KARTOGRAFSKE RAZISKAVE SPREMEMB PROSTORSKE STRUKTURE ZEMLJIŠČ V KRAKOVSKI ČETRTI PODGÓRZE NA POLJSKEM V OBDOBJU 1847–2016

CARTOGRAPHIC ANALYSIS OF TRANSFORMATIONS OF THE SPATIAL STRUCTURE OF LANDS OF PODGÓRZE IN KRAKOW IN POLAND IN THE PERIOD OF 1847–2016

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IZVLEČEK

Prvi kartografski prikazi in raziskovanja s področja rabe zemljišč so nastali v Združenih državah Amerike že pred prvo svetovno vojno. V letih med vojnama so takšna raziskovanja izvajali predvsem za potrebe regionalnega načrtovanja. Podatki in statistične metode omogočajo primerjavo med stanjem prostora v različnih časovnih obdobjih ter so v pomoč pri prostorskem načrtovanju na vseh ravneh. V prispevku so predstavljeni rezultati raziskave sprememb prostorske strukture zemljišč v četrti Podgórze (Poljska), ki je del mesta Krakov, in sicer v preteklih 169 letih. Temeljno gradivo za raziskave in analize so kartografska gradiva za izbrana obravnavana leta, to so leta 1847, 1909, 2003 in 2016. Na podlagi teh gradiv so bile določene značilnosti zemljiških parcel kot prostorskih objektov ter njihove spremembe v obdobjih 1847–1909, 1909–2003 in 2003–2016. V ta namen so bile izvedene računalniške prostorske analize, pri čemer so bile med drugim določene porazdelitve ter korelacije med izbranimi prostorskimi spremenljivkami, ki opisujejo lastnosti zemljišč oziroma parcelne strukture obravnavanega območja.

KLJUČNE BESEDE

katastrski načrt, zemljišče, parcela, prostorske analize, statistične analize, raba zemljišč

ABSTRACT

The first maps and studies in the field of land use were initiated in the United States as early as before World War I. Between the two world wars such studies were carried out with the main focus on regional planning. Planning process at all levels is usually based on rich statistical materials, which allows to compare the state of the space in different time periods. In the presented paper, the authors investigated transformations of the spatial structure of lands for a part of Podgórze, the district of Krakow for the period of the past 169 years. Source materials utilised for the research works and analyses included cadastral maps from the selected analysed years, i.e. 1847, 1909, 2003 and 2016. Based on the mentioned materials, the characteristics of land parcels as spatial features were analysed and changes were determined for the periods of 1847–1909, 1909–2003 and 2003–2016 showing the present situation. Computer processing of maps was performed for this purpose, and distributions and correlations between spatial variables characterizing parcel structure were analysed for the study area.

KEY WORDS

cadastral map, land, land parcel, spatial analyses, statistical analyses, land use

1 INTRODUCTION

The first maps and studies in the field of land use were initiated in the United States already before World War I. Between the two world wars such studies were carried out with the main focus on regional planning. However, their greatest extension was noticed in England. The work published by Stamp (1948) is considered as the pioneer work of a very high scientific potential, related to investigations of land use in the cities. Stamp was the initiator and the executor of research works performed in the period 1930–1949 in England, Wales and Scotland; as a result, the new method of land use analyses was developed, which presented the spatial distribution of main land use forms.

Historical works include studies, which refer to the past development of a city and, at the same time, discuss issues of land use. Works by Conzen (1960) and Smailes (1964) can be mentioned as examples. Conzen (1960) analysed changes, which occurred in the spatial structure of Newcastle within the period of 230 years. The performed analyses allowed detection of a development cycle and pointed to the succession of land use forms, which were generalised onto other British cities. Smailes (1964) presented the general process of land use changes which had taken place in London since the Roman period till the sixties of the twentieth century; he also highlighted historical processes of transformations. Planning works are usually based on rich statistical materials, which allows to compare various data i.e. information. The authors of such works are mainly experts involved in spatial planning. Some works of American authors may be given as an example. Bartholomew (1955) performed comparative land use studies in 97 American cities of different size. He stated that in a city, land use mainly depended on the number of inhabitants and on the type of a city, i.e. whether a city was a central or a satellite place. The another American spatial planner, Chapin (1965), analysed 22 cities and discussed the theory of growth of cities and land use planning methods.

In Poland, research works concerning land use were performed by spatial planners, surveyors and geographers. Jahn (1946) presented the instruction on creation of a land use map for the entire country using a unified method. The results of the collective works on these issues were published in Poland in 1957 (Uhorczak, 1957). The works were performed by Polish universities and geography centres. A general land use map at the scale of 1:300,000 was produced; it was then photographically reduced to the scale of 1:1000000. During the first years after World War II works aiming at preparation of general plans of development of cities and suburban zones were also initiated.

Works by Bromek (1955, 1966) can be considered as the first achievements in this field. In his first work, the author explains trends and conditions of land use changes in Krakow, based on comparative analyses. He considers reciprocal interdependence between the environmental impacts on the intensity of a given type of land use and the impacts of a given type of land use on particular components of the geographical environment. In his second work (Bromek, 1966) discussed basic type of land use and changes which occurred within the last 100 years in Krakow and in the surrounding areas. He also distinguished land use zones, assuming the distance from the city centre. The results of the research work suggested that this distance was the basic factor, which influenced the division of lands and their types of use. In order to detect the impacts of the city centre, which result in "urbanity" or "suburbanity" of land use, the author defined certain measures, which became the basis for identification of particular land use zones.

Nowadays, many works in the fields of contemporary geodesy and cartography concern the use of digital maps or satellite images in the analysis of the land use or the environmental structures. The application of fractal analyses consisting in appraising the similarities of images provides valuable information on the spatial structure of the study areas (Buttenfield, 1995; Chen and Zhou, 2006). Furthermore, topologic, cartometric and statistic approaches to computer data processing together with selected procedures provide many options for spatial data analysis. These possibilities can be widened by means of statistical programming, photogrammetric and spatial analytical techniques. Among the others, Bitner (2015) suggested the method of land use analyses based on cadastral maps, using mathematical models as well as special statistical programs. The morphology of the parcel mosaic was investigated in Krakow (Bitner, 2015).

The development of digital cartography, including digital cadastral maps, have caused the wide use of maps as scientific research resources (Gotlib, 2008; Moellering, 2000). The morphological analyses of the spatial pattern created by cadastral parcel boundaries can be conducted using cadastral maps created within a geographic information system – GIS (Maguire et al., 2005). Apart from digital cadastral maps, these data concerning particular parcels included information, such as the area, the circumference and the coordinates of all cusps of polygons depicting parcels. The findings may lay the foundation for planning works related to the study on the determination of the degree of urbanization of a given area.

The study on land use in cities is connected with the introduction of new terms and definitions presenting specified areas of intensive use and frequent spatial alterations. In Slovenia, as an example, single classification of land use categories had not been established until the adoption of the 2007 Rules (OPN Rules 2007) on the format and drawing-up of municipal spatial plan and criteria for specifying settlement areas in need of restoration and for specifying areas for the settlements. Since that time, a new term relating to urban land use has been introduced in Slovenia (in Slovene: urbana raba; Drobne et al., 2014). The similar terminology has been introduced to the spatial planning documentation in Poland.

In the presented paper, the authors investigated transformations of the spatial structure of lands for a part of Podgórze, the district of city Krakow (Poland) for the period of 169 years. This allows determination of the intensity of landscape and land use changes and substitution of agricultural functions by elements characteristic of urban areas. Graphical computer techniques enable the visual evaluation of land divisions, which occurred within the period of 156 years. The knowledge of the development of social-and-economic relations in Podgórze and in Krakow allows to identify the reasons of transformations of types of land use, changes of land functions and surveying divisions of arable and building lands.

The aim of the research was to define the tempo and the scope of the alterations in the land use for the district of Podgórze in Krakow based on cartographic, archival and contemporary documentation.

2 METHODOLOGY

The methodology of the study is based on statistical, chronological and comparative analyses relating to the time periods for which cartographic data of the study area, the district of Podgórze in Krakow, were available. In this relation, the methodology involved the following chronology:

— Preparation and computer processing of maps;
— Measurements of spatial features of parcels in the periods of 1847–1909 and 1909–2003;

- Distributions and correlations between spatial variables of parcels for the periods of 1847–1909 and 1909–2003;
- Transformations of the spatial structure of lands in the period of 2003–2016.

Successive research included the analysis of correlation coefficients of the above features, which determined relations between the features of the parcel layout for the years 1847, 1909 and 2003. In the process of the interpretation, three elements were considered. Firstly, the scale of correlation is the following: 0–0.1: variables are not correlated; 0.1–0.3: weak correlation; 0.3–0.5: average correlation; 0.5–0.7: high correlation; 0.7–0.9 very high correlation; 0.9–1.0: complete correlation. Secondly, the minus sign (-) of the correlation coefficient means the reverse relation, i.e. when one feature increases, the other feature decreases; and the plus sign (+) of the correlation coefficient means that when one feature increases the other one also increases. The star sign (*) is used to mark correlation coefficient that is not significant, and belongs to the range 0–0.3.

2.1 Characteristics of study area

Podgórze, a city of the 18th century located within the boundaries of medieval Krakow, is a phenomenon at the European scale. The uniqueness of Podgórze resulted from the situation when, on a narrow belt of lands between the Vistula River and the rock masses of Podgórskie Krzemionki, a type of a belt (line) city was developed whereas in the upper parts, close to Lasota Street, a residential area of a garden type was created. This practical, urban-and-architectural implementation preceded theoretical assumptions from the end of the 19th century, concerning the line city of Arturo Soryi and garden cities of Ebenezer Howard. In Podgórze, two landscape zones were developed. In the lowland, the zone of the urban, cultural landscape was developed, and on the southern and eastern slopes of Podgórski Kamionki, the zone of the agricultural landscape was created. The division into such landscape zones can be confirmed by land use forms presented in large-scale maps, cadastral maps and iconographic materials from the 18th and 19th centuries, as well as by the area balance of land use forms, based on measurements on maps covering different parts of Podgórze. This is also confirmed by the contemporary development of the Old Podgórze area, which is perceived as a public utility area (Chmielewski, 2013).

At present, changes in the structure of land use in Krakow are stimulated by the processes of metropolization resulting from spatial policy (Luchter, 2016) and urbanization (Reed et al., 2002; Exner et al., 2009), which are characterized by an increase in a number of parcels and decrease in their areas. Researches on the city of Krakow anticipate alterations in land use, inclusive of arable areas which over the last years have been subject to intense development and building processes. The forecasts to 2020 based on the research (Luchner et al., 2015) show a declining tendency for arable areas in the whole city of Krakow as well as in its particular districts including Podgórze.

2.2 Preparation and computer processing of maps

In order to analyse the spatial structure changes of the lands it was necessary to determine cartographic materials, which condition could guarantee that they could be used for comparing purposes. The cadastral map of Podgórze from 1847, at the scale of 1:2880, the cadastral map of the town of Podgórze from 1909, at the scale of 1:1000, and the cadastral map of Podgórze from 2003, at the scale of 1:1000, were selected. The analysis covered areas, which were dominated by agricultural activities in 1847, i.e. fragments of fields

of Bonarka, Wilki and Krzemionki (Figure 1). Figure 1 presents locations of the selected parcels and contains order numbers of the parcels – they are not cadastral numbers from the original map. The present transportation system of Old Podgórze is presented in the background in order to easily locate the discussed area. Its area equals to 75 hectares, which is approximately 14 of the past town communes of Podgórze (540 ha).

Figure 1: A general drawing of locations of selected parcels: Bonarka, Wilki and Krzemionki of the town community of Podgórze, covered by the results of the performed analysis, as for 1847; the original scale 1:2880. (Source: The State Archives in Krakow – pressmark 444. The authors' original work.)

Figure 2: A general drawing of locations of parcels in the parts of fields: Bonarka, Wilki and Krzemionki of the town community of Podgórze as for 1909; the original scale 1:1000. (Source: The University Archives in Krakow Faculty of Geodesy. The authors' own work.)

Figure 2 presents a fragment of the cadastral map of Podgórze from 1909. It may be noticed that not all sections of this map are in a good condition. This also influenced the selection of the study area. In order to illustrate the growing intensity of the parcel division process, the parcel structure from 1847 was presented on the map from 1909; thus it is possible to visually evaluate crosswise or lengthwise divisions of old parcels from 1847, as well as shapes and locations of new parcels from 1909.

Figure 3 presents a fragment of the cadastral map from 2003, originally provided at the scale 1:1000. This map belongs to the resources of the Krakow City Office, the Department of Geodesy. The structure of parcels of 1847 was also marked on this map.

Figure 3: A general drawing of locations of parcels in the Old Podgórze area as for 2003; the original scale 1:1000. (Source: The University Archives in Krakow Faculty of Geodesy The scale of work 1:6000. The authors' own work.)

Cartographic materials were prepared in three stages:

1. Scanning of existing maps using the drum scanner Eagle Anatech 3640 with the real resolution of 400 dpi.

2. Calibration (matching) and digitising (redrawing) of rasters and obtained raster images to nominal coordinates in the Krakow reference system. Calibration was performed using the Iras/B Intergraph software in Microstation v. SE Bentley environment.

3. The obtained drawings in the DGN format were used for further interpretation of results obtained from the measurements of parcels.

2.3 Measurements of spatial features of parcels in the periods of 1847–1909 and 1909–2003

Prepared cartographic materials were used for the analyses of selected 179 parcels from 1847, 775 parcels from 1909 and 576 parcels from 2003. Map descriptions allowed identification of parcels and types of

land use. The study involved inter alia the analyses of parameters of parcels, such as width, length, size, parameter distance between the parcel centre and a build-up zone (a straight line), distance between the parcel centre and the Podgórze centre – the market square (the straight line), types of land use, parcel shape and access to road. Due to extensive analyses, the original table presenting the results is not included in the paper.

The analysis of data allows to state that acquired and systematised data enabled the statistical analysis of transformation of the spatial structure of parcels in the periods of 1847–1909 and 1909–2003, using the STATISTICA software tool. Values, which characterised distributions and correlations between spatial features of parcels, allow to quantitatively recognise particular phenomena.

2.4 Distributions and correlations between spatial variables of parcels for the periods of 1847–1909 and 1909–2003

The basic statistical descriptive characteristics were considered as the features of the parcel layout for the years of 1847, 1909 and 2003. The following features of parcels for the analysed periods were assumed:

1. The parcel layout as: the size, width, length, elongation, perimeter and shape;
2. The parcel location as: the distance from built-up areas, the distance from the centre of Podgórze, access to the road;
3. The land use and divisions of parcels: the land use, number of parcels resulting from the division of one parcel in the period of 1847–1909, the number of parcels resulting from the division of one parcel in the period of 1847–2003.

The statistical calculations (Przegon, 2004) should be interpreted together with the images for the analysed years. Due to the high number of images, the figures below present the selection to illustrate the results: Figures 4, 5 and 6 present diagrams for selected parcels' characteristics in the study area from 1847, while Figure 7 illustrates the changes in the number of parcels in the study area for the period 1847–1909.

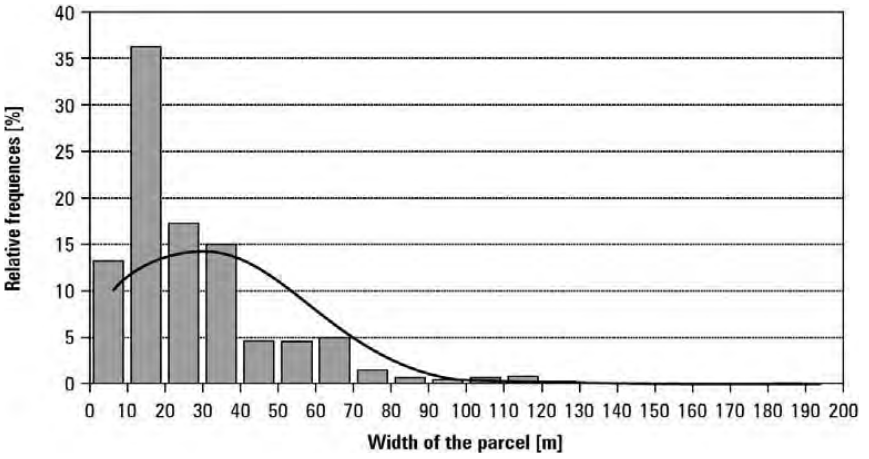
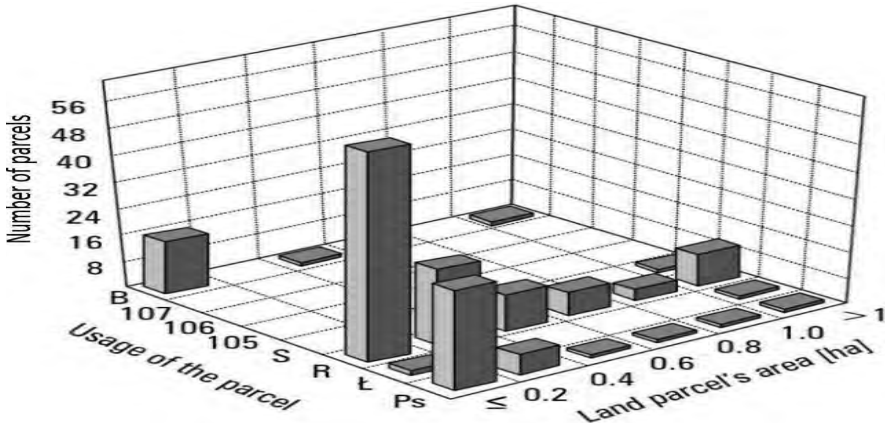
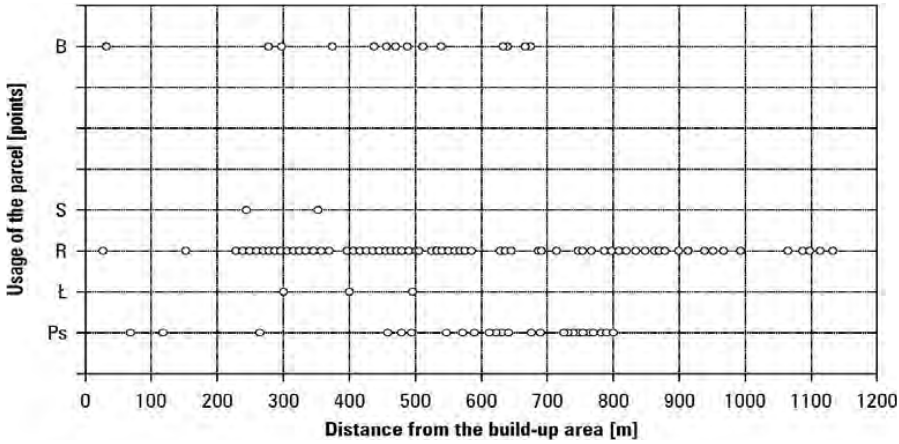


Figure 4: The distribution of numbers of parcels by their widths for the situation in 1847.



Definition of abbreviations in histogram: B – building area; S – orchards; R – arable area; Ł – meadows; Ps – grazing
Figure 5: The histogram of size and types of land use of parcels in 1847.



Definition of abbreviations in histogram: B – building area; S – orchards; R – arable area; Ł – meadows; Ps – grazing
Figure 6: The scatter plot of distances from built-up areas and types of land use in 1847.

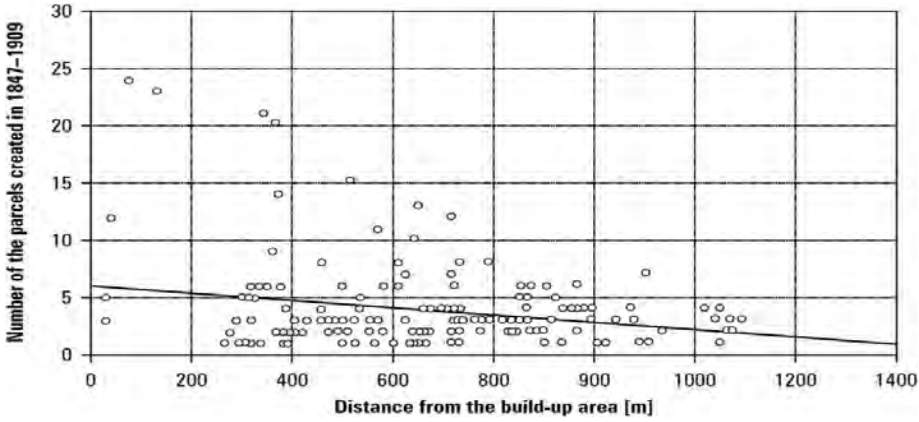


Figure 7: The scatter plot of distances from built-up areas and the number of parcels created in the period of 1847–1909.

2.5 Transformations of the spatial structure of lands in the period of 2003–2016

The vector cadastral map from the Centre for Geodetic and Cartographic Documentation in Krakow was used for the analysis of the current state of the real estate cadastre in 2016. After comparing with the land registry of 2003 it may be stated that in practice no larger changes occurred within the analysed 13-year period. Only several parcels were divided. Therefore, the parcels parameters were not significantly changed comparing to the year 2003. Many factors could influence this situation. The north-western part of the analysed area, presented in Figure 8 are the areas highly suffused by investments. The very dense development and high fragmentation of cadastral parcels occur in those areas. This influences the lack of interests and possibilities to divide them. The central part of the analysed area is the Bednarski Park (Figure 8). This area is fully covered with the park greenery. Areas planned for recreation and the area used for television and telecommunication services are located close to the analysed area. They are fully developed areas, where no significant changes related to the land registration occurred.

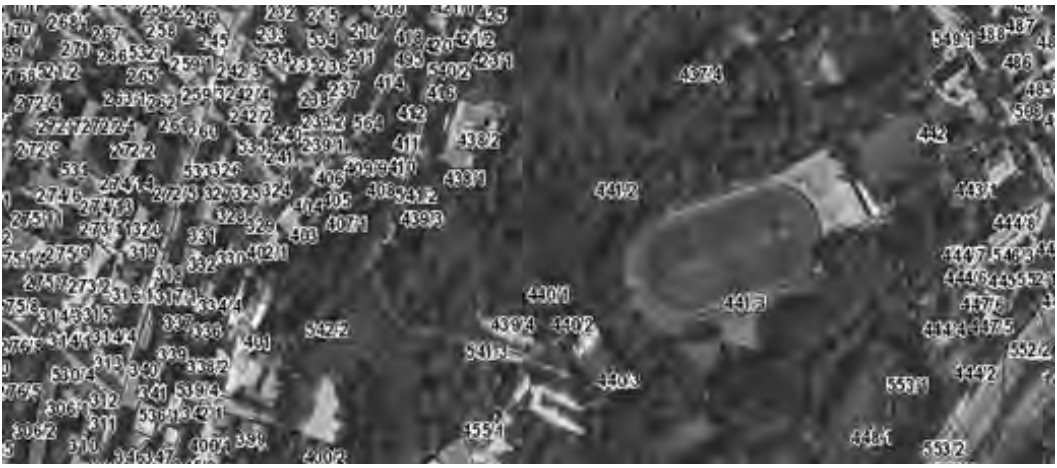


Figure 8: The north-west part of Podgórze - a fragment of an orthophoto with cadastral parcels. (Source: http://mapy.geoportal.gov.pl)

The southern part of the area, presented in Figure 9, is located in the direct neighbourhood of the stone pit. The area is mostly covered by trees. Some allotments are also located there. In this case changes in the land registry were not noticed as well. The important reason for the minimal changes in the spatial structure is the arrangement and development of railway, road and pedestrian transport.

The property structure has a strong influence on possible changes in the land registry. The property of the State Treasury and the City of Krakow prevails in this area. Although the parcels are big, it is not necessary to divide them as in the case of parcels being private property. On the other hand, private parcels included in the analysed area are usually small and intensively developed and therefore the possibility to divide them is limited. The private parcels situated in the southern part of the analysed area, completely covered by trees, are exceptions. They are big parcels, which have not been divided, most probably because of the low profitability of possible investments in that area.

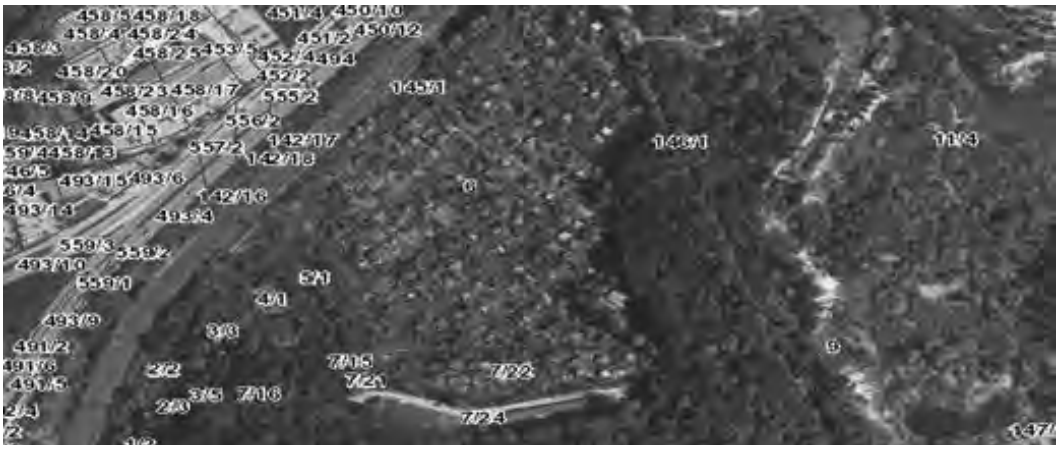


Figure 9: The south part of Podgórze – a fragment of an orthophoto with cadastral parcels. (Source: http://mapy.geoportal.gov.pl)

3 RESULTS AND DISCUSSION

Acquired and analysed statistical materials allow to recognise relations between parcel features. Description of all diagrams and analyses of tables is very wide and therefore only those interpretations, which allow to sufficiently recognise transformations of the spatial structure of the selected part of Podgórze within the specified periods, are presented. Considering the above mentioned issues in the context of the situation in 1847 it should be stated that:

- The distance from the built-up zone and from the centre of Podgórze did not significantly influence the fragmentation and shapes of the parcels. Unimportant correlation coefficients are usually smaller than 0.10*. Farther located parcels were slightly smaller and narrower or more elongated.
- The distance from the built-up zone influenced the land use significantly. Parcels were more intensively used close to residential areas, which is shown by the correlation coefficient r = -0.17*. It should be stressed that the above mentioned trends commonly occur in rural areas.

When interrelations between the parcel layout features are interpreted it should be stated that bigger parcels are wider and longer. Relevant correlation coefficients are equal to: r = 0.85 and r = 0.63. This not only proves the functional relations of those measures but also the high variability of the length and the width of the analysed parcels. The parcel length is relatively highly connected with its width (the relation – almost high), which does not occur in rural areas, since parcels are divided based on their size and not their width or length.

In the period of 1847–1909 big, long and wide parcels were divided. The correlation coefficient for the year 1909 varies between 0.4 and 0.7. In 2003, this trend is weaker but it still exists, since the correlation coefficient value remains between 0.3 and 0.4. Parcels located closer to the built-up zone were divided. The correlation coefficient for 1909 is equal to r = -0.21* and for 2003 r = -0.25*.

Interpretation of the distribution of numbers of parcels by their sizes, widths and lengths in 1847 proves that parcels were too small (60% parcels smaller than 20 ares), too narrow (almost 50% parcels narrower than 20m) and too short (50% parcels shorter than 70m). These parameters are not favourable even in the case of horse cultivation.

In 1847 the distribution of distances between parcels and the built-up area is typical of residential areas developed along a road through a village. The distribution of parcels from residential centres in 1847 indicates that the minimal distance from a centre equalled to 400m. The histogram shape is not typical of a residential area located in the village centre. But it is typical of a village with a residential area located close to the boundaries. The distribution of the numbers of parcels created out of one parcel in the period of 1847–1909 proves that almost 80% of parcels were divided; they were mostly divided into 2–3 parts (50%) and into 4–6 parts (25%).

The distribution of parcels created out of one parcel in the period of 1909–2003 was decreased by approx. 25%, and approx. 40% parcels were not divided in 2003 comparing to the year 1909. The division into 2–3 parcels concerned 35% parcels, and the division into 4–6 parts concerned 15% parcel; one parcels was divided into three parts, on average.

The distribution of the numbers of parcels by land use proves that parcels on arable lands were dominating in 1847 (65%), which were characterised by the best outlay and the biggest area. Those was almost 22% pastures which was characterised by the worse outlay (smaller parcels). 10% of building parcels indicate that one building was allocated to the area of about 10 parcels.

The diagrams of the scatter of parcel features, i.e. correlations determined by correlation coefficients, point to the increase of distances from the built-up zone which is connected with the decreased land use intensity (correlation coefficient = -0.17*). Pastures exists close to the densely built-up area (300–700 m). Arable lands exists with an even intensity between 200 and 1000 m. It should be noted, that changes in distances from the built-up zone significantly influence only the type land of use and the parcel shape; they do not influence the other features of a parcel.

The correlation between sizes of parcels and the number of parcels created in the period of 1847–1909 is also of great importance. The high value of the correlation coefficient (r = 0.72) results from the clear tendency concerning division of parcels with big areas located in far distances. The parcel of 10 hectares divided into 87 small building lots can be shown as an example. This proves that in the 2nd half of the 19th century a city built-up area was developed in this part of Podgórze along the transportation route.

Some correlations between the features of parcels of 1909 are also interesting. Mutual connections of the features of parcel outlay may be seen by the following relations:

- connections between lengths and widths of parcels are expressed by the correlation coefficient of the value: r = 0.50. It is not a relation typical of parcels located in arable lands. Divisions of lands in a suburban zone are connected with creation of small building lots of smaller widths and lengths, compared to agricultural parcels;
- the parcel size mainly depends on its width (r = 0.83). This is connected with the high, relative variability of the parcel width whose standard error is higher than the average value;
- the relatively strong influence of the parcel length on the parcel size (r = 0.64) proves the high variability of lengths of parcels which is not always the case in agricultural areas;
- the shape of parcels is irregular since their size is bigger (r = 0.17*), they are longer (r = 0.25*) and wider (r = 0.21*). Obviously, parcels of longer parameters have disadvantageous shapes (r = 0.26*).

The performed analyses also covered relations between the distances from the built-up area, from the

Podgórze centre and the features of parcel outlays, their shapes and the types of land use. It was proved by the analyses that the influence of the distance from the built-up area on the size and the shape of a parcel is stronger than the influence of the distance from the town centre. Parcels located in longer distances from the built-up area are slightly bigger (r = 0.13*), wider (r = 0.11*), longer (r = 0.31) and more elongated (r = 0.16*). They are also less intensively used (r = 0.58).

The parcel use depends not only on the distance from the built-up area, but also on the features of the parcel outlay. Bigger and longer parcels are less intensively used. This means that mainly the small (r = -0.18*), narrow (r = -0.19*) and short (r = -0.35) parcels are developed.

Interpretation of the distribution of numbers of parcels of 1909 by their size, width and length proves that parcels were very small (90% smaller than 20 ares), narrow (80% narrower than 20m) and very short (88% shorter than 70m). These parcel parameters are worse than these ones which characterised parcels in 1847, whose values equalled 60%, 50% and 50%, respectively. The bad parcel parameters were considered to be the following: the area smaller than 20 ares, the width smaller than 20 m, the length smaller than 70 m.

Analyses also covered the distribution of numbers of parcels by land use in 1909 with the distribution in 1847. In 1909 the analysed area was covered with building lots (49%), arable lands (29%), roads (14%), pastures (5%) and railways (3%). In 1847 the following values were noticed: arable lands (65%), pastures (22%), building lots (10%), meadows (2%) and orchards (1%).

A considerable increase of intensively used parcels occurred within 62 years. The results of the discussed analyses, performed at the micro-scale level for a selected area proved the general trend of succession of land use forms in the town of Podgórze. This phenomenon was particularly strong in the 2nd half of the 19th century. The scatter plot of distances between the parcels and the built-up area and the land use prove the high correlation of variables - the distance and the type of land use (r = -0.58). This means that the land use intensity decreases when the distance between the parcel and the built-up zone is grows.

The analyses of distributions and correlations of parcel features in 2003, compared to the data of 1909, point that in 1847 and 1909 the influence of the distance from the built-up area was stronger than the influence of the distance from the town centre. In 2003 the land use more greatly depended on the distance from the town centre (r = -0.49) than from the boundary of the densely built-up area (r = -0,32). In other words, in 2003 a residential centre had a stronger influence on the type of land use than the neighbourhood of the built-up area. Comparing to 1909, the number of parcels was decreased in 2003, but their sizes, lengths and widths increased. Important changes in the parcel widths occurred. The number of parcels of the width up to 10 m decreased from 49% to 37%, and the number of parcels of the width between 10 m and 20 m is bigger (an increase from 33% to 39%); it is very convenient for the parcel development. Parcel lengths were changing with the lower intensity than parcel widths. In 2003, 45% parcels were shorter than 25 m, i.e. 8% less than in 1909. The distance between the parcels and the built-up zone decreased in 2003 since this zone was systematically getting closer in the 20th century. Comparison between the distribution of the numbers of parcels according to the distance from the centre of a build-up area in 1909 and in 2003 proves that this distribution is more equalised in 2003. This also proves the lower fragmentation of lands in the analysed area. Considering the distribution of the numbers of parcels by the land use it may be noticed that

the number of arable parcels decreased from 29% in 1909 to 9% in 2003. The number of building lots was increased only by 5%. This proves that this part of Podgórze was already highly developed as early as at the beginning of the 20th century. Parcels used as forests, meadows and different types of land use also appeared. The area of parcels under the transportation networks was increased from 14% in 1909 to 18% in 2003.

When the shape and size are analysed it should be noticed that the scatter of lengths and widths and the scatter of lengths and size of parcels in 2003 were almost identical as in 1909; this is proved by the correlation coefficients. For the first relation they are equal to: r = 0.48 in 2003 and r = 0.50 in 1909; for the second relation: r = 0.65 in 2003 and r = 0.64 in 1909.

When the scatter of parcel distances from the centre of the built-up area and their land use are analysed for 2003 it may be stated that the land use in 2003 depend much more on the distance from the centre (Podgórski Market). than on the distance from the densely built-up area: r = -0.49; this is opposite to the situation in 1909. Therefore, the role of the centre was increased. Forested areas which were created in the period of 1909-2003 are located in the furthest distances from the centre. These are the previous Bonarka fields. In 2003, building lots are dominating in the analysed area; their numbers are equalised in distance zones between 400 m and 1000 m. Arable lands cover only a small part of parcels, mostly located within the further distances from the centre, i.e. from 700 m to 1400 m. The influence of the parcel distance from the densely built-up zone on the parcel length is similar to the one in 1909 and it is equal: r = 0.35 and r = 0.31, respectively, although this distance is considerably (2 times) smaller. For the scatter of the length and the land use in 2003 the correlation coefficient equals to r = -0.17*. Since in 1909 the correlation coefficient equalled to r = -0.35, weaker relations between both variables are noticed in 2003. Longer parcels are still more frequently used as arable lands than building lots, however, this relation is weaker since the number of arable parcels is three times smaller than in 1909.

5 SUMMARY

Summarising the results of statistical, chronological-and-comparative analyses of changes in the system and outlays of parcels in the selected part of the past town of Podgórze and current Old Podgórze for the years of 1847–1909, 1909–2003 and 2003–2016 it should be stated that:

- Computer graphics allows fast, visual determination of transformation changes of the land use and the extension of surveying divisions, which occurred in the analysed area in the period of 156 years. The knowledge of social-and-economic relations in the given area allows to analyse reasons of existing divisions. For example, in 1909 in the area where "Ford Krzemionki" was located, all divisions which took place after the year 1847 resulted from redemption and destination of lands for military purposes. Since the sixties of the 20th century the "Kraków Krzemionki" television centre has been located there, that is why the current divisions result from changes of terrain functions and ways of development of this area.
- In the interpretation of distributions of variables and correlation coefficients between the parcel features for the year 1847 it was specified that some relations are typical of rural areas. It proves the previous observations that Podgórze was characterised by strong features of an agricultural town in that period. In the lowland part of Podgórze the urban type settlements were developed and in the arable zones of Krzemionki intensive agricultural activities were performed. This is proved by the domination of arable lands in the entire land use structure.

- During the 2nd half of the 19th century fragmentation of lands was intensified. In the period of 1847–1909 only 20% analysed parcels were not divided. Intensification of surveying divisions was caused by the development of the social-and-economic development of Podgórze. The demographic growth, industrial development, as well as the development of fortifications and railway transport were the reasons for succession divisions of lands, divisions resulting from sales of parts of agricultural and building parcels, expropriation of lands for military purposes and construction of railway lines, delineation of areas for industrial and housing development. The turnover of lands concerned both, the lands of the town and the private lands. 179 parcels presented on the cadastral map of 1847 were selected for the statistical analysis. In 1909, there were 775 parcels in the same area, and in 2003, their number was decreased to 576 parcels. The reduction of the number of parcels within 100 years is the rare case of an independent improvement of the spatial structure of lands. The extreme fragmentation, which occurred at the end of the 19th century, was a barrier for the urbanisation process. Parcels of the average size of 8 ares and the width of 13 m were too small and, in particular, they were too narrow for their appropriate development. As a result of the land market, small parcels were enlarged in order to meet the requirements of the urban development. In the period of 1909–2003 the average parcel size was increased to 11 ares and to the width of 17m, i.e. by approx. 30%. Advantageous changes of the spatial structure may also be explained through the disappearance of agricultural function in that area, development of areas for individual and multi-family houses and the final determination of areas for railway, road and pedestrian transport. Divisions related to industrial and military investments do not exist in the area.
- Performed analysis presented the transformations of the spatial structure in the selected area of the past town of Podgórze and the present Old Podgórze in the quantitative approach. Results of statistical analysis confirmed the trends of land use changes, which occurred in the 19th and 20th centuries in the area.
- The analysis of distributions and relations between variables of parcels lead to interesting conclusions concerning processes of urbanisation and changes in terrain functions. They may be utilised in programmes of revitalisation of areas of high landscape and cultural values. In 2016, the analysis of the status of the land registry was performed and it was compared with its status of the year 2003. It should be stated that only several parcels were divided within the period of 13 years. Therefore, parcel parameters were not changed in comparison with to the year 2003. The programme of revitalisation of "Old Podgórze", which is being performed at present is not related to property divisions and the land use structure.
- Statistical analyses of transformations of the spatial structure of a part of Podgórze performed for the periods of 1847–1909 and 1909–2003 prove that in the 2nd half of the 19th century the intensity of lands disaggregation was increased. In the period of 1847–1909 only 20% of parcels were not divided. The extreme disaggregation of lands was the barrier in the process of urbanisation.
- It should be stated that only several parcels were divided within the last 13 years. Therefore parameters of parcels were not changed compared to the year 2003. The process of revitalisation of "Old Podgórze" which is being implemented is not connected with property divisions and land use issues.
- Summarising the obtained results, it should be stated that considerable changes of the spatial structure did not occur in the analysed area in the period of 2003–2016 due to the specific location of that area.

The results should be considered by urban planners who are developing programmes of revitalisation of Podgórze, with the protection of landscape and cultural values.

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