SPACE – SOCIETY – ECONOMY · 23 · 2018 · 95–110

http://dx.doi.org/10.18778/1733-3180.23.06

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DIFFERENTIATION OF LAND COVER AND GEOMETRIC FEATURES OF PARCELS ALONG MOTORWAYS AND EXPRESSWAYS IN POLAND

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ABSTRACT: The aim of this work is both to assess differentiation of geometric features of parcels in the immediate neighbourhood of motorways and expressways in Poland (as divided into provinces) as well as to analyze their land cover. In order to achieve this, the authors used data on parcels from the Land Parcel Identification System (LPIS) as well as information on land cover from the Database of Topographic Objects (obtained from the Head Office of Geodesy and Cartography). It was concluded that there is a correlation not only between the existence of motorways and expressways and the land cover along them but also between geometric features of parcels. In those cases when motorway interchanges are located in the vicinity of big cities as it is exemplified, for instance, by the province of Silesia, Mazovia or even Łódź, there is an increase in development intensity in their vicinity. Besides that, parcels tend to be smaller on those areas where the density of motorways and expressways is the greatest.

KEYWORDS: land cover, motorways, expressways, Poland, GIS.

ZRÓŻNICOWANIE POKRYCIA TERENU I CECH GEOMETRYCZNYCH DZIAŁEK WZDŁUŻ AUTOSTRAD ORAZ DRÓG EKSPRESOWYCH W POLSCE

ZARYS TREŚCI: Celem pracy jest ocena zróżnicowania cech geometrycznych działek bezpośrednio sąsiadujących z autostradami i drogami ekspresowymi w Polsce (z podziałem na województwa) oraz analiza ich pokrycia terenu. Dla jego realizacji wykorzystano dane o działkach pochodzące z systemu LPIS (System Identyfikacji Działek Rolnych) oraz informacje o pokryciu terenu pozyskane z Bazy Danych Obiektów Topograficznych (pozyskane z Centralnego Ośrodka Dokumentacji Geodezyjnej i Kartograficznej). Stwierdzono, że występuje zależność nie tylko pomiędzy istnieniem autostrad oraz dróg ekspresowych a sposobem pokrycia terenu wzdłuż nich, ale również pomiędzy cechami geometrycznymi działek. W przypadku, gdy węzły autostradowe znajdują się w pobliżu dużych miast – przykład województwa śląskiego, mazowieckiego czy nawet łódzkiego, wzrasta intensywność zabudowy w ich pobliżu. Ponadto w obszarach, w których istnieje największa gęstość autostrad oraz dróg ekspresowych, działki są zazwyczaj mniejsze.

SŁOWA KLUCZOWE: pokrycie terenu, autostrady, drogi ekspresowe, Polska, GIS.

6.1. Introduction

Construction of motorways in Poland belongs to the most needed and urgent investment projects. The necessity to build them results from the country's economic and social development (Szafrańska 2011). The network of public roads comprises investments of linear character which occupy considerable areas of land, mainly farm and woodland, which in this way lose their previous function (Dzikowska 2006; Szafrańska 2011). This means disorganization in the existing development structure for many homesteads whose dwellings and farmland are located alongside such roads or in their immediate vicinity. The impact of motorways and expressways on the adjacent areas is a natural phenomenon (Szafrańska 2011). Construction of motorways and expressways brings about both positive and negative consequences in the environmental (Curzydło 1998; Badora 2004; Stuczyński 2011; Szafrańska 2011), social and economic spheres (Dzikowska 2006; Rekowski, Kawa, Jurczak 2011; Szafrańska 2011) as well as tourism (Liszewski, Włodarczyk 2011). There are certain benefits of investing in motorways, such as:

– about 25% savings on fuel consumption;
– travel time reduction by 30–40%;
– reduced risk of accidents by 75–80%;
– reduced level of fuel emissions and noise by 25–30% (Dzikowska 2006).

In turn, adverse consequences of accomplishing the analyzed linear investments include, for instance:

– cutting the existing land development, which hampers local transport connections;

– reclassification of land to non-agricultural and non-forest production for transport purposes, which entails a complete loss of the productive potential of the land in question;
– changes in structure of land use, hydrographic conditions in the soil and area investment;
– excessive fragmentation, dispersion and elongation of land in homesteads as well as formation of the so-called residues;
– reduction in the market value of property;
– changes in the shape and size of parcels;
– collision between the motorway and utility elements;
– environmental pollution *etc*. (Szafrańska 2011).

According to K. Badora (2004), the motorway has a direct impact in an extreme way on areas at a distance of up to 20 m from the road edge, the area up to 50 m may be considered to be a danger zone and that of up to 150 m – a nuisance zone (Lechowski 2013). On the basis of experiences of developed countries it is possible to say that the impact of motorways on land ownership structure goes far beyond the zone of direct impact of investment on the environment (Lechowski 2013 after: Wegener, Fürst 1999; Tesařova, Halounová 2006). Yet in reality the impact zone of motorways with regard to land cover is far greater, and it may reach as many as over a dozen kilometres, which depends on the location of interchanges, motorway flyovers, the policy of local governments and the space around those motorways (Ziobrowski, Korecki 2009; Lechowski 2013).

Motorway interchanges also play an important role in the economic development of cities. They make it possible to join the system of motorways with cities, which are places of concentration of economic and service potential. The fact that interchanges perform the function of connecting the motorway with the city makes their surrounding particularly important. Naturally, this depends, nonetheless, on their location in relation to urbanized areas.

There are three groups of motorway interchanges: inside cities, on the outskirts or outside them. Interchanges situated inside cities usually occupy the smallest space as compared to the other types. Development in this case tends to fill tightly not only the space in the immediate neighbourhood of the interchange but also the space between road splits as it happens with interchanges in Tokyo or Los Angeles. They are surrounded usually by car services, multi-storey car parks, office blocks, less often by hotels and only sporadically or even never by residential development. In contrast, motorway interchanges on the outskirts and their surroundings are developed in a number of ways. Sometimes their surrounding remains an open space used mostly in the same way as before constructing the motorway, but sometimes it is used intensively. This depends on the distance of the interchange from the city and how active the local authorities are in promoting investment areas in their immediate neighbourhood. If the distance

of the interchange to the city exceeds 20 km and the local authorities do not undertake any promotion activities, the surrounding of such interchanges remains the same as before motorway construction. In contrast, in a situation when the distance of the interchange to the city does not exceed these arbitrary 20 km and the local government is active enough, it is possible to observe an increase in investment in areas which have not been invested before as it is shown by the example of Kąty Wrocławskie. In the case of interchanges localized outside urban centres, their surroundings are not intensified (Ziobrowski, Korecki 2009).

The aim of this work is to assess the differentiation of geometric features of parcels in the immediate neighbourhood of motorways and expressways in Poland (in the division into provinces) as well as to analyze their land cover. The research includes only the parcels in the immediate neighbourhood of those parcels which motorways and expressways go through.

6.2. Methodology and source materials

Layers with parcels come from the System of Agricultural Parcel Identification (LPIS). Parcels in the immediate neighbourhood of motorways and expressways were characterized in accordance with their geometric features. The authors calculated, for instance, the average parcel surface, the indicator of parcel shape differentiation and the indicator of parcel shape density. In order to measure parcel shape they used measurements of length of their borders and surface. Two gauges of this shape were elaborated by J. Dzieciuchowicz (Dzieciuchowicz, Dmochowska-Dudek 2014). The first one describing shape differentiation is represented by the ratio of average length of parcel boundaries (*dj*) to their average surface in the province within the boundaries of which they are situated (*pj*):

$$[1] \quad Kzj = dj/pj \text{ x } 100$$

The more sections of diversified directions the parcel has, the more of its length falls per one unit of land surface. Hence the indicator in question increases together with the growing differentiation of parcel shape in the given territorial units.

The other indicator used in the work defines the relation of the average real length of parcel boundaries (*dj*) of the given province to the hypothetical length of these parcels *Lj*, which corresponds to length of the circumference of a circle if it had the surface equal to the average real surface of parcels of this province:

$$[2] \quad Khj = dj/Lj, \text{ where } Lj = 2\pi r,$$

for the circle of average parcel surface in the province *j* (Dzieciuchowicz, Dmochowska-Dudek 2014).

In order to analyze the land cover of parcels in the immediate neighbourhood of the researched roads the authors used data from the Database of Topographic Objects obtained from the Geodetic and Cartographic Documentation Centre in Warsaw. Land cover is understood here as all space location elements remaining on its surface which may be distinguished on the basis of their physiognomic features (*Wytyczne techniczne*… 2008). The objects belonging to this class describe the given area in a continuous way (Borowska-Stefańska 2015ab).

There are 12 main complexes of land cover in the the Database of Topographic Objects:

1. Surface waters: sea waters (PTWP01), flowing waters (PTWP02), standing waters (PTWP03);
2. Development area: multi-family residential units (PTZB01), single-family dwellings (PTZB02), industrial and storage development (PTZB03), commercial and service development (PTZB04), the remaining development (PTZB05);
3. Woodland and woodlot: forest (PTLZ01), coppice (PTLZ02), woodlots (PTLZ03);
4. Woody plants: dwarf mountain pine (PTRK01), bushes (PTRK02);
5. Permanent crops: allotment gardens (PTUT01), plantations (PTUT02), orchards (PTUT03), forest tree nurseries (PTUT04), ornamental tree nurseries (PTUT05);
6. Grass vegetation and agricultural crops: grass vegetation (PTTR01), crops on arable land (PTTR02);
7. Areas under motor, track and airport roads: area under a motor road (PTKM01), area under a track (PTKM02), area under a motor road and a track (PTKM03), area under an airport road (PTKM04);
8. Unused areas: scree, rock slide or rubble (PTGN01), rocky area (PTGN02), sand or gravel area (PTGN03), the remaining unused area (PTGN04);
9. Squares: square (PTPL01);
10. Landfill site: area of municipal landfill site (PTSO01), area of industrial landfill site (PTSO02);
11. Excavations and spoil tips: excavation (PTWZ01), spoil tip (PTWZ02);
12. The remaining undeveloped areas: area under technical or construction facilities (PTNZ01), industrial and warehousing area (PTNZ02) (*Rozporządzenie*… 2011).

On this basis the authors calculated the share of land cover form in the neighbourhood of expressways and motorways, the average surface of land cover form within parcel boundaries and the average share of land cover form within parcel boundaries. Moreover, they determined the power of relation between land cover form and parcel shape, parcel density and the distance from a big city and the nearest road interchange, using Pearson correlation coefficient. The indicated

distances were expressed in units of time, adopting the path which guarantees the shortest theoretical travel time (in accordance with traffic regulations) between the centroid of each parcel and the central point of cities and road interchanges.

6.3. Characteristics of research area

There were over 3,000 km of motorways and expressways in total in Poland at the end of 2015[1], most of which can be found in the province of Łódź, Greater Poland and Silesia: 405 km (including 217.8 km of expressways and 187.6 km of motorways), 361 km (including 150.2 km of expressways and 210.5 km of motorways) and 3 017 km (including 130.9 km of expressways and 176.4 km of motorways) respectively (Table 1).

Table 1. List of motorways and expressways in Poland according to the province as of 31.12. 2015

Region	Expressways and motorways	Expressways	Motorways
	[km]		
Poland	3 051	1 492.2	1 559.2
Lower Silesian	286	64.3	221.9
Kuyavian-Pomeranian	200	35.0	165.0
Lublin	79	79.3	0.0
Lubusz	232	142.4	89.2
Łódź	405	217.8	187.6
Lesser Poland	173	21.8	151.0
Masovian	255	188.6	66.4
Opole	88	0.0	88.1
Subcarpathian	123	11.0	111.9
Podlaskie	46	45.9	0.0
Pomeranian	138	72.3	65.9
Silesian	307	130.9	176.4
Świętokrzyskie	57	57.1	0.0
Warmian-Masurian	141	140.5	0.0
Greater Poland	361	150.2	210.5
West Pomeranian	160	135.1	25.3

Source: www.stat.gov.pl.

[1] www.stat.gov.pl (accessed on 18.05.2017).

There are 3 main motorways in Poland, including:

– A1 motorway connecting Gdańsk with Łódź and the Silesian agglomeration in the trans-European transport corridor no. VI;
– A2 motorway which connects Poznań with Łódź and Warsaw in the trans--European transport corridor no. II;
– A4 motorway connecting Wrocław with Katowice, Kraków and Rzeszów in the trans-European transport corridor no. III.

This primary network is complemented by A6, A8 and A18 motorways. All of them provide incorporation into the European network of freeways, ensuring comfortable connections of Polish agglomerations with Berlin, Dresden, Prague and Bratislava. Motorway connections are complemented, in turn, by a network of motorways which make it possible to connect Poland's main economic areas with the center and one another (*Program budowy*… 2011) (Fig. 1).

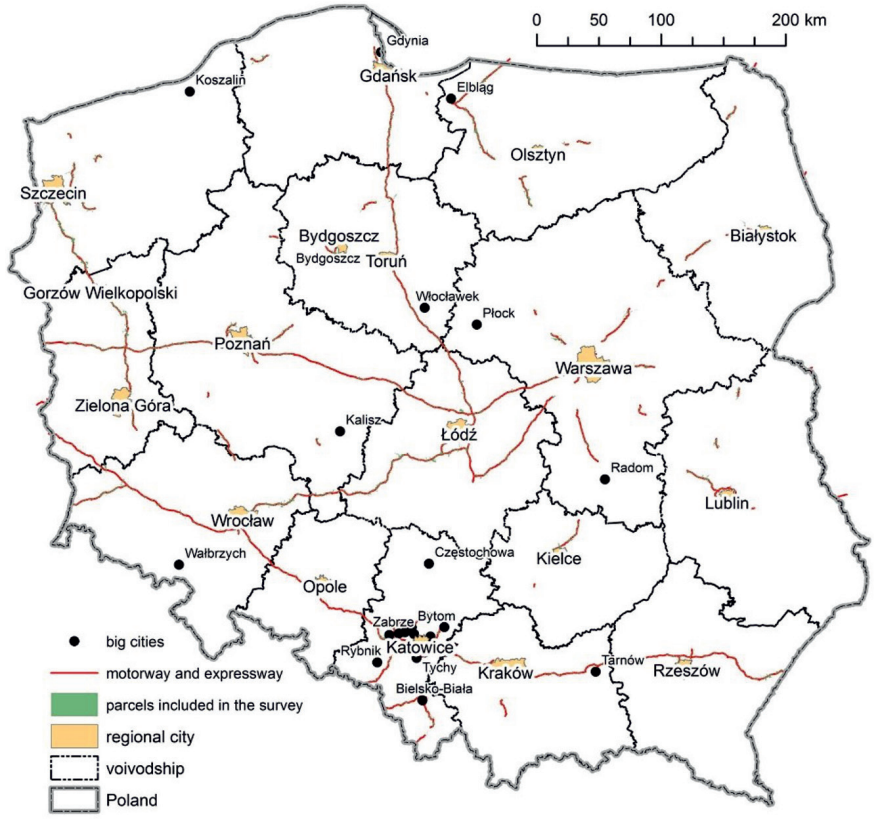

Fig. 1. Polish expressways and motorways as well as parcels adjacent to them

Source: own elaboration on the basis of data from the General Directorate for National Roads and Motorways, the Database of Topographic Object and LPIS.

6.4. Results

As a result of the conducted analyses it was established that the biggest number of parcels located in the immediate neighbourhood of motorways and expressways can be found in the provinces of Łódź (30–35 thousand), Silesia (approximately 25 thousand), Subcarpathia and Mazovia (from 20 to 25 thousand). This concerns, in particular, those provinces where the length of these roads is the longest nationwide, with the exception of the Subcarpathian province. The smallest number of parcels in the immediate vicinity of the roads in question can be found in the provinces of Opole, West Pomerania, Warmia-Masuria, Podlasie and Pomerania (0–5 thousand) (Fig. 2). These are provinces in which the length of motorways and expressways is the shortest as compared to the remaining areas (Table 1).

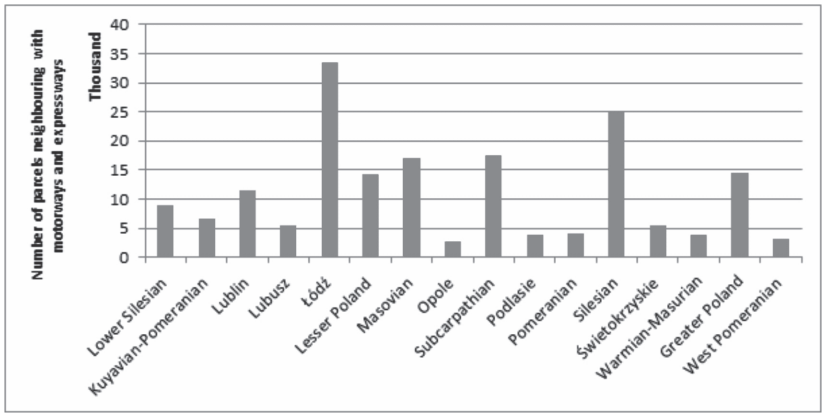

Fig. 2. The number of parcels neighbouring with motorways and expressways in Poland according to the province

Source: own elaboration on the basis of the Database of Topographic Object and LPIS.

The average surface of parcels remaining in the immediate neighbourhood of motorways and expressways is the largest in those provinces in which their number is the smallest, i.e. in West Pomerania (40–45 thousand m²), Warmia--Masuria (30–35 thousand m²). In contrast, the smallest parcel surface can be found in the provinces of Subcapathia and Lesser Poland (0–5 thousand m²), (Fig. 3).

The indicator of parcel shape differentiation ranges from about 18 in the Warmian-Masurian province to slightly above 51 in the Opole region. Its values depend on the average surface of parcels; they increase as their surface shrinks, and they decrease in the provinces where parcels in the immediate neighborhood of motorways and expressways are the largest (Fig. 4).

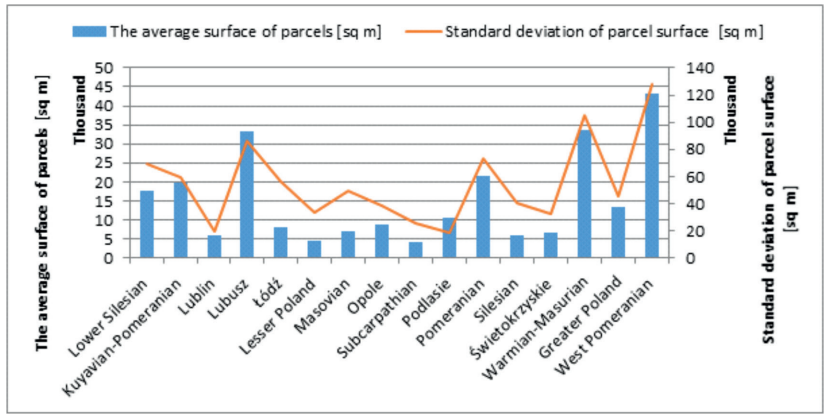

Fig. 3. The average parcel surface and standard deviation of surface of parcel neighbouring with motorways and expressways in Poland according to the province

Source: own elaboration on the basis of the Database of Topographic Object and LPIS.

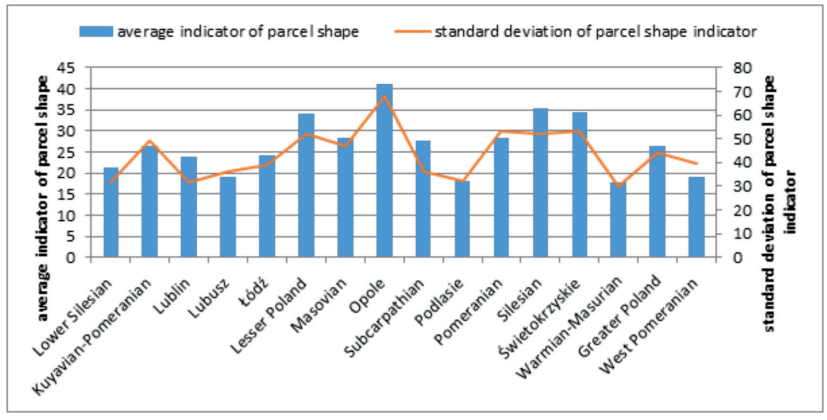

Fig. 4. The average indicator of parcel shape and standard deviation of shape indicator of parcel neighbouring with motorways and expressways in Poland according to the province

Source: own elaboration on the basis of the Database of Topographic Object and LPIS.

In turn, the indicator of parcel shape density in the researched provinces ranges from about 9 to 51 (Fig. 5). Parcels located mainly along motorways and expressways in the provinces of Lublin, Subcarpathia and Świętokrzyskie are characterized by low density whereas high density can be observed within the boundaries of, for instance, Lubusz and West Pomerania.

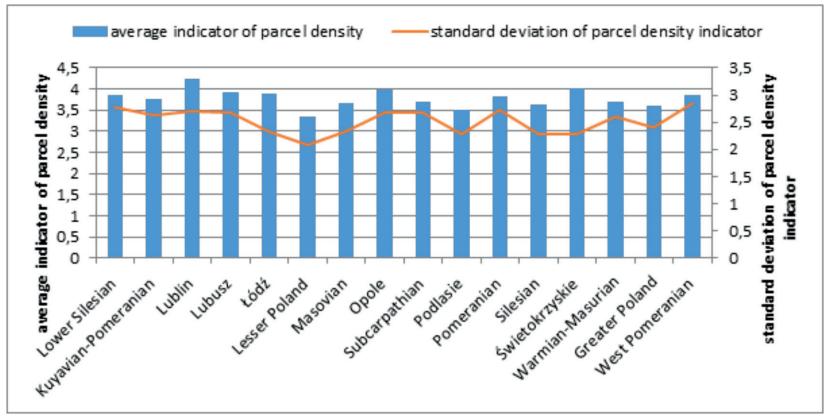

Fig. 5. The average indicator of parcel density and standard deviation of density indicator of parcel neighbouring with motorways and expressways in Poland according to the province

Source: own elaboration on the basis of the Database of Topographic Object and LPIS.

Another issue that became subject to analysis was the fragmentation of areas in the immediate neighbourhood of motorways and expressways. This feature was defined by means of the number of parcels per one kilometre of roads of limited accessibility (Fig. 6). It turned out that regions of south-eastern Poland clearly stand out against this background. The opposite situation takes place on the western and north-western outskirts.

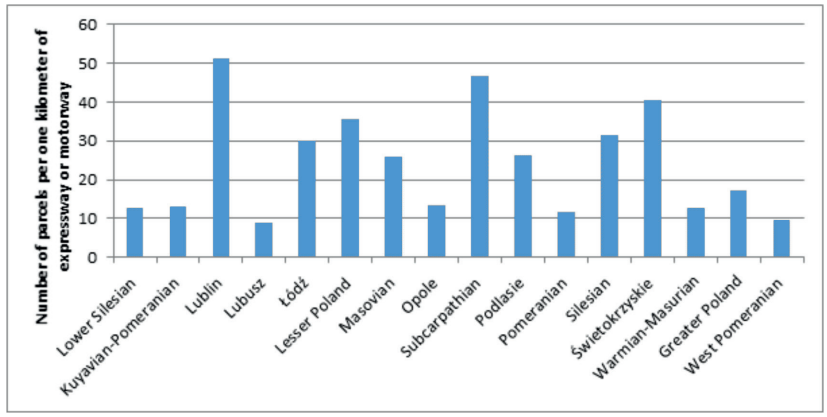

Fig. 6. Number of parcels per one kilometre of expressway or motorway in Poland according to the province

Source: own elaboration on the basis of the Database of Topographic Object and LPIS.

The following forms of land cover dominate within the researched parcels: crops on arable land (PTTR02) – about 36%, forests (PTLZ01) – 28% and grass vegetation (PTTR01) – 18% (Fig. 7). These parcels are, therefore, in the majority of cases free from development.

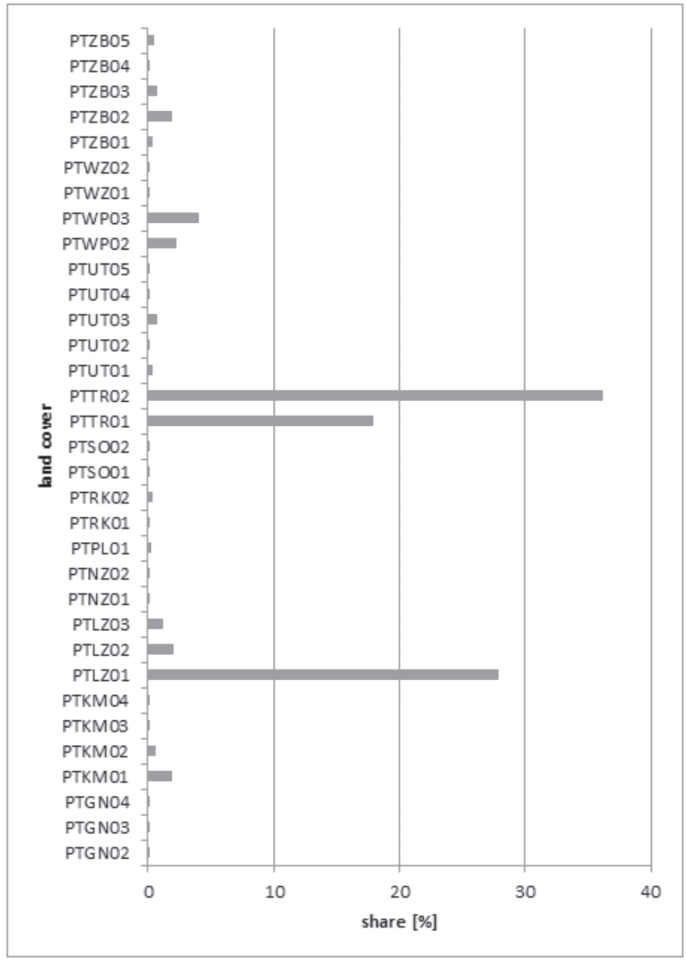

Fig. 7. The total share of land cover form in the neighbourhood of expressways or motorways

Source: own elaboration on the basis of the Database of Topographic Object and LPIS.

The strength of relations between the land cover form and parcel shape, parcel density, distance from a big city and the nearest road interchange is very diversified. The only significant relations (Pearson correlation coefficient above 0.5) refer to that between the type of land cover and parcel density (Table 2).

Table 2. The strength of relations between the land cover form and shape parcel, parcel density, distance from a big city and the nearest road interchange is very diversified

Land cover	Parcel shape	Parcel density	Distance from city	Distance from road interchange
PTGN	0.17	-0.34	-0.07	0.05
PTKM	0.27	-0.33	-0.20	-0.14
PTLZ	0.19	-0.60	-0.07	0.13
PTNZ	0.14	-0.59	-0.03	-0.03
PTPL	0.17	-0.63	-0.10	0.03
PTRK	0.30	-0.49	-0.20	0.03
PTSO	-0.05	-0.51	-0.21	0.05
PTTR	0.12	-0.48	-0.17	0.02
PTUT	0.12	-0.64	-0.24	-0.12
PTWP	0.18	-0.35	-0.21	0.02
PTWZ	0.08	-0.61	-0.21	-0.08
PTZB	0.13	-0.77	-0.10	0.18

Source: own elaboration on the basis of the Database of Topographic Object and LPIS.

As a result of the conducted research it was concluded in relation to the 12 main land cover forms that the most intensive development can be found in parcels neighboring with motorways and expressways in the Silesia province where the average share of developed areas is 41.37% (Table 3). This coefficient ranges from 20 to 30% also in other provinces such as Mazovia, Lesser Poland, Świętokrzyskie, Warmia-Masuria, Greater Poland, Pomerania, Łódź, Subcarpathia, Podlasie and West Pomerania (Table 3).

The conducted analyses confirm research results obtained by other authors, such as I. Jażdżewska (1999), K. Badora (2004), Z. Ziobrowski, D. Korecki (2009) and Ł. Lechowski (2013) which state that location of motorways in particular (in these cases also of expressways) affects the growth of developed areas in their neighborhood, mainly in the vicinity of interchanges.

6.5. Conclusions

The conducted research shows that the existence of motorways and expressways affects not only land cover alongside them but also geometric features of parcels. When motorway interchanges are located in the vicinity of big cities, as it is exemplified by the provinces of Silesia, Mazovia or even Łódź, there is an increase in development intensity in their neighbourhood. Besides that, in areas with the biggest number of motorways and expressways, parcels tend to be smaller, which is most often connected with their price. A clearly dominant number of parcels neighbouring with motorways and expressways in Poland concerns the provinces

Table 3. The average share of land cover form in the surface of parcel neighbouring with an expressway or a motorway in Poland according to the province

Land cover	Province*															
	02	04	06	08	10	12	14	16	18	20	22	24	26	28	30	32
PTGN	27.43	28.87	40.40	34.02	30.46	33.99	10.99	18.58	35.39	22.39	7.03	14.24	30.76	1.28	20.24	12.12
PTKM	19.64	34.61	32.89	20.53	31.65	37.49	39.48	59.63	40.42	25.19	31.81	29.43	35.59	24.77	40.57	18.87
PTLZ	23.99	32.14	45.63	35.03	40.01	35.54	32.42	33.74	27.83	33.41	29.26	38.23	35.98	23.59	29.34	29.03
PTNZ	24.20	26.83	22.10	19.94	36.14	22.73	23.78	34.96	24.46	9.57	33.09	29.69	28.32	26.39	23.98	18.55
PTPL	21.28	18.33	29.55	19.49	28.04	36.63	20.30	15.17	25.76	24.81	20.89	27.88	34.12	20.51	18.12	19.58
PTRK	26.04	11.90	30.44	7.42	17.19	31.76	20.38	46.79	11.35	6.05	11.69	32.06	9.63	13.45	15.29	6.25
PTSO	11.36	11.52	47.29	19.73	0.10	12.19	34.83	0.00	10.67	0.00	14.49	34.32	0.00	0.00	7.02	0.00
PTTR	53.54	46.09	58.78	44.78	55.48	58.72	48.63	42.24	57.46	53.98	48.04	55.23	56.88	44.32	53.71	48.98
PTUT	28.50	19.06	17.88	24.85	23.50	24.10	41.93	44.83	19.29	14.10	29.15	32.50	18.58	33.91	21.61	25.43
PTWP	11.18	30.29	8.77	8.67	8.58	42.56	11.04	19.12	44.40	6.43	8.21	19.45	5.61	6.64	15.75	8.57
PTWZ	36.13	31.40	35.17	37.18	28.58	43.43	31.30	0.00	43.07	15.52	0.00	62.41	2.54	12.26	20.20	12.91
PTZB	22.90	16.50	18.48	17.02	19.86	28.77	24.66	18.58	21.70	21.68	23.10	41.37	27.67	23.53	23.12	21.34
	The average share in the surface of parcel in provinces [%]															

The intensity of red increases as the share grows

* Province territorial code: 02 – Lower Silesia, 04 – Kuyavia-Pomerania, 06 – Lublin, 08 – Lubusz, 10 – Łódź, 12 – Lesser Poland, 14 – Masovia, 16 – Opole, 18 – Subcarpathia, 20 – Podlasie, 22 – Pomerania, 24 – Silesia, 26 – Świętokrzyskie, 28 – Warmia-Masuria, 30 – Greater Poland, 32 – West Pomerania.

Source: own elaboration on the basis of the Database of Topographic Object and LPIS.

of Łódź and Silesia, which represents considerable potential of those regions as far as investment into, for instance, logistics infrastructure is concerned. This naturally refers mostly to areas accompanying interchanges on the analyzed roads, yet the tunnel effect accompanying transport infrastructure of the highest parametres represents an important location factor due to its barrier character.

The average surface of parcels neighbouring with a motorway or expressway coincides with the general tendencies concerning parcel size in Poland. The markedly biggest units can be found on the Regained Territories. This naturally entails the way in which these areas are developed. Slight fragmentation of land is a very valuable feature when, for example, location analysis of large format warehousing facilities is carried out. Excluding from analysis arrangements of local spatial policies of individual communes which the analyzed roads go through, it may be concluded that Poland has some considerable area potential (Fig. 8) to be invested for non-agricultural purposes.

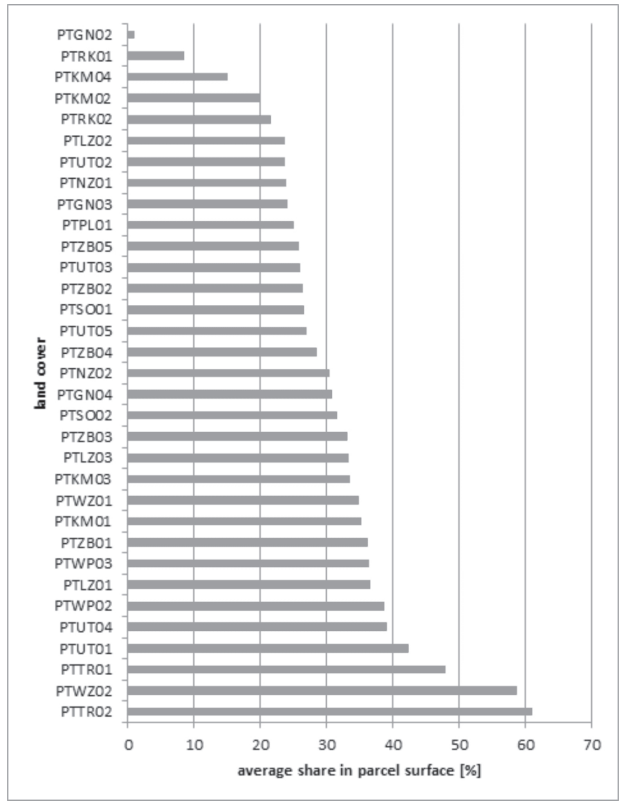

Fig. 8. The average share of land cover form within parcel boundaries in the neighbourhood of motorways and expressways

Source: own elaboration on the basis of the Database of Topographic Object and LPIS.

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Article history
Received 5 November 2017
Accepted in revised form 30 December 2017