

THE ACT of 20 June 1997 *Law on Road Traffic* (Official Jurnal 2012 No. 1137- consolidated text, as amended).

WILKOWSKI W. 1995. *Wielokryterialna metoda oceny wpływu autostrady na gospodarstwa rolne (Multi-criteria method of estimating the impact of motorways on farms).* Prace Naukowe Politechniki Warszawskiej, ser. Geodezja, Warszawa, z.33. p. 5-19.