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FOREWORD

Rural areas in Poland belong to one of the most specific and complex issues in Europe. The most critical of them are high land fragmentation level, unclear legal status of lands and complicated historical conditions. The adoption of EU directives on changes in spatial structure and landscape development has brought significant results in recent years. We gladly observe that cities and rural areas are more closely related, if only on such planes as farm produce market or suburbanization.

In order to meet emerging challenges, of which the most fundamental is establishing close connections between science and economy, for many years scientific offer of Departments of the University of Agriculture in Krakow has been subject to modifications. Particularly valuable in this respect are the activities undertaken by the Department of Environmental Engineering and Land Surveying. They adhere to the guidelines, which could be called the elements of integrated development policy. We see that students expect from the University not only high level of theoretical knowledge, which we are obviously providing, but also practical skills. And it corresponds with employers' expectations, as we are constantly reported.

The current sixth issue of the scientific journal edited by Prof. Urszula Litwin presents a whole range of innovative research marked by close correlation with practice. Therefore, I am really glad that the Scientific Board of Geomatics, Landmanagement and Landscape has been carrying out this mission for more than a year and that the published articles, while being an interesting read, contribute to the exchange of scientific ideas and are the source of valuable research and implementation initiatives. The same applies to the current issue of GLL. Moreover, the subjects examined by authors are related with the requirements included in the European Union operational programmes for 2014–2020.

Let me refer shortly to the subjects of the presented issue. The first article focuses on the real estate market in Krakow while using spatial econometrics methods. The next one examines the vital problem of improvement of accuracy of digital aerial photography. The third paper discusses the issue of demand for land consolidation works as exemplified by the Pasym commune in Warmian-Mazurian Voivodeship. The topic of the forth article is a significance of Polish architectural heritage in the Lviv region. The next paper is a detailed analysis on modern rural management works carried out in an integrated formula, consistent with the EU policy. The same subject is elaborated in the next article, but this time it is presented from the perspective of planning possibilities.
of rural management works. The last article focuses on the importance of the objective functions and flexibility on calibration of parameters of Clark instantaneous unit hydrograph. The survey of articles’ topics and titles already shows that the authors have undertaken a successful research, not limited to the area of southern Poland, but covering the European reality, and thus they proved the existence of correlation between architectural area and economic and cultural conditions.

As a rector of The University of Agriculture in Krakow I am very happy that the authors of most of the articles are young scholars, who decided to give their attention to these important matters. The University is now faced with the necessity of creating new research personnel – and I am absolutely certain that we will manage this task. Thanks to its high competence level the Journal fully deserves a name of academic publication, and for this reason I am convinced that it in a short time it will be highly ranked.

Prof. dr hab. inż. Włodzimierz Sady
Rector of the University of Agriculture in Krakow
A STUDY OF REAL ESTATE MARKET IN KRAKÓW USING THE METHODS OF SPATIAL ECONOMETRICS

Agnieszka Bitner, Jakub Bysina

Summary
The article presents implementations of statistics and spatial econometrics that can be used to study real estate market. The analysis covered the area of the administrative unit of Śródmieście district of Kraków. It is a very diverse area of research as it includes both the city core of Kraków and its outskirts. Śródmieście is divided into three districts: Stare Miasto, Grzegórzki and Prądnik Czerwony. The transactional data come from the notarial deeds drawn up in 2011. During that period 739 purchase/sale transactions of apartments were concluded. The purpose of the article is to create a map of the average prices of apartments situated in the administrative unit of Śródmieście. The analysis of the apartment prices was conducted both for the separate districts of cadastral registration (bounds, cadastral districts) and districts and for the whole administrative unit.

Keywords
spatial econometrics • real estate market • statistical analysis • transaction prices • apartments • Kraków

1. The characteristics of the studied area

Kraków is located in southern Poland, on the Vistula River. The area of municipality is 326.8 km², which on 31 December 2011 was inhabited by 759,137 people. In 2011 the unemployment rate in Kraków varied from 4.5% to 5.0%, the average for Poland being around 12%. Kraków is conveniently located at the intersection of major transportation and communication routes connecting Western Europe with Eastern Europe (Frankfurt – Kiev) and Southern Europe with the Baltic Sea (the Gdansk – Budapest route) [Adamczewski 1992]. It is a university town. There are 24 higher education institutions in Kraków, such as: the Jagiellonian University, the Agricultural University, the University of Economics, the Pedagogical University, the University of Science and Technology, and the Technical University of Kraków. In the 2011/2012 academic year more than 180 thousand students studied at higher education institutions in Kraków [Szkolnictwo… 2012]. The scientific character of Kraków has a significant impact on the property market in this city. Kraków was divided into four administrative units: Krowodrza, Nowa Huta, Podgórze and Śródmieście (Figure 1), which are then divided into districts and bounds.
Fig. 1. Administrative units in Kraków

Source: www.Krakow.pl/plan

Fig. 2. The districts in Śródmieście

Source: www.Krakow.pl/plan
Administrative units consist of areas of grounds located within the administrative region of cities. In those cities where districts were created, the area of a district or of several neighbouring districts can be a administrative unit [Rozporządzenie... 2001]. This is also the case with Kraków. The cadastral district of Śródmieście, which is the subject of the study, consist of three districts: District I – Stare Miasto, District II – Grzegórzki, and District III – Prądnik Czerwony (Figure 2).

Each of the three districts consists of bounds. Similarly to administrative districts, bounds are units of the territorial division used for land and building registration purposes. The borders of bounds in urban areas correspond with district borders and, where possible, they overlap the borders of urban agglomerations, residential areas and the borders delimited by streets, watercourses, railway lines or other physiographical objects.

District I – Stare Miasto – consists of bounds with the following numbers: 1, 2, 3, 7, 8, 11, 12, 13, 14, 15, 59, 60, 61, 62, 116, 118, 119, 120, 145, 146, 216 (Figure 3). That

Source: www.Krakow.pl/plan

Fig. 3. District I – Stare Miasto – division of the area in sections
District includes the oldest parts of the city, in the first place the Wawel Hill, where a fortified city and the surrounding settlements were established in the ninth century, but also of poorly urbanized areas.

District II – Grzegórzki – consists of the following bounds presented in Figure 4: 5, 6, 8, 16, 17, 50, 51, 52, 53, 63. Formerly a village outside Kraków, which comes from the fourteenth century. In 1910 it became a part of the border of Kraków. In the territory of the district there is a botanical garden founded in 1783.

District III – Prądnik Czerwony – consists of the following bounds: 4, 21, 22, 23 (Figure 5). Formerly a village outside Kraków, which was first mentioned at the beginning of the twelfth century as the areas belonging to the St. Benedict Monastery in Tyniec. At the beginning of the nineteenth century the Rakowicki Cemetery was founded in that area, and the Batowicki Cemetery in the twentieth century. In 1910 a part of the today’s district became a part of the border of Kraków. The rest became a part of that border in 1941.
2. Characteristics of the database

In 2011 in the administrative unit of Śródmieście 739 sales were made. Transactions involving apartments in very poor condition, intended for general renovation, the price of which included a garage or a parking space, were not included in the database as well as the transactions, in which a company, a commercial enterprise, or a civil partnership was a party or where the parties were interrelated. Transactions that showed important data gaps, for example concerning the type of ownership rights to property, were not included in the analysis either. As a result the database consists of 589 records. The selection of data before applying the tools of spatial econometrics [Anselin 1988] is an essential step of the analysis of real estate market [Głuszak 2010, Bitner 2010].
3. The results of the analysis

Examining the apartments unit price trend in the analyzed period [Bitner 2003] was the first step of the statistical analysis of real estate market [Hozer et al. 2002, Adamczewski 2011, Bartuś et al. 2009]. The analysis carried out for both the whole administrative unit of Śródmieście and for its separate districts showed that apartment market was stable. The prices were relatively similar.

The average unit price of apartments in Śródmieście was 7469.78 zloty · m⁻². The maximum price of 17551.42 zloty · m⁻² was noted in District I – Stare Miasto, in the bounds 62, in Cyberulskiego St. That flat is located in a building with a high standard of finishing and situated in an attractive area. The lowest price of 3458.21 zloty · m⁻² was noted in District III – Prądnik Czerwony, in the bounds 23, in Wieniawskiego St.

Table 1 and Figure 6 show the distributions of apartment unit prices in Śródmieście. The division into 10 price ranges (classes) of 1410 zloty · m⁻² was adopted.

Table 1. The distribution of apartment unit prices

<table>
<thead>
<tr>
<th>Class number</th>
<th>The lower class limit [zloty · m⁻²]</th>
<th>The upper class limit [zloty · m⁻²]</th>
<th>Number of sale transactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3458</td>
<td>4868</td>
<td>26</td>
</tr>
<tr>
<td>2</td>
<td>4868</td>
<td>6278</td>
<td>139</td>
</tr>
<tr>
<td>3</td>
<td>6278</td>
<td>7688</td>
<td>233</td>
</tr>
<tr>
<td>4</td>
<td>7688</td>
<td>9098</td>
<td>95</td>
</tr>
<tr>
<td>5</td>
<td>9098</td>
<td>10508</td>
<td>47</td>
</tr>
<tr>
<td>6</td>
<td>10508</td>
<td>11918</td>
<td>18</td>
</tr>
<tr>
<td>7</td>
<td>11918</td>
<td>13328</td>
<td>12</td>
</tr>
<tr>
<td>8</td>
<td>13328</td>
<td>14738</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>14738</td>
<td>16148</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>16148</td>
<td>17558</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: authors’ study

Our analysis indicates that most of the transactions belong to the price range 6278–7688 zloty · m⁻². They constitute almost 40% of all transactions on the market. The smallest amount of apartments sold was noted in the highest price ranges above 16148 zloty · m⁻². The distribution of unit prices is asymmetric, skewed right.

Figure 7 shows an overview of the transactions made in three districts in each month of 2011.

In the table in Figure 7 Roman numerals indicate the consecutive months, whereas Arabic numerals indicate the number of transactions. The biggest number of transactions was made in District I – 219 transactions, then of District III – 206, and the smallest number in District II – 164 transactions. The biggest number of transactions was noted in the third quarter of the year in December (61 transactions) and September.
Source: authors’ study

**Fig. 6.** The distribution of apartment unit prices

**Fig. 7.** Number of sales in districts

Source: authors’ study
(57 transactions) and before the summer holiday in May (56 transactions). Large number of transactions in May and September is caused by the academic character of Krakow. High number of transactions in December reflects the customers’ fear of changes in the apartment market in the new calendar year.

The analysis of prices in the individual bounds of Śródmieście was depicted in the cartogram showing price differentiations for that administrative unit. A map is the most transparent form of presenting spatial data [Howes 1980, Longley and Batty 1997, Kelsey et al. 2012]. Figure 8, thanks to differentiation of colours, presents the spatial distribution of apartment unit prices. The map of prices was drawn in a way that average prices were determined in each of bounds and they were grouped into seven price ranges. Table 2 provides the details of the division into classes.

**Table 2. Division of bounds according to the price level**

<table>
<thead>
<tr>
<th>Class number</th>
<th>Number of bounds in each class</th>
<th>Price range [zloty · m⁻²]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>from</td>
</tr>
<tr>
<td>1</td>
<td>13</td>
<td>6136.00</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>7039.00</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>7942.00</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>8845.00</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>9748.00</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>10651.00</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>11554.00</td>
</tr>
</tbody>
</table>

Source: authors’ study

The cartogram shown in Figure 8 implies that the prices depend on the distance from the city centre. The longer the distance of a bounds from the Rynek Główny (the Main Market Square), the lower the average price of 1 m². All bounds of District III – Prądnik Czerwony, most remote from the city centre, belong to the first price class. In District II – Grzegórzki – prices belong to classes 1–3. In one bounds marked by the white colour no transaction was noted – it is the Botanic Garden area.

Location in the vicinity of the Vistula boulevards is an important factor. The Vistula boulevards do not only protect from flooding, but they also serve recreational functions. There are many walking alleys and bicycle paths there, which attract both the citizens and tourists. A regularity has been observed that the closer the boulevards the higher the prices of the apartments. This is confirmed by the prices in bounds 17, 12, 15, or 216. The apartment houses situated in these bounds do not differ from those situated in the neighbouring bounds 11 and 13, with regard to age or finishing standards; but there is a considerable price differentiation.

The highest prices are found in District I – Stare Miasto. It is mostly due to the apartments’ location in the centre of Kraków, the historical setting, and the beautiful,
historic apartment houses. The bounds located very close to the Wawel castle belong to the VII price class. The area surrounding Rynek Główny (the Main Market Square) belongs to the VI price class, despite its excellent location. It is due to very few transactions at very low prices for such location. In these cases poor technical condition of the buildings had a significant effect on the apartment prices.

Fig. 8. The cartogram showing unite price differentiations of apartments in Śródmieście

Legend:
- no transaction
- I class
- II class
- III class
- IV class
- V class
- VI class
- VII class

Source: authors’ study
4. Conclusions

The article focuses on using spatial econometrics for the analysis of apartment market. The goal of the project was to create the cartogram showing price differentiations of the apartments in the administrative unit of Śródmieście district of Kraków. Creating the cartogram was preceded by a thorough preparation of the database, from which 149 records were removed, resulting finally in the database of 589 transactions. The transactional data come from the notarial deeds drawn up in 2011. Then a statistical analysis was carried out, which was aimed at examining the prices levels of the apartments in Śródmieście. The analysis indicated that apartment market was stable in the analyzed period. The cartogram was created using the average transactional prices in the individual bounds of the analyzed administrative unit. The price range thus obtained was divided into 7 price classes, which correspond to 7 different cartogram colours.

The analysis of a spatial distribution of the prices indicated that the distance from the city centre, the neighbourhood, and the technical condition of the buildings have the biggest impact on the level of apartment prices.

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A STUDY OF REAL ESTATE MARKET IN KRAKÓW...

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WAYS OF IMPROVING THE ACCURACY OF DIGITAL AERIAL PHOTOGRAPHY BY THE RAILWAY TRANSPORT INVENTORY

Oleksandr Dorozhynskyy, Lubomyr Dychko

Summary

The development of railway sector around the world has always been a vital issue, as it plays important social, financial and economical role and influences the development of the country a lot. Because of constant growth and modernizing of the railway sector all processes and items of land and property fund have to be monitored. On the basis of the world experience, trends in the development of methods and technologies of area mapping it has been established that for the inventory of land and property fund objects cartographic material at 1 : 500 or 1 : 1000 scales suits the most. With the large amounts of work (for example area of mapping and number of railroad objects) it is reasonable to use digital aerial photography and technology of digital data processing, in particular methods of digital photogrammetry. In order to increase the accuracy of creating the cartographic component, the authors suggest, when choosing the parameters of aerial photography, taking into account spatial resolution of camera system, its geometrical properties, the influence of external factors and first of all the atmospheric refraction. It has been proved that by highly precise aerial photography the accuracy of fixation of angular elements of camera orientation with the help of Inertial Navigation Systems (INS) may be insufficient. Therefore it is recommended to thicken core network using block phototriangulation. This paper presents the description and results of experimental work, which helped to create cartographic material from digital images at 1 : 3000 scale with an accuracy of 4–5 cm, which fully meets the requirements for holding inventory, monitoring, maintenance, design and construction.

Keywords

railway • inventory • digital aerial camera • spatial resolution (GSD) • atmospheric refraction • phototriangulation

1. Introduction

Technical re-equipping of railway sector requires significant investments and well thought-out technical decisions. Such actions are of irreversible nature. In our opinion it is necessary to monitor lands and railroad objects, plan and design comprehensive measures concerning expansion of the industry.
Creation of cartographic materials, which include all constituent elements of monitoring, detailed project reports and operational tasks, is the basic part of such monitoring and inventory of land and objects.

In some works [Balcer 2010, Барладін et al. 2012] concerning regulatory framework and requirements for cartographic representation of objects it is recommended to create and use cartographic materials at scales from 1 : 500 to 1 : 25000. Choice of concrete value of cartographic material depends on its purpose and further usage [Заłącznik do zarządzenia N20/2010, Розенберг et al. 2007].

The highest requirements for minuteness and accuracy of mapping the objects concern plans at 1 : 500 scale. This is based on world experience and on reconstruction and modernisation practices of railways in Europe and Asia as well. In Ukraine such materials have to meet requirements for state land cadastre [Барладін 2012] and also for design, survey, construction and maintenance works. Detailed list of requirements can be found in regulatory documents [Державні будівельні норми 2008a, b].

It is also important to mention that the final product of mapping on the railway is topographical plan, which depicts:

- elements of a situation (objects), which are shown on area including drainage area within conventional boundaries, which are adjusted by executor and employer,
- terrain in the form of contour lines with inscriptions for altitude points, or in the form of digital terrain model (regular or irregular grid),
- all kinds of vegetation (woody, scrub, grass, cultivated, etc.),
- soils and microorganisms of the surface: wetlands, sands, salines, pebbly, clay, and rubbly surfaces and others,
- boundaries of administrative division, protected areas and reserves,
- boundaries of land use,
- schematic information concerning geographical names of the area (towns, railway stations, lakes, rivers, etc.).

The separate specific group is dedicated to data about railway objects, in particular:

- vertices of railway angles of rotation, pickets, signs and lines, pointers of kilometres,
- numerical values of curve elements (angles of rotation, radii etc.),
- utilities,
- stations, passing tracks, overtaking points, crossings, switchers, rail numbers.

This list is rather long as it depends on the elements on the railway in the given area.

In addition to the plan for railway areas with the existing (built) digital model of area (DMA), there can be built longitudinal and cross direction profiles that will meet the applicable requirements of railway services.

It is obvious that the requirements for accuracy of inventory and mapping documents for such an integrated approach are regulated by:

a) requirements for cadastral plans,

b) the requirements for the plans of railways.
For cadastral plans of town areas the recommended scales are 1:2000, 1:1000 and the scale 1:10000 for all others.

The recommended scales for the plans of the railway are 1:1000 and 1:500 as they need to display detailed information about all of the objects that are mentioned above and also to determine their coordinates with the required accuracy. Among the methods for creating cartographic components distant methods deserve special attention. Their effectiveness for large areas and for large number of objects by inventory is beyond competition.

2. Methods

2.1. General characteristics of effectiveness of digital aerial photography

A number of publications [Załącznik do zarządzenia N20/2010, Balcer 2010, Барладін 2012] and analysis of regulatory framework and requirements for cartographic representation of objects and lands of railway transport that have been carried out before, shows that reconstruction of railway transport is based on project documentation, which requires cartographic materials at scales from 1:500 to 1:25000. Choice of concrete scale value of cartographic material depends on its purpose and further usage.

After exploring the problems and world tendencies of solving separate problems there appeared a conclusion that digital aerial photography can supply cadastral, project and geoinformation work with high-quality and accurate data [Butowtt and Kaczyński 2003, Casella and Franzini 2005, Kurczynsky 2006, Kurzyński et al. 2012, Paszotta and Szumilo 2007, Дорожинський and Тукай 2008].

The effectiveness of aerial photography depends on correctly chosen and theoretically substantiated choice of aerial photography method, on the type of devices and on parameters of aerial photography. Among latter – the flight altitude for defining the altitude of objects’ points and the scale of photography in defining the horizontal location of objects are the most important. Taking into account the current state and tendencies of remote sensing development, aerial photography has been chosen by us as one of the most competitive methods in creation of large-scale maps and plans. Alongside with this all specific conditions of project and cadastral works, where railway functions, have to be taken into account.

Depending on the kind of works with reformation of railway transport there appear different requirements to horizontal and vertical location of objects on the cartographic material. The dominant value at cadastral works is horizontal location of borders of lands that belong to railway. Then altitudes of the points (digital terrain model) are necessary for creation of orthophotomaps or plans. However, for performing project works spatial models (3D models) are required. Moreover, the demands to accuracy of defining the coordinates may be rather high, mainly on the level that can be supplied with engineering geodesy methods.

Modern methods of remote sensing allow to create high quality cartographic materials that are suitable for solving different kinds of applied problems. With comprehensive assessment of input data and methods of processing for creation of cartographic
component the question is to meet the main demands that concern accuracy, adequacy (topicality) and economic feasibility. These three components allow to assess the effectiveness of distant methods.

As it has been pointed out, the expected accuracy of digital aerial photography for creation of cartographic component allows to create plans for railway at 1 : 500–1 : 1000 scales. However, a task to improve cartographying accuracy remains important. Its aim is to search for possible ways and methods of improvement of metric characteristics of digital images, taking into account the features of the object, i.e. railway transport.

2.2. Spatial pixel and its role in project designs

The important parameter for project calculations is δ-size of spatial pixel (GSD), which at first approximation can be calculated by [Butowtt and Kaczyński 2003, Kurczynsky 2006, Дорожинський and Тукай 2008]:

$$\delta = \frac{H}{F},$$  \hspace{1cm} (1)

where:

- \(H\) – flight altitude in cm,
- \(F\) – focal distance in pixels,

It is known that for digital cameras.

$$F = \frac{f}{\Delta},$$  \hspace{1cm} (2)

where:

- \(f\) – focal distance in mm,
- \(\Delta\) – size of pixel in matrix in \(\mu m\).

Taking into account technical parameters of photography systems, we get the sizes of spatial pixel GSD, given in Table 1, for three types of digital cameras at different altitudes of shooting.

**Table 1. Spatial pixel GSD for three cameras**

<table>
<thead>
<tr>
<th>Camera</th>
<th>(f) [mm]</th>
<th>Pixel [(\mu m)]</th>
<th>(F) [pixels]</th>
<th>GSD [cm] at (H) [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>300</td>
</tr>
<tr>
<td>ADS80</td>
<td>62.5</td>
<td>6.5</td>
<td>10000</td>
<td>3.1</td>
</tr>
<tr>
<td>DMCII 140</td>
<td>92</td>
<td>7.2</td>
<td>12800</td>
<td>2.3</td>
</tr>
<tr>
<td>DMCII 230</td>
<td>92</td>
<td>5.6</td>
<td>16400</td>
<td>1.8</td>
</tr>
<tr>
<td>DMCII 250</td>
<td>112</td>
<td>5.6</td>
<td>20000</td>
<td>1.5</td>
</tr>
<tr>
<td>UltraCam</td>
<td>210</td>
<td>5.2</td>
<td>40400</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>5.2</td>
<td>19200</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>5.2</td>
<td>15400</td>
<td>1.9</td>
</tr>
</tbody>
</table>
Ways of Improving the Accuracy of Digital Aerial Photography...

Data from Table 1 concern nadir pixel; on the edge of the picture physical pixel is projected at $\phi$ angle; so that spatial pixel increases. After simple transformations we get

$$(GSD) = (GSD)_N \frac{1}{\cos^2 \phi},$$

where:

- $\phi$ – angle between nadir and tilted beams,
- $(GSD)_N$ – size of spatial pixel in nadir.

For example, at the angle that is within the eyesight of the scanner across the flight direction $2\phi = 64^\circ$ increase of a pixel in comparison with nadir is equal to 1.4 times. For full-length cameras, indicated in Table 1, with taking into account the angle $2\phi$, we get the value $(GSD)$ at the edge (Table 2).

Table 2. Lateral spatial pixel for three cameras

<table>
<thead>
<tr>
<th>Camera</th>
<th>$2\phi$ [deg.]</th>
<th>GSD [cm] at the flight altitude H [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADS80</td>
<td>64</td>
<td>4.3 7.2 14.4 21.7 28.9 43.4</td>
</tr>
<tr>
<td>DMCII 140</td>
<td>50.7</td>
<td>2.8 4.8 8.8 14.4 19.2 28.8</td>
</tr>
<tr>
<td>DMCII 230</td>
<td>49.4</td>
<td>2.0 3.6 7.4 11.0 14.8 22.1</td>
</tr>
<tr>
<td>DMCII 250</td>
<td>46.6</td>
<td>1.6 2.7 5.4 8.1 10.8 16.2</td>
</tr>
<tr>
<td>UltraCam 210</td>
<td>28</td>
<td>0.7 1.3 2.6 3.9 5.3 7.8</td>
</tr>
<tr>
<td>UltraCam 100</td>
<td>28</td>
<td>1.7 2.7 5.5 8.3 11.0 16.5</td>
</tr>
<tr>
<td>UltraCam 80</td>
<td>33</td>
<td>2.7 4.5 9.2 13.8 18.5 27.7</td>
</tr>
</tbody>
</table>

The size of spatial pixel GSD is one of the factors which determine and influence the accuracy of photogrammetry works. Each process in the chain “picture – processing – result” makes its errors on obtaining spatial coordinates. The main processes are:

- photography: the quality of photography system, influence of the atmosphere (refraction),
- geodesic binding of the pictures: creation of the net of strong points (accuracy of identification of the points, accuracy of identification of coordinates),
- determining the spatial coordinates of the centre of projection from the (GPS) registration,
- determining the angular orientation of the photography system by INS,
- construction of aerial triangulation,
- construction of CIE, CMR, TSMPT.

That is why the total effect of these factors, on condition of equality, gives general average quadratic error of defining the coordinates in the plan:
\[ m_{x,y} = \sum_{i=1}^{n} m_{x,y}^i \]  
\[ m_z = \sum_{i=1}^{n} m_{z}^i \]

where:
- \( n \) – the amount of influential factors.

### 2.3 The quality of photography system

First of all the distortion of optical system is a source of errors meant [Sitek 1991]. The manufacturers claim that optical systems are without distortions, it means that distortion is not more than 1–3 microns. Special researches for digital cameras have not been carried out or published. Calibration parameters are determined mainly by a paper method with an accuracy of 1–3 microns for the main points and 3–5 microns for the focal distance. This concerns full-length metric cameras. Small-format or amateur cameras are not considered for high-accuracy mapping of the railways.

### 2.4. Outer factor – atmospheric refraction

Atmospheric refraction was an object for studies in the eighties of the twentieth century. The formulae for calculation the refraction effect for standard atmosphere were made up [Paszotta and Szumilo 2007, Куштин and Лысков 1984]. For digital aerial photography such calculations were not made. That is why we use the formula of Ashenbrener for calculation the refraction angle \( \lambda \):

\[ \lambda'' = 3.1d[1 - 0.035(3Ha - H)], \]  
\[ \delta r = \frac{f}{\cos \phi} \cdot \frac{\lambda''}{\rho}, \]

where:
- \( d \) – is the distance to the point on land from the camera (km),
- \( Ha \) – the altitude (km),
- \( H \) – the flight altitude (km).

The shift of the point on the image by refraction effect:

In Table 3 there are calculations of refractive effect that causes the increase of the size of spatial pixel for digital cameras of three types.
Table 3. Influence of the refraction on extreme pixels in the cameras of three types

<table>
<thead>
<tr>
<th>Camera</th>
<th>Pixel [µm]</th>
<th>Φ [deg.]</th>
<th>f [mm]</th>
<th>GSD, cm at the flight altitude H [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>300</td>
</tr>
<tr>
<td>ADS80</td>
<td>6.5</td>
<td>22</td>
<td>62.5</td>
<td>0.3</td>
</tr>
<tr>
<td>DMCII 140</td>
<td>7.2</td>
<td>25.3</td>
<td>92</td>
<td>0.5</td>
</tr>
<tr>
<td>DMCII 230</td>
<td>5.6</td>
<td>29.7</td>
<td>92</td>
<td>0.5</td>
</tr>
<tr>
<td>DMCII 250</td>
<td>5.6</td>
<td>23.3</td>
<td>112</td>
<td>0.6</td>
</tr>
<tr>
<td>UltraCam 210</td>
<td>5.2</td>
<td>14</td>
<td>210</td>
<td>1.0</td>
</tr>
<tr>
<td>UltraCam 100</td>
<td>5.2</td>
<td>14</td>
<td>100</td>
<td>0.5</td>
</tr>
<tr>
<td>UltraCam 80</td>
<td>5.2</td>
<td>33</td>
<td>80</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Analysis and comparison of received data indicates that images from the camera ADS80 throughout the range of elevation (300÷3000 m) do not undergo decetration larger than ½ pixel. For camera DMCII, focal lengths 230 and 250 mm, decetration exceeds the pixel size, and therefore the effect of refraction must be taken into account. For camera UltraCam altitude of 1500–3000 are already noticeable on the effect of refraction, and therefore such decentrations should be taken into consideration.

In particular, we note that the following recommendations can not be found in literature. Especially it concerns software.

2.5. Fixation of linear and angular elements of external orientation in flight

In the practice of aerial photography GPS data are used for the registration of the plane flight trajectory and linear objects of the centre of projection $X_S$, $Y_S$, $Z_S$. According to the research data, for example [Leberl and Gruber 2005, Kurczynsky 2006], the accuracy of such registration is within 10 cm. Inertial Navigation System INS fixes during the time of flight the acceleration across three axes and changes of angular orientation of the camera, i.e. angles $\alpha$, $\omega$, $\kappa$. If GPS and INS work constantly, then the trajectory of flight is fixed with an accuracy of 2–3 cm.

The drawback of INS is a systematic error (so-called drift) during long flight. However, GPS data allow to correct registered angles, which is one more positive factor of GPS usage. In its turn INS data are used to correct the trajectory, i.e. the GPS data, when the connection with the satellites is lost for a short time, perhaps during banked turn of a plane or other reasons.

That is why the important thing is the recommendation to use GPS+INS data during the photography of the area and railway objects.

Let us make the analysis of requirements for the registration of angular elements of external orientation.

Starting position is minimal size of photography system pixel $\Delta$.

From the centre of projection this angle is seen at the angle:
where:
\( f \) – focal distance of the system.

Taking into account the parameters of the camera, given in Table 2, we get angular resolution for the next cameras and their modifications.

- ADS80: \( \delta \phi = 20^\circ.8 \)
- DMCII(140): \( \delta \phi = 15^\circ.6 \)
- DMCII(230): \( \delta \phi = 15^\circ.6 \)
- DMCII(250): \( \delta \phi = 10^\circ.0 \)
- UltraCam (210): \( \delta \phi = 4^\circ.9 \)
- UltraCam (100): \( \delta \phi = 10^\circ.4 \)
- UltraCam (80): \( \delta \phi = 13^\circ.0 \)

Test researches of INS, conducted by different researchers [Casella and Franzini 2005] suggest that the real accuracy of INS angles registration is within 30\(^\circ\). Means that angular elements of external orientation, recorded in flight have insufficient accuracy. Therefore INS data can be used only with some restrictions, and the angles need to be defined more precisely. One of such approaches is the usage of aerial triangulation.

### 2.6. Experimental researches of photo triangulation constructions for railroad

It is known [Butowtt and Kaczynski 2003, Дорожинський and Тукай 2008, Куштін and Лысков 1984] that in comparison with route photo triangulation block photo triangulation gives better results. It is achieved because of additional photogrammetry conditions and because of self calibration of the images.

At the photo shooting of railway as a linear object it is more convenient to take picture in one way. That is why there appears a contradiction between factors – accuracy – economy, which requires research at the railway.

Such studies were conducted by us and their results are given below.

For experimental verification of photo triangulation accuracy as a component of the overall technological scheme of mapping the railway objects, the digital aerial photography materials made with UltraCam-D camera at 1 : 3000 scale on four areas of railroad and the data of field binding (in the arbitrary coordinate system) are used. Scheme of the road and placing of strong points (object number 1) are shown in Figure 1. Processing of digital images was performed by us at digital photogrammetric station and a network of photo triangulation covering the railroad with length of 21 km was built.

Methodology of measurements and calculations is the same as given in Дорожинський and Тукай [2008].

The assessment of accuracy was held with the help of 26 control points, coordinates of which are defined with an accuracy to 2 cm and with usage of forced centring of
geodesic equipment. At photogrammetric calculations each strong point has undergone several sightings (3–4 times). Arithmetical mean has been taken as the last value.

![Fig. 1. Scheme of aerial photography and field binding for the area of the railroad (object no. 1)](image)

Data from assessment of photogrammetry construction accuracy are given in the Table 4.

**Table 4. Data from assessment of photogrammetry construction accuracy**

<table>
<thead>
<tr>
<th>No. section</th>
<th>No. point</th>
<th>Absolute values of errors at control points [cm]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>δx</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>5.0</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>4.0</td>
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<td>3</td>
<td>13</td>
<td>3.0</td>
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<td></td>
<td>14</td>
<td>6.0</td>
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<td>2.0</td>
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<td></td>
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<td>5.0</td>
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<td></td>
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<td>5.0</td>
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<td></td>
<td>18</td>
<td>4.0</td>
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<tr>
<td>4</td>
<td>19</td>
<td>6.0</td>
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<tr>
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<td>20</td>
<td>6.0</td>
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<tr>
<td></td>
<td>21</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>4.0</td>
</tr>
</tbody>
</table>
\( m_x = 4.4 \text{ cm}, \, m_y = 4.4 \text{ cm}, \, m_z = 5.0 \text{ cm} \)

\( \delta_x = 0.9 \text{ cm}, \, \delta_y = 0.9 \text{ cm}, \, \delta_z = 1.0 \text{ cm} \)

The obtained average quadratic errors \( m_x, \, m_y, \, m_z \) and their confidence intervals \( \sigma_x, \, \sigma_y, \, \sigma_z \) coordinate with project values very well.

Another object number 2 is the track with the small angles of rotation with length of 12 km. It is taken with one aerial photography route at 1 : 3000 scale. Strong points have been situated in pairs in 600 m (Figure 2).

![Fig. 2. Scheme of strong points, object number 2](image)

Construction of the phototriangulation network has been conducted with two different options. In the first option the network was built separately in each of the sections 1, 2, 3. In the second option network was built simultaneously for three sections. For the assessment of accuracy in each sections there were 7, 8, 10 strong points respectively. The calculated average quadratic errors are given in the Table 5.

<table>
<thead>
<tr>
<th>Section 1</th>
<th>Section 2</th>
<th>Section 3</th>
<th>Object no. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( m_x )</td>
<td>5.0</td>
<td>4.8</td>
<td>5.2</td>
</tr>
<tr>
<td>( m_y )</td>
<td>4.3</td>
<td>4.6</td>
<td>5.0</td>
</tr>
<tr>
<td>( m_z )</td>
<td>5.5</td>
<td>6.0</td>
<td>5.8</td>
</tr>
</tbody>
</table>

These results suggest that in the case of one route phototriangulation the better results are on short sections rather than on all of the sections, i.e. for the whole area.

The next experiment dealt with processing of two parallel routes of photo shooting that covered the railroad and created phototriangulation unit (Figure 3).
The length of the road is 14 km, and there are 16 strong points on the area. 14 strong points are situated uniformly across the axis of the road. Block phototriangulation has been built without self calibration.

The results are:

\[ m_x = 4.4 \text{ cm}, \quad m_y = 4.2 \text{ cm}, \quad m_z = 4.4 \text{ cm} \]

As objects number 1 and 3 are identical in length, even object number 3 is longer at 2 km, then a comparative analysis and a conclusion can be made. The conclusion is: block phototriangulation gives better results of defining the horizontal coordinates ca in 1.3 times and in altitude in ca1.4 times. At the same time road number 3 is longer than the road number 2. The number of strong points has been 16 and 80. Therefore two route aerial photography and block triangulation deserve absolute preference.

3. Conclusions

1. It has been proved that the main source of information for cartographic supply for inventory of land and property fund is a digital picture.

2. To increase the accuracy of photogrammetry works it is necessary to take into account the effect of atmospheric refraction under condition of shooting from the altitude of 1500–3000 m. In modern software absent modules for consideration of refraction effect are supplied. Therefore in the software it is necessary to provide modules for calculation the atmospheric refraction effect.

3. It has been established that the accuracy of angular elements registration at the railroad with the help of INS is insufficient. Since GPS/INS systems in the majority of cases do not fix elements of external orientation with sufficient accuracy then it is necessary to use phototriangulation, better with self-calibration.

4. The performed works that concern thickening of supporting network have shown high accuracy of photogrammetry thickening (with an accuracy of 4–5 cm). In the future such materials will allow to create orthophotoplans and other final products for projecting and planning the reconstruction of the railroad.
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ASSESSMENT OF LAND FRAGMENTATION FOR THE PURPOSE OF LAND CONSOLIDATION WORKS AS EXEMPLARY BY THE PASYM COMMUNE

Małgorzata Dudzińska, Katarzyna Kocur-Bera

Summary
In Poland there are no uniform regulations and legal norms establishing the principles of space assessment aimed at determining the demand for land consolidation works. The article is an attempt to answer the following question: what factors are important today in determining the demand for this kind of works?
The factors were set on the basis of professional literature and on a questionnaire conducted on a group of specialists in land consolidation and on farmers. The aim of the questionnaire was to examine the preferences of chosen land fragmentation factors. The survey was carried out in the Pasym commune, situated in the Warmia and Mazury Voivodeship.
The results of the research show that the land fragmentation mostly depends on the number of land plots (parcels) in a farm, their distance to a settlement and the size of a land plot. The least significant factors in this respect proved: a size of a farm and its irregular shape. The research has confirmed a general tendency in spatial changes of small farms in the Warmia and Mazury Voivodeship.

Keywords
land consolidation • land fragmentation • land plot • farm

1. Introduction
Many researchers indicate areas where consolidation procedures should be carried out. Their recommendations are aimed at improving agricultural production environment in a village. This environment is confronted with many problems, such as: high land fragmentation (patchwork of fields), unfavourable land layout of farms, maladjustment of spatial parameters of land plots to a current mechanized cultivation, landscape impoverishment (disappearance of such elements as: between-fields afforestation, forests, water holes, beauty spots), deficient transport network of access roads to rural areas and forests (not adjusted to the use of modern agricultural machinery), in many cases lack of road access to rural areas resulting from a high land fragmentation, unregulated water relations and lack of important land reclamation structures, fallowing of
lands or arable areas that are not used for what they were intended, existence of lands belonging to land communities, which in fact means that they are now “no-man’s” lands [Błaż et al. 2010]. In Poland there are no uniform regulations and legal norms establishing the principles of space assessment aimed at determining the advisability of land consolidation works. In a document containing directives on preparation of guidelines for land consolidation project [Wytyczne do opracowania... 2011] the basic factors considered in determining the demand for such works in Lower Silesian Voivodeship have been established. These factors are: analysis of a state of land ownership, a level of interest in consolidation works among land owners, a level of interest in arrangement and investment works that accompany a land consolidation process. Additional factors that decide the order of consolidation works are: unfavourable land patchwork, occurrence of high class of soils, relatively high mean size of a farm, extended land patchwork between villages, linear investments disruptive to agricultural production and a possibility of a farm enlargement thanks to consolidation.

2. Objectives and methods

The article is an attempt to answer the question as to what factors (parameters) are important today in determining the demand for land consolidation works, as exemplified by the Pasym commune.

Presentation of essential factors and description of demand for consolidation works was preceded by three research tasks that were logically interrelated. The research tasks were completed in the following stages:

1. Finding current land fragmentation factors used in determining the demand for consolidation works.
2. The choice of authors’ factors for assessing land fragmentation in a selected area.
3. A case study – determining the demand for consolidation works in the Pasym commune.

Qualitative methods, in particular analytical, logical topology and identification methods were used in the above research tasks [Dawidowicz 2012]. The deployed methods support a comprehensive approach to the analysed problem and the formulation of optimal solutions. Other research methods involved comparative analysis as well as analyses of literature, documents and legal regulations related to the discussed issues [Dudzińska 2011].

3. Finding current land fragmentation factors used in determining the demand for consolidation works

Land fragmentation, alternatively named by Bentley as pulverization, parcellization or scattering [Bentley 1987], is defined as a situation where a farm possesses several non-contiguous land plots (parcels), often scattered over a wide area. It is an observed phenomenon in many countries around the world, and is generally viewed as an obsta-
According to findings of King and Burton [1982] land fragmentation is associated with six factors:

- the landholding size,
- the number of parcels belonging to the holding,
- the size of each parcel,
- the shape of each parcel,
- the spatial distribution of parcels,
- the size distribution of the parcels.

Simmons [1964] suggested an index of land fragmentation that takes into account the number of parcels in a farm and a relative size of each parcel. He calculated the index by devising the following formula:

\[
FI = \frac{\sum_{i=1}^{n} a_i^2}{A^2},
\]

where:
- \(FI\) – fragmentation index,
- \(n\) – number of parcels in a farm,
- \(a\) – size of a parcel,
- \(A\) – total size of a farm.

If \(FI\) equals 1, it means that a farm consists of only one parcel, if the value is close to 0, it indicates higher degree of fragmentation.

Dovrin [1965] assumed that a fragmentation is defined by a distance that a farmer has to cover to get to each of his parcel and to get back to his farmstead after each visit to a parcel. This method however does not take into account the number of real annual number of his visits to his parcels nor a situation when each parcel can be visited without the necessity of going back to a farmstead.

Januszewski [1968] devised a similar index to the one used by Simmons, by combining the number of parcels in a farm with their spatial layout and he obtained a coefficient \(K\):

\[
K = \frac{\sqrt{\sum_{i=1}^{n} d_i}}{\sum_{i=1}^{n} \sqrt{a_i}},
\]

where:
- \(n\) – number of parcels,
- \(a\) – size of parcels.

The value of \(K\) stays between 0 and 1. The value of \(K\) index closer to 0 means a high degree of fragmentation. The index has three main characteristics: the degree of fragmentation increases proportionally with the number of parcels; fragmentation...
increases when the range of parcel sizes is small and fragmentation decreases as the area of large parcels increases and that of small parcels decreases.

Igbozurike [1974] proposed an equation based on a mean size of parcels and a distance covered by a farmer on each consecutive trip to all his parcels (in one journey to and from all his parcels). The equation is as follows:

\[ P_i = \frac{S_i}{S} \cdot \frac{D_t}{100}, \]

where:
- \( P_i \) – index of land fragmentation for of \( S_i \) of each parcel,
- \( D_t \) – total distance to and from all parcels.

According to King and Burton [1982] this method does not determine explicitly the distances nor it takes into account the number of parcels. They gave an example of a farm consisting of two parcels of size \( S \), located 10 km from each other, which would give an index \( P_i \) twice as high as a farm consisting of ten parcels of size \( S \) located 1 km from each other.

Schmook [1976] defined a fragmentation index as a ratio of surface area of a polygon surrounding all the farm parcels to a surface area of a farm itself. An index value is always higher than 1. The higher the value, the higher the degree of fragmentation. Schmook also suggested other fragmentation quotient obtained as a ratio of mean distance to parcels to their mean size.

Gaśiorowski [2014] defined fragmentation in selected Polish communes by taking into account such factors as: the size of a parcel, index of parcel’s shape, a number of border points of a parcel (it shows the degree of border’s complexity or irregularity of its shape), a distance of a parcel’s centroid to a farm’s centre (it is defined as a complex of residential and utility buildings, and distance is not measured in a straight but in the shortest line), a percentage share of agricultural lands in a total size of a parcel, a percentage share of a parcel in a total size of a farm.

Gawroński [2005] included four variables describing the demand for land consolidation and exchange works. The variables are: \( x_1 \) – fragmentation of an area structure of single farms, \( x_2 \) – mean number of recorded parcels that make one farm, \( x_3 \) – mean size of a single farm, and \( x_4 \) – share of lands belonging to Agricultural Property Agency in a size of agricultural lands of studied territorial units.

Similar fragmentation factors were used by Van Hung et al. [2007]. They defined two main measures of fragmentation: the number of plots per farm and a measure, based on Simpson’s diversification index, which considers the number of plots, plot size and farm size. Blarel et al. [1992] have also used these two indicators to measure land fragmentation in Ghana and Rwanda.

Demetriou [2012] developed a method called LandFragmentS, which can include all recorded and essential measures of land fragmentation. The method is flexible,
because a user can choose which measures should be included in a specific project. In this method a weight is ascribed to each measure, which reflects its importance for the whole project. LandFragmentS compares a current state of land fragmentation to its state in ideal conditions, which in most cases is purely theoretical. Moreover, the method takes into account a ratio of current land fragmentation to its worst possible state. First a planner chooses the measures that influence fragmentation and which will be included in a model, and then he ascribes to each of them an appropriate weight. In the next stage he calculates the quantity of these factors.

In Table 1 each line represents a farm or a land plot (parcel), and each column a land fragmentation factor. The results are then standardized (if necessary), by appropriate methods (e.g. by means of a value function), to create a standardized table of land fragmentation. Land fragmentation index ($LF_i$) is calculated by multiplying standardized value of each factor ($f_{ij}$) by appropriate weight of each factor ($w_j$) and then summing up the value of each line or farm in the following way:

$$LF_i = \sum_{j=1}^{m} f_{ij} w_j$$

Table 1. Land fragmentation factors in relation to each farm, according to LandFragmentS method

<table>
<thead>
<tr>
<th>Ownership ID of ownership</th>
<th>Land fragmentation factors (weights)</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$F_1 (w_1)$</td>
<td>$F_2 (w_2)$</td>
</tr>
<tr>
<td>1</td>
<td>$f_{11}$</td>
<td>$f_{12}$</td>
</tr>
<tr>
<td>2</td>
<td>$f_{21}$</td>
<td>$f_{22}$</td>
</tr>
<tr>
<td>…</td>
<td>…</td>
<td>…</td>
</tr>
<tr>
<td>n</td>
<td>$f_{n1}$</td>
<td>$f_{n2}$</td>
</tr>
<tr>
<td>GLFI</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Demetriou 2012

A farm will have a value between 0 (full fragmentation or the worst efficiency of a system) and 1 (no fragmentation or the highest efficiency of a system). General land fragmentation index (GLFI) for a whole research site is calculated as a mean of $LF_i$:

$$GLFI = \frac{\sum_{i=1}^{n} LFI_i}{n}$$

The presented method is flexible and in all conditions it represents characteristic factors for local determinants of a researched area.
4. Authors’ study

4.1. The choice of factors for assessing land fragmentation in a selected area

From the analysis of professional literature a conclusion can be drawn that factors taken into consideration in estimating land fragmentation are often related to a spatial specificity of an analysed area (e.g. mountain areas), to a possibility of acquiring certain data and to an accessible technology of analyses. Usually the researchers take into account an outcome of three factors influencing the land fragmentation degree in farms (number of land plots, size of each land plot and size of a whole farm).

In an era of modern technologies used for estimation of land fragmentation the researchers take into consideration an increasing number of factors, e.g. Demetriou [2012] and Gąsiorowski [2014] additionally include, among other things, shape of land plots or a road access to a land plot.

In his method LandFragmentS Demetriou [2012] introduces yet another feature: an element of a free choice of factors that are important in estimating the demand for land consolidation works, and besides he determines weight and importance of each factor.

4.2. Authors’ choice of factors

For the purpose of this article a research was carried out to determine new factors that would enable accurate assessment of land fragmentation. The kind of factor and weight indexes for each factor were determined based on a questionnaire sent to a group of specialists in land consolidation and to farmers. The aim of the questionnaire was to examine the preferences of chosen patchwork parameters (land fragmentation).

The values of weights were established based on the obtained results to indicate factors influencing the patchwork index (land fragmentation index) and to determine a degree of their influence. The questionnaire was designed to allow the respondents to compare all fragmentation factors presented in lines of a table with the same factors presented in columns. If a feature in a line proved to be more important than a feature in a column, then 1 should be put down. Otherwise a respondent was asked to write 0.

The research was carried out in the Pasym commune, in the Warmia and Mazury Voivodeship. As a result of it a percentage value of each factor influencing the degree of land fragmentation factor was calculated (Table 2). The factors are presented in Table 3.
### Table 2. Table model used in the presented questionnaire

<table>
<thead>
<tr>
<th></th>
<th>Size of a farm</th>
<th>Number of land plots in a farm</th>
<th>Distance of a farm's land plots to a settlement</th>
<th>Land layout index</th>
<th>Size of a land plot</th>
<th>Elongation of a land plot</th>
<th>Irregular shape of a land plot</th>
<th>Access of a land plot to a road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of a farm</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of land plots in a farm</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance of a farm's land plots to a settlement</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land layout index</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of a land plot</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elongation of a land plot</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irregular shape of a land plot</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access of a land plot to a road</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: authors’ study
Table 3. Assessing weight of particular factors

<table>
<thead>
<tr>
<th>Factor's name</th>
<th>Mean assessment [Oᵢ]</th>
<th>Weight [Wᵢ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of a farm</td>
<td>8</td>
<td>9.5%</td>
</tr>
<tr>
<td>Number of land plots in a farm</td>
<td>13</td>
<td>15.5%</td>
</tr>
<tr>
<td>Distance of farm's land plots to a settlement</td>
<td>12</td>
<td>14.3%</td>
</tr>
<tr>
<td>Land layout index</td>
<td>11</td>
<td>13.1%</td>
</tr>
<tr>
<td>Size of a farm</td>
<td>12</td>
<td>14.3%</td>
</tr>
<tr>
<td>Elongation of a land plot</td>
<td>10</td>
<td>11.9%</td>
</tr>
<tr>
<td>Irregular shape of a land plot</td>
<td>8</td>
<td>9.5%</td>
</tr>
<tr>
<td>Access of a land plot to a road</td>
<td>10</td>
<td>11.9%</td>
</tr>
<tr>
<td>Total</td>
<td>84</td>
<td>100%</td>
</tr>
</tbody>
</table>

Source: authors’ study

4.3. Case study – assessing the demand for land consolidation works in the Pasym commune

The commune covers an area of 149.4 km², 46% of which are arable lands, 31% – forests, and 11% is under water. The commune has a population of 5156 inhabitants, which means that its population density is 34.5 person per km². The analysed area covers in total 31.07 km², which for the purpose of the study was divided in the six following precincts: 1 – north, 2 – north-east, 3 – east, 4 – south-east, 5 – south, 6 – west. The boundaries of the precinct are shown in Figure 1. In the north precinct there are 531 land plots of a size from 0.10 ha to 45 ha. The mean size of a land plot in this area is 2.2530 ha and the configuration of land plots there has an irregular patchwork type.

The north-east precinct includes 682 land plots of size from 0.10 ha to 35 ha. The mean size of a land plot in this area is 1.1518 ha. Configuration of land plots suggests an irregular patchwork type. There is 1287 land plots in the area of mean size 1.0263 ha, but a size of the biggest land plot does not exceed 45 ha. The south-east precinct covers 223 land plots. The size of land plots stays within the range from 10 ares to 19 ha. The mean size of a land plot in the area is 2.2953 ha. The south precinct covers 548 land plots of a mean size of 3.8773 ha and none of them is bigger than 15 ha. The west precinct includes 1704 land plots of a mean size of 0.7529 ha. The biggest land plot in the area is of 27 ha.

The elongation of an agriculture land plot, that is a ratio of its length to its width, has much influence on a land plot’s shape. The elongation can be calculated by a formula (6) that requires value of a factor and a surface area. To derive the formula presented below, a square was used as a basic figure, the elongation of which (marked as w) equals 1. In addition, this factor is judged visually [Litwin and Szewczyk 2012].

\[
W = \frac{O + \sqrt{O^2 - 16P}}{O - \sqrt{O^2 - 16P}},
\]

where:
- \(O\) – perimeter of a land plot,
- \(P\) – surface area of a land plot.

Source: Waluk 2013

**Fig. 1.** The division of the Pasym commune into studied precincts

The land plot that have a favourable shape are characterized by longer parallel sides and angles that are close to 90°. Preferably a border line should be as short as possible and least varied and meet all the previous requirements. The examples of favourable shapes of land plots are shown in Figure 2.

Source: author’s study

**Fig. 2.** Examples of favourable shapes of land plots
**Table 4.** Assessment of a degree of land fragmentation in the Pasym commune

<table>
<thead>
<tr>
<th>Factor’s name</th>
<th>Number of land plots and their point value in the adopted scale</th>
<th>Total</th>
<th>Fragmentation degree value</th>
<th>Fragmentation degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Very favourable – 1 point</td>
<td>Favourable – 2 points</td>
<td>Satisfactory – 3 points</td>
<td>Unfavourable – 4 points</td>
</tr>
<tr>
<td></td>
<td>Number of land plots</td>
<td>Point value</td>
<td>Number of land plots</td>
<td>Point value</td>
</tr>
<tr>
<td>Size of a land plot</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North precinct</td>
<td>54</td>
<td>54</td>
<td>3.7</td>
<td>170</td>
</tr>
<tr>
<td>North-east precinct</td>
<td>36</td>
<td>36</td>
<td>61</td>
<td>122</td>
</tr>
<tr>
<td>East precinct</td>
<td>61</td>
<td>61</td>
<td>113</td>
<td>226</td>
</tr>
<tr>
<td>south-east precinct</td>
<td>30</td>
<td>30</td>
<td>45</td>
<td>90</td>
</tr>
<tr>
<td>South precinct</td>
<td>65</td>
<td>65</td>
<td>94</td>
<td>188</td>
</tr>
<tr>
<td>West precinct</td>
<td>62</td>
<td>62</td>
<td>112</td>
<td>224</td>
</tr>
<tr>
<td>Elongation index</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North precinct</td>
<td>225</td>
<td>225</td>
<td>3.2</td>
<td>350</td>
</tr>
<tr>
<td>North-east precinct</td>
<td>398</td>
<td>36</td>
<td>177</td>
<td>354</td>
</tr>
<tr>
<td>East precinct</td>
<td>707</td>
<td>707</td>
<td>382</td>
<td>764</td>
</tr>
<tr>
<td>South-east precinct</td>
<td>83</td>
<td>83</td>
<td>85</td>
<td>170</td>
</tr>
<tr>
<td>South precinct</td>
<td>190</td>
<td>190</td>
<td>235</td>
<td>470</td>
</tr>
<tr>
<td>West precinct</td>
<td>907</td>
<td>907</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>% of land plots in the irregular shape</td>
<td>North precinct</td>
<td>221</td>
<td>221</td>
<td>2.6</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>---------------</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>North-east precinct</td>
<td>454</td>
<td>454</td>
<td>93</td>
<td>186</td>
</tr>
<tr>
<td>East region</td>
<td>892</td>
<td>892</td>
<td>179</td>
<td>358</td>
</tr>
<tr>
<td>South-east precinct</td>
<td>91</td>
<td>91</td>
<td>61</td>
<td>122</td>
</tr>
<tr>
<td>South precinct</td>
<td>196</td>
<td>196</td>
<td>177</td>
<td>354</td>
</tr>
<tr>
<td>West precinct</td>
<td>911</td>
<td>911</td>
<td>291</td>
<td>582</td>
</tr>
<tr>
<td>% of land plots without road access</td>
<td>North region</td>
<td>499</td>
<td>499</td>
<td>1.2</td>
</tr>
<tr>
<td>North-east precinct</td>
<td>655</td>
<td>655</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>East</td>
<td>1234</td>
<td>1234</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>South-east precinct</td>
<td>202</td>
<td>202</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>South precinct</td>
<td>530</td>
<td>530</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>West precinct</td>
<td>1634</td>
<td>1634</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Total</td>
<td>North precinct</td>
<td>999</td>
<td>999</td>
<td>335</td>
</tr>
<tr>
<td>North-east precinct</td>
<td>1181</td>
<td>1181</td>
<td>331</td>
<td>662</td>
</tr>
<tr>
<td>East</td>
<td>2984</td>
<td>2894</td>
<td>674</td>
<td>1348</td>
</tr>
<tr>
<td>South-east precinct</td>
<td>406</td>
<td>406</td>
<td>191</td>
<td>382</td>
</tr>
<tr>
<td>South precinct</td>
<td>981</td>
<td>981</td>
<td>506</td>
<td>1012</td>
</tr>
<tr>
<td>West precinct</td>
<td>3514</td>
<td>3514</td>
<td>903</td>
<td>1806</td>
</tr>
</tbody>
</table>

Source: Waluk 2013
The above spatial elements of agriculture lands were confronted with weights obtained from the questionnaire, were classified into five-point scale and presented in a table. The results of calculations of spatial and technical factors of land plots were divided into quality classes, according to the scale: very favourable state – 1 point, favourable state – 2 points, satisfactory state – 3 points, unfavourable state – 4 points, very unfavourable state – 5 points.

Numbers in Table 4 show that mean size of land plots in the north precinct of the Pasym commune is unfavourable, while the elongation index and shape of land plots are satisfactory. There is also a very favourable number of land plots without road access. On the other hand the north-east precinct of a commune has an unfavourable degree of a feature called “the size of a land plot”, the elongation index however as well as the shape and number of land plots without road access are very favourable or favourable.

In the west precinct of the commune there are very few land plots without an independent access to a road, which was regarded as a very favourable feature. As favourable were judged such features as: an elongation index and shape of land plots. The mean size of land plots is unfavourable in this precinct.

In the south precinct of the studied area the mean size of a land plot was a feature regarded as only satisfactory, and the best marks were given to the share of land plots without road. The west precinct of the commune is characterized by the unfavourable mean size of land plots and by very favourable number of plots without road access. The remaining features are satisfactory.

5. Conlusions

The main objective of the article was to define a set of factors important in the assessment of land fragmentation. The goal was achieved by the questionnaire survey distributed among farmers living in studied area and specialists in land consolidation. Thanks to it a hierarchy of geometric and technical factors has been established that are taken into account in the assessment of demand for land consolidation works. The results of the study show that the land fragmentation mostly depends on the number of land plots (parcels) in a farm, their distance to a settlement and on the size of a land plot. The land fragmentation is least influenced by such factors as: the size of a farm and an irregular shape of a land plot. The research has confirmed the general tendency in spatial changes taking place in small farms in the Warmia and Mazury Voivedship.

References


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THE SIGNIFICANCE OF THE POLISH ARCHITECTURAL HERITAGE IN ATTRACTIVENESS OF TOWNS IN LVIV REGION

Oleksandra Dyda

Summary

It is very typical for a modern city and especially a smaller town to become a spot of a particular tourist attraction due to its economic and cultural factors. This applies to towns of Lviv regions in Ukraine, owing to historic reasons as well as to the specific geographic location, their culture and architecture acquired special features. The Polish state contributed much to the distinctive character of their town dimension. The architectural buildings and monuments constructed between the fourteenth and nineteenth centuries are the important elements of the town dimensions of Lviv region. These elements play the vital role in the formation of town architectural attractiveness.

Keywords

architectural attractiveness • town dimensions • town • architectural heritage

1. Introduction

The architectural dimension is the integral part of tourism. The architecture of a town should attract tourists and pilgrims. Many researchers of different fields study the question of city and town attractiveness. The research activity dwells on the problems of uniqueness and local architectural tradition preservation. A. Wojtowicz-Wrobel states: “The modern uncontrollable transformation of the town texture of cities and towns is one of the reasons why their uniqueness has been extinguished” [Wojtowicz-Wróbel 2009].

The above mentioned research activity is motivated by the question of regional architectural tradition preservation. Several critical remarks are made to the modern architecture. The architectural dimension may be interesting for a man due to various aspects: comfortable planning, functionality, historic value, identity. The statement is confirmed by the studies dedicated to the problem of the town image. The scholar activity of prof. Bohdan Cherkes [2008] is dedicated to the identity in the architecture. G. Curdes [1997] partially analyses the issue of uniqueness and exclusivity of architec-
tural dimension. He recalls the notion of *genius loci* (the spirit of the place). The works of I. Fomin [2002] focus on the aspect of the town dimension aesthetics. However the ability of the architectural dimension as the cluster of the objects that is supposed to attract the attention by its outer appearance and inner essence is not studied enough. We recommend to use the term “architectural attractiveness” (from Latin *attraho* “to attract”) to define such an ability of architectural objects.

2. Research object characteristics

The object of the presented research is the architectural dimension of the towns of Lviv region. A particular attention is paid to the role of Polish architectural heritage in town attractiveness formation.

3. Research methods

The historic, bibliographic and card-data sources have become the basis of our research. The analysis of the modern planning schemes of the towns was made. The real life examination was conducted as well as photo applications were analyzed.

The body of the research

The architectural attractiveness of the object or dimension may be both essential and visual. Essential attractiveness is formed by some characteristic features of the object or dimension connected with the history of the location, with the objects situated there, with the events which took place in the past and are taking place in the present. A typical buildings marked by the events or famous personalities who lived there may carry essential attractiveness. Visual architectural attractiveness is created by means of form, colours, the dimensional location of the architectural object, without taking into consideration its meaning in the town dimension. Visual attractiveness acts on the level of instincts. It does not need to inform the spectator in advance.

The territory of Lviv region is interesting for its density in the location of its towns. It takes the first place in Ukraine for the quantity of the towns (up to 50 thousand of the inhabitants).

It creates a competition between the towns in the way of attracting visitors and tourists, especially in the tourism and recreation brunch highly developed in this region.

The territory of Lviv region is deeply rooted into the complicated history. Many peoples with their cultures contributed to the town dimension architectural formation. Lviv land was finally conquered by Polish Kingdom in 1349 [Istoriya L’vova 2006]. Since that time and up to the twentieth century it was under the influence of Poland. Polish architectural impact has become an integral part of urban landscape of the towns of this region. Two opposite directions have the tremendous influence on the appearance of the towns: regulative one was the result of the Polish cultural influences and traditions, and non-regulative one was connected with the natural situation of the

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places [Dyda 2009]. The interconnection of these two concepts is more noticeable in towns, because of the several factors:

a) the lack of finance for building purposes and building reconstruction,
b) the lack of ideological motivation to promote total changes of urban dimension,
c) the border status of many towns of Lviv region during the times of the Soviet Union has isolated them and preserved their architectural dimension,
d) rather chaotic development of the towns after the collapse of the Soviet Union; it happened without active participation of the professional architects.

In some cases the principles of new buildings at the territory return to the old local traditions of non-regularity, stressing the mixed character of architectural landscape “East–West”.

There are 73 towns in the Lviv region. The region has old traditions of wide autonomy in city governing. It is known that 38 towns were given a status of Magdeburg Law. Some of them later received status of town cultural centers in spite of their unsatisfactory local economy. Such a tradition was almost lost at the territories that found themselves under the influence of Russian empire. Near 78% of regional Lviv towns were founded in the period between the fourteenth and the nineteenth centuries. In the majority of them estate way of housing system prevails. Most of the buildings are located along non-regular planned streets, giving them rather rustically oriented character. At the central part the housing system creates the city architectural image – multi storey stone buildings, town hall, Roman Catholic church and so on. Sometimes the difference between the central part and the outskirts is very sharp and the view of town dimension differs at the length of some meters (Figure 1).

The results of photo fixing analysis show that the churches dominate (as a rule they are Orthodox, Greek-Catholic and the Polish Roman Catholic churches).
This two types of buildings make a contrast to their architectural surrounding in different ways in terms of size, proportions, and characteristic forms. The churches have their domes ended with the round and static shape. Polish Roman Catholic churches create more dynamic bias to vertical silhouette. At the modern stage the dimension of the towns is non regular and unpredictable. In order to preserve the image of the town, the role of historic house building is extremely important. The architectural impact of Polish architectural heritage influenced much the formation of essential, visual attractiveness of the small towns dimension of Lviv region.

The content attractiveness of the architecture of the period between the fourteenth and nineteenth centuries is shown the following way:

1. At the urban level. The systematic itinerary of planned streets and the location of key objects in the town. The traces of Magdeburg Law town planning of the central part may be found in near 40% of the regional towns. As prof. H. Petryshyn puts it “The right-angled public square with the town hall in the middle and the city blocks housing surrounded is a distinctive feature of the planning of town settlement” [Petryshyn 2006]. In the 15% of the towns these squares still functions as main town's square. The initial structure of town's planning is the frequent object research and a unique carrier of information on historic development of the town. G. Curdes indicates: “The networks, originally created once (...) in fact are finally stable. The society may change something in the core features of the network structures in case of specific circumstances of mentioned above financial recourses mentioned above” [Curdes 1997]. Urban level includes the schemes of architectural objects location as well as civil and administrative objects in particular. The way of their location demonstrates the importance of the house building for the city.

2. On the level of separate architectural objects. Their content may become a single source of attractiveness or may be added by some interesting architectural form. Sacral and administrative buildings, defensive objects and residences, sometimes even civil buildings have content meaning. Sacral buildings identify cultural priorities of the society, its spiritual values. Up to the twentieth century the national identity was defined in accordance with the practiced religion. That is why the location of the sacral objects and their dimensional decision is connected with the practicing religion – an outstanding feature of civil identity. The number and types of sacral objects show the status of the town in the region throughout the history, as well as its financial recourses, the coexistence of different nationalities at the town's area, their number and social status.

The administrative buildings, as a rule, are represented by town halls. Their towers mark the location of the town centre as well as the town status of its inhabitants. The defensive objects and residents have a rich content bias because they are connected with the famous historic personalities and events. They serve as specific markers, first of all because they show the traces of trade routes and the lines of the state borders. O. Matsiuk indicates: “Taking into consideration the fact that many towns and small towns were located at the crossroads of Tatar hordes movement as well as other conquerors, their inhabiting and trade development was only possible
if they were defended by huge stone walls of castles and other defensive buildings” [Macyuk 1997].
The residences may be the chief attractant both for the outskirts of one town and the whole region. The local castles influence the attractiveness tremendously. It is the attraction of particular interest in Ukraine. The reconstructions of such objects, “barbarian” from the professional point of view, have sometimes unexpected effect. In Komarno, for example, the stadium is located in the middle of the ramparts that remain as a part of renaissance castle. The inner side of ground fortifications works as tribunes for spectators. This is the sample of occasional architectural attractiveness. Today, the educational, administrative and clinical institutions are located in many of historic residences. It develops their content attractiveness.
The preserved civil housing, as a rule, originates from the twentieth century. It demonstrates the age of the town, its old status, secures the location of the town centre.

3. The small architectural forms, the elements of town design. These are necropolis in particular. They are the important carriers of information about the history of the towns. Many of them originate from the Polish period. When the territories of the towns expend – these objects found themselves almost in the center of the town. It forced their content influence on the environment.

Visual attractiveness is formed on the following levels:

1. Town construction level. The street network naturally demonstrates dimensional, historic and cultural town structure. The system of dimensional boundaries is being created. They provide the orientation in space, facilitate the remembering of the roads, assist in the mental schematic image creating process. The location of the key objects in this system has an important visual constituent. They often have the specific forms and dimensions and dominate in the architectural space.

The character of the landscape where they are located plays a vital role as well as the distance from these objects to the center of the town.

2. On the level of separate architectural objects. Visual attractiveness of the separate object works on three levels:

A. Panoramic level. These are the objects well seen from the margins of the town. It covers transit roads, and the objects that are visually approachable from all the spots of the town territory. These are Polish Catholic churches well seen from the town scenery by their forms (high straight towers or high huge basilica with straight roofs and as a rule with a bell tower in the upper part).

Polish Catholic churches dominate in 48% of the panoramas of examined towns. The old town halls have the similar dimensional characteristics. It should be mentioned, that the tradition of the town hall construction as a symbol of self-governing sometimes proceeds after establishment of the Soviet power.

The castles and fortifications visually dominate as a rule. Olesko, Zolochiv are the most popular towns with fortification objects in Lviv region. Some palace-residences also have their potential in this aspect. For instance, Villa Anna in the town Stara Sil. Its dimensional and architectural decision turns it into the dominant in the town landscape (Figure 2).
B. Internal town level. The objects are visual dominants only for the part of the town. These are residences, palaces, small castles, and so on. These objects form the closest environment for spectators and create special image for some parts of the town. The preserved civil buildings are clustered in small architectural ensembles. They form the general image of the town. One may identify the ancient town centre that facilitates the orientation of a person in a town space.

![Photo by Dyda 2013](Photo by Dyda 2013)

Fig. 2. The Town Stara Sil. Villa Anna

C. On the local level. Visual attractiveness may appear on the basis of stylistic contrast when the historic building is surrounded by the modern building construction. The monuments, memorials, sculpture compositions, fountains that work as space vectors, have a great influence in creating the architectural attractiveness of the town. Today, the construction process with the assistance of the Polish side in Lviv region is less noticeable. As a rule, these are restoration, renovation of the historic objects, ensembles (Polish Roman Catholic churches and monasteries), the renovation of cemeteries, as well as the building of the new facilities near these constructions. The renovated buildings get new colorful decorations, that make it more visual in the environment. During the con-
struction of the new Polish Roman Catholic churches the tradition of its visual approaching is preserved. Borynia town is an example of such a situation. It is located near the important international highway, but because of the specific relief is almost unnoticeable from that spot. A traveler views only a newly built chapel while going by (Figure 3). It is located at the outskirts. Such a location makes it a chief visual marker of Borynia.

Fig. 3. Borynia town. The view of the chapel from the highway

4. Research results

1. The architectural environment of the towns of Lviv region was formed under the influence of West-European architecture. The Polish cultural influence was the mediator of the process.

2. The Polish Roman Catholic churches and fortification objects are the chief dominants in the majority of towns in Lviv region. Greater part of them were constructed during the Polish times. Along with the objects built according to the local architectural traditions they form a unique image combining at the limited territory different approaches to the town planning and the location of the architectural dominants.
3. The preserving of these two approaches to the formation of architectural environment of the town with the compositional balance promotes the unique view of towns of Lviv region and the formation of its architectural attractiveness.

References


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LAND CONsolidATION DEVELOPMENT – DISCUSSION OF A NEW APPROACH RECOMMENDED FOR POLAND

Jacek M. Pijanowski

Summary
The article is an opinion in the ongoing discussion on the directions of the legislative changes in the field of rural structures in Poland, expressed mainly in connection with the forthcoming EU programming period 2014–2020. In the very centre of discussion is a new approach to planning and implementing investment activities related to land consolidation (defined as “land consolidation development”) in Poland.
If investments in post-consolidation development are realized in coordination with water engineering, land improvement and flood control, then even under Rural Development Programme (RDP) for 2007–2013 more funds can be raised for improving rural structures. A prerequisite for this is to create integrated guidelines for land consolidation projects.

Keywords
rural development • post-consolidation development • land consolidation • rural structures

1. Introduction
For the first time post-consolidation development (road network and land improvement structures) was defined in The Regulation of the Minister of Agriculture and Rural Development of 24th of April 2008 on detailed conditions and procedures of providing financial aid within the project: “Improvement and development of infrastructure related to development and adaptation of agriculture and forestry by land consolidation” included in the Rural Development Programme for 2007–2013 [Rozporządzenie Ministra Rolnictwa i Rozwoju Wsi... 2008a; hereafter referred to as: The Regulation of RDP on land consolidation]. The issue is also presented in The Act of 29th of July 2011 amending the act on consolidation and exchange of land [Ustawa... 2011], but mainly in the context of how to fully use EU funds for land consolidation carried out as part of The Regulation of RDP on land consolidation.
However both legal acts define only the entity that carries out post-consolidation development works, who is a starosta (district governor), and the scope of works (described below), but the acts do not specify the activities required to prepare a post-consolidation development plan. Therefore it should be concluded that the legislator...
decided to leave up to starosta the question of how to prepare a plan and how to put it into operation.

The above-mentioned legal acts do not regulate many vital issues, such as:

- Should a plan of post-consolidation development be comprehensive or is it allowed to formulate separate (partial) plans concerning access roads to rural and forest areas, land improvement structures and the remaining elements of land consolidation?
- Which institutions should approve a post-consolidation development plan?

Leaving these questions unanswered means that land consolidation works might be ineffective and puts into question the durability and functionality of investments realized after these works.

Another problem is that the investments realized as part of post-consolidation development are perceived by the legislator only as a process that allows a consolidation participant to take possession of consolidated lands and not as an important element of rural development.

The article presents the results of an analysis of a current model of implementing post-consolidation development in Poland and formulates a proposition of a new approach to technical and legal aspects of post-consolidation development being a part of current EU programming period (2007–2013). And this proposition, the author hopes, can contribute to the discussion on organizational and legal aspects of rural structures in Poland in the next period of programming (2014–2020).

2. Objective and method

The goal of the article is a presentation of a new approach to planning and realization of the post-consolidation development (zagospodarowanie poscaleniowe) in Poland, especially with respect to investments in rural roads network and in land improvement and water resources.

The methodological basis of the study was an analysis of current legal conditions in Poland concerning land consolidation and exchange and of support for rural development with financial aid of European Agricultural Fund for Rural Development.

An important part of the study was also the analysis of consolidation proceedings records and of post-consolidation development plans for the following objects in Małopolskie Voivodeship: Ilkowice, Łukowa, Marcinkowice, Przybyslawice and Wola Przemykowska.

3. Post-consolidation development – synthesis of a current model issues

The post-consolidation development is defined in the article 1, section 2, clause 1 of The Act of 29th of July 2011 amending the act on consolidation and exchange of land [Ustawa... 2011] in the following words: “the works defined in an approval decision about the land consolidation, enabling a consolidation participant to take possession of lands sectioned off in the consolidation process, and consisting in:
LAND CONSOLIDATION DEVELOPMENT – DISCUSSION OF A NEW APPROACH...

a) construction or reconstruction of access roads to agricultural and forest lands and access roads to settlements of a consolidation participant,

b) route adjustment and improvement of technical parameters of land improvement structures,

c) elimination of redundant boundary strips and roads and implementing land rehabilitation measures that make mechanized cultivation possible”.

These works are planned and carried out by a starosta as one of his governmental administration tasks, and they are financed by state budget funds, subject to provisions of article 3, sections 5–7, and article 4, section 2 of The Act of 26th of March 1982 on consolidation and exchange of land [Ustawa… 1982], which allows the use of EU funds, other public resources, state earmarked funds, resources of local government units (LGU), resources of a landholder taking part in land consolidation process or money of a motorway investor [Ender et al. 2012].

Much earlier, in 2008, in The Regulation of RDP on land consolidation, paragraph 4, section 1, clause 2, a broader definition of post-consolidation development was introduced, according to which, in relation to organizing the agricultural production environment, the following tasks can be subsidized:

- construction or reconstruction of access roads (to agricultural and forest lands) marked off during the consolidation proceedings and access roads to settlements of a consolidation participant, including construction of culverts,
- route adjustment and improvement of technical parameters of land improvement structures that are indispensable to facilitation of land development,
- adaptation of newly marked off land plots (parcels) to rational agrotechnical procedures, including elimination of redundant boundary strips and roads and implementing land rehabilitation measures that make mechanized cultivation possible,
- preparation of design and cost documentation, geodesic services and construction supervision related to facilitation of post-consolidation development.

Lack of uniform standards of preparing post-consolidation development plans is a grave problem in Poland [Noga 2001]. In view of increasing frequency of waterlogging of arable lands or even local floods occurring in Poland it seems extremely dangerous that measures aimed at accurate identification of local and regional water conditions and at solving the problems associated therewith cannot be included in the post-consolidation development plan.

It is mostly the question of investments ensuring the outflow of water from areas under post-consolidation proceedings to surface water reservoirs – investments in which local and regional topographical and hydrological conditions and technical efficiency of land improvement structures would be taken into account (Figure 1). Unfortunately, according to the letter of law, post-consolidation development plans are limited to construction or development of rural transport network and to route adjustment and improvement of technical parameters of land improvement structures that are indispensable to facilitation of land development. It is so though the problems

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related to water engineering and land improvement network are often included in land consolidation plan guidelines, which must be annexed to application for financing works carried out as part of The RDP for 2007–2013.

In The Act on consolidation and exchange of land and in The Regulation of RDP on land consolidation there are no provisions for connection and/or coordination of planning and implementing post-consolidation development with the investments provided for in The Regulation of the Minister of Agriculture and Rural Development of 25th of June 2008 on detailed conditions and procedures of providing financial aid within the project: “Improvement and development of infrastructure related to development and adaptation of agriculture and forestry by rural water resources management” included in the Rural Development Programme for 2007–2013 [Rozporządzenie Ministra Rolnictwa i Rozwoju Wsi... 2008b; hereafter referred to as: The Regulation of RDP on water resources]:

The outline of the Action no. 125 of RDP for 2007–2013, defined by this regulation, allows the realization of such investments as [Ministerstwo... 2011]:

• improvement of soil quality by regulation of water conditions,
• increase of water retention capabilities,
• improvement of flood control on arable lands.

In practice, however, there were no cases of planned joint investments provided for in The Regulation of RDP on land consolidation and in Regulation of RDP on water resources. This statement is confirmed by the following case studies:

• In the Ilkowice object a new drainage ditch of 300 m in length is necessary. In the prevailing part of the precinct existing ditches need cleaning.
• In the Łukowa object improvement of the existing ditches or digging of new drainage ditches of about 1–1.5 km is badly needed, which would enable to channel water to the Żabnica river from the north part of the village.
• In the Marcinkowice and Przybysławice objects the existing ditches will fulfil their functions only if they are unclogged. Within the scope of the post-consolidation development in Przybysławice a new drainage ditch of 200 m, necessary to take up new water level, was built (Sectoral Operational Program “Restructuring and modernization of the food sector and rural development” – SOP-RURAL) as well as ditches along some new roads. However no additional but necessary investments in the land improvement of the south part of Przybysławice were made.

• In the Wola Przemykowska object there is a great need of cleaning and improving technical conditions of existing land improvement structures. But as part of the post-consolidation development only a regulation of the existing channel Drwień was possible, which is the key outlet of water from the west part of the village to the Vistula river.

The absence of legal obligation to coordinating all kinds of flood prevention activities in the area intended for land consolidation – including construction of a system that slows downs rain and thaw water outflow and enables its retention and of systems of bypassing village settlement units – has no economic justification, because it allows to invest public funds in post-consolidation development without eliminating or minimizing the risk of waterlogging or floods.

The consequences of this kind of neglect always lead to a decrease in effectiveness of land consolidation, and especially they increase the risk of quick devastation of rural roads constructed after consolidation process (Figure 2) and farmland flooding. In extreme cases the neglect may also result in flood hazard in built-up areas [Magel 2003, Woch et al. 2011].

4. Discussion of a new approach to consolidation development

In order to create a new and long-lasting (in the infrastructural and functional sense) structure of rural production environment, it is necessary to prepare, in compliance
with integrated guidelines for a proceedings plan, post-consolidation development plans devised in accordance with The Regulation of RDP on land consolidation, but with simultaneous, coordinated preparation of comprehensive land improvement and flood control plans developed in accordance with The Regulation of RDP on water resources [Pijanowski J.M. 2007].

Current provisions of The Regulation of RDP on land consolidation already allow planning of all necessary works in the post-consolidation development before initiation of the proceedings. In accordance with the provisions of paragraph 5, section 1: “eligible costs, referred to in paragraph 4, section 1, include general costs, directly related with the preparation and realization of the project, incurred to:

1) preparation of the technical documentation of the project, including:
   a) guidelines for a land consolidation plan,
   b) cost estimates,
   c) architectural or building designs,
   d) geodesic and cartographic documentation, geological or hydrological,
   (…)
3) analysis and assessment of geodesic and cartographic materials with respect to the possibility of using them in the consolidation project,
4) urban, architectural, construction and maintenance supervision,
5) services related to project management, including financing and accounting services,
   (…)
7) investor’s supervision”.

From practical point of view in many cases it would be possible to coordinate, in compliance with the current legal order, planning and realization stages of above-mentioned investments with provisions of The Regulation of RDP on water resources. It could be done on condition that a starosta would closely cooperate with a Voivodeship Land Melioration and Water Units Board (Wojewódzki Zarząd Melioracji i Urządzeń Wodnych, hereafter referred to as VLMWUB). According to provisions of paragraph 4, section 1 of this Regulation: “The aid is provided in the form of partial refund of costs related with the project realization and incurred to:

1) construction or renovation of the following specific land improvement structures:
   a) ditches with their functional structures,
   b) pipelines of diameter less than 0.6 m,
   c) drainage,
   d) embankments in irrigated areas,
   e) gravity irrigation systems,
   f) phytomelioration and agromelioration,
   g) anti-erosion systems,
   h) initial development of meliorated meadows and pastures,
2) construction or renovation of basic land improvement structures and development of longitudinal and transverse cross sections as well horizontal layout of natural
stream channels, which is outside the scope of water maintenance activities, including:

a) impoundment, sluice and water intake structures,
b) barrages and water reservoirs,
c) channels with their functional structures,
d) pipelines of diameters below 0.6 m,
e) flood control structures,
f) regulation structures,
g) pump stations, save for stations used for pressure irrigations,
h) structures for controlling water erosion,
i) access roads indispensable for proper use of meliorated lands and for maintenance of basic land improvement structures,

(…) 4) purchase of lands for investments necessary to carry out the project (…)”.

Many investments listed above are a whole range of important complementary actions or even actions conditioning investments made as part of the post-consolidation development based on The Regulation of RDP on land consolidation, and it seems reasonable that a legal framework for coordinating investments provided for in the regulations during planning and realization stages and before the next EU programming period, that is before 2014, should be established and proper technical and organizational instructions or directives should be adopted. Moreover, many investments that could be realized as part of The Regulation of RDP on water resources are essential for agriculture, which is why these investment should be coordinated with land consolidation works.

It is suggested that all the activities provided for in both regulations are called “land consolidation development”.

The very important positive aspect of realizing land consolidation development in the proposed form is that more funds could be used in the current post-consolidation development based on The Regulation of RDP on land consolidation (it is now 900 euro per ha of land under consolidation procedure) with funds allocated for investments realized in accordance with The Regulation of RDP on water resources.

Figure 3 shows a diagram of the proposed model of coordinated land development proceedings adopted according to The Regulation of RDP on land consolidation and carrying out tasks provided for in The Regulation of RDP on water resources.

Integrated guidelines for a land consolidation and reclamation plan should be an obligatory document prepared before initiation of the proceedings and optionally the actions related to Renewal of rural areas programme should be included. As it is desirable from the public interest point of view, the scope of the guidelines should be legally sanctioned. The proposed working title of the document should be: “Guidelines for a plan of land consolidation and reclamation and Village renewal”. It is also suggested that a Voivodeship Offices of Geodesy and Agricultural Areas (Wojewódzkie Biura Geodezji i Terenów Rolnych, hereafter referred to as: VOGAA) should be responsible for the preparation of a plan.
Fig. 3. Coordinated implementation of land consolidation carried out in accordance with The Regulation of RDP on land consolidation with completion of tasks provided for in The Regulation of RDP on water resources with the optional inclusion of the Village renewal programme.

The diagram presented in Figure 3 takes into consideration legal conditions of the current period of EU programming, namely designing and execution of works related with land consolidation and land consolidation development, land improvement and water resources and (optionally) Village renewal, which are carried out by three separate institutions, that is respectively: a starosta, VOGAA and a commune (or a cultural institution of LGU, or a church institution). This separation of institutions also applies to financing of investments, which comes from three different actions provided for in The RDP for 2007–2013, complemented with own budgets funds of aforementioned institutions.

In preparing the guidelines, broad agreements about plans, intended investments, restrictions concerning the area subjected to proceedings, must be negotiated. It is also
indispensable that the guidelines are consulted with the following, adequate local institutions (not mentioning those listed in Figure 3):

- Regional Board of Water Management (Regionalny Zarząd Gospodarki Wodnej),
- Regional Directorate of Environmental Protection (Regionalna Dyrekcja Ochrony Środowiska),
- Voivodeship Roads Authority (Zarząd Dróg Wojewódzkich),
- District Roads Authority (Powiatowy Zarząd Dróg),
- Regional Directorate of State Forests (Regionalna Dyrekcja Lasów Państwowych),
- Agricultural Advisory Centre (Ośrodek Doradztwa Rolniczego).

Aims and plans of the above-mentioned institutions should be included in the guidelines.

Extensive public consultations with inhabitants and farmers during village meetings and with the participation of these institutions are also extremely important.

The backbone of the presented model is land consolidation. Before its initiation VOGAA in collaboration with a starosta, VLMWUB and optionally with a commune should create “Guidelines for a plan of land consolidation and reclamation and Village renewal”. After the initiation of proceedings and after taking inventory of the “previous model” the following plans should be worked up:

- consolidation development plan prepared by VOGAA as the consolidation executor,
- building design “Land improvement / water resources” prepared by VLMWUB,
- investment plan as part of the Village renewal (optionally).

Mandatory preparation of consolidation development plan in the first stage of proceedings allows the plan to address infrastructure and water relation problems described in “Guidelines for a plan of land consolidation and reclamation and Village renewal” even before implementing “Lands estimation” and a plan of “New model” and its “Geodesic works” [Thomas 2010, Thöne 2000].

The approach should bring two major benefits:

- Firstly, project team working on “Consolidation development” and building design team working on “Land improvement and water resources” will focus on creating technically appropriate road network (its construction and expansion) as well as on water engineering and land improvement structures, without paying too much attention to property relations.
- Secondly, it will lead to identification of areas, which due to their water conditions:
  - should be excluded from agricultural production (buffer zones, permanent wetlands and others), or
  - should be intended for water engineering and land improvement or flood control structures,
which would be an important directive for establishment of a “new model” [Gniadek et al. 2013].
When coordinating “Guidelines for a plan of land consolidation and reclamation and Village renewal” with local development plan, it would be possible to take into account, while carrying out land consolidation, also new areas intended for building, commercial, utility and other public purposes [Magel 2001].

5. Conclusions

In the light of achievements of Polish science, which for many years has been calling for adoption of a law on rural development that would made comprehensive and not isolated actions obligatory, the author of the article is aware that the diagram presented in Figure 3 should have been put into practice long ago [Litwin 2008, 2010, Pijanowski Z. 2008, Weiss and Pijanowski Z. 2005, Wilkowski 2004, Woch 2010].

In our country there are many examples of post-consolidation development plans, in which a plan of rural road network had no connection with management of water problems.

However without at least provisional specification and legal sanctioning of the indispensable (from the public interest point of view) coordination of technical plans of investments realized in Poland as part of the aforementioned actions of The RDP for 2007–2013 within the scope of (proposed as the final solution) “Guidelines for a plan of land consolidation and reclamation and Village renewal”, there will always be a risk that a bulk of planning work and considerable financial outlays – mainly for rural road network – can be wasted in a very short time. Therefore necessary legal actions should be taken as quickly as possible.

Unfortunately in Poland there are no examples of realized plans of this kind, in which in the stage of preparing guidelines to a proceedings plan and in the stage of preparing a post-consolidation development plan the possibilities opened by both described regulations (on land consolidation and on water resources) would be combined and in which starosta would closely cooperate with a locally competent VLMWUB.

Fig. 4. Examples of badly located dirt roads – probably without prior analysis of water conditions
One should begin to see in land consolidation in Poland what has been previously overlooked, namely the benefits it can bring to local community, such as new road and land improvement infrastructure and better flood control.

Land consolidation that puts emphasis on visible benefits in rural infrastructure could arouse interest of farmers for the works, because it would considerably improve the farming conditions and would open up an opportunity for using modern rural technology.

References

Documentation on land consolidation proceedings and post-consolidation plan for the following objects (Małopolskie Voivodeship): Ilkowice, Łukowa, Marcinkowice, Przybysławice oraz Wola Przemykowska


Rozporządzenie Ministra Rolnictwa i Rozwoju Wsi z dnia 24 kwietnia 2008 r. [a] w sprawie szczegółowych warunków i trybu przyznawania pomocy finansowej w ramach działania „Poprawianie i rozwijanie infrastruktury związanej z rozwojem i dostosowywaniem rolnictwa i leśnictwa przez scalanie gruntów” objętego Programem Rozwoju Obszarów Wiejskich na lata 2007–2013.
Rozporządzenie Ministra Rolnictwa i Rozwoju Wsi z dnia 25 czerwca 2008 r. [b] w sprawie szczegółowych warunków i trybu przyznawania pomocy finansowej w ramach działania „Poprawianie i rozwijanie infrastruktury związanej z rozwojem i dostosowywaniem rolnictwa i leśnictwa przez gospodarowanie rolniczymi zasobami wodnymi” objętego Programem Rozwoju Obszarów Wiejskich na lata 2007–2013.


Ustawa z dnia 26 marca 1982 roku o scalaniu i wymianie gruntów (Dz. U. z 1982 r. Nr 11, poz. 80, t. j. z 2011 r.).

Ustawa z dnia 29 lipca 2011 r. o zmianie ustawy o scalaniu i wymianie gruntów (Dz. U. z 2011 r. Nr 185, poz. 1097).


THE ANALYSIS OF PLANNING POSSIBILITIES
OF RURAL MANAGEMENT WORKS AS EXAMPLICED
BY THE KOZŁÓW COMMUNE

Beata Szafrańska

Summary

Rural management works are carried out for the purpose of creating more favourable conditions
for management and use of agriculture areas. The activities are fundamental to comprehensive
development of a village, farm and the protection and maintenance of natural environment.
The principal goal of these works is the improvement and development of the structure of rural
areas.
The paper indicates priority areas for planning of rural management works and especially for
land consolidation works. The research was based on The programme of rural management
works in the Kozłów commune [Program prac urządzeniowo-rolnych... 2011] and on geo-
desic and planning materials. Combination of various kinds of data obtained at District and
Voivodeship offices of geodesy and cartography and their appropriate analysis have proved effec-
tive in identification of areas in the Kozłów commune most urgently requiring the improvement
of the use and ownership structure of lands and in defining the areas where the current land
use structure should be transformed. The condition of reasonable planning of rural manage-
ment works, leading to an indication of priority areas for this kind of activities are – on the level
of voivodeships – the consistent and synchronized spatial databases founded on the land and
property register.
The analysis of geographic, natural, environmental, socio-economic, demographic conditions
and of cartographic documents with the use of GIS tools led to the identification of three pre-
cincts: Przybysławice, Bryzdzyn and Wierzbica, urgently requiring rural management works.

Keywords

agricultural structure • rural development • land and property register • agricultural geodesy

1. Introduction

Rural management works (prace urządzeniowo-rolne) are carried out to create more
favourable conditions of management and use of agricultural areas. The activities are
fundamental to a sustainable development of villages, farms and environment protec-
tion. Their general goal is an improvement and development of rural structures.
Agriculture in Małopolska is characterized by a considerable regional diversity, unfavourable agricultural structure that largely maintained its traditional character. This state of affairs is a result of historical, natural and socio-economic factors and especially regional tradition [Wytyczne „Monitorowanie zmian...” 2000].

Therefore rural development must be based on comprehensive structural changes, which would help in modelling the proper agricultural structure, including the area structure of farms. The agricultural structure can be improved substantially by: land sales, land consolidation and land exchange, a system of structural pensions and creation of producers’ groups [Litwin 1997].

The principal objective of this article is an analysis of data gathered from land and property register, of results of land inventory and pieces of information found in planning studies, and as a result of the analysis – an indication of those precincts in the commune, where land consolidation is most advisable. For local and economic reasons it is necessary to identify the areas that are most problematic and that most badly need repair works, such as:

- improvement of agricultural structure and functioning of farms,
- improvement of living and working standards of rural population,
- protection and modelling of environment.

2. Range and methods of the study

The range of the study covers the Kozłów commune in the Miechowski district, in the north part of Małopolska Voivodeship, situated within the Miechowska Upland.

The study is based on the data gathered in the analysis of land and property register (with respect to parameters of size and number of land plots and farms), information on the manner in which agricultural lands are used, the cartographic documentation and the programmes of the commune development plans with its specific tasks related with the scope of the research. The statutory tasks of the commune defined in the development strategy were taken into account in the questionnaire and in the inventory of the actual state of lands use. The record data were verified in the field while taking the above-mentioned inventory, which covered the assessment of agricultural production environment (space), environment and cultural landscape.

Technological process included the use of a commercial software ArcGIS, SWDE Manager and many geodesic and information technologies, which required supplying of vector and raster databases with information layers for the whole Kozłów commune in the form of:

- digital aerial orthophotomaps (RGB) of terrain resolution 0.25 m, validity date: 2009–2010 (sources: Voivodeship Centre for Geodesic and Cartographic Documentation; LPIS),
- record data in the form of.shp and.dbf,
- digital soil and rural land maps in the form of the ESRI Shapefile (source: Voivodeship Centre for Geodesic and Cartographic Documentation),
layers: buildings and roads included in the Topographic data base (source: Voivodeship Centre for Geodesic and Cartographic Documentation),

layers: forests and protected areas included in the Topographic data base (source: Voivodeship Centre for Geodesic and Cartographic Documentation),

the topographic map of scale: 1 : 10 000 (source: Voivodeship Centre for Geodesic and Cartographic Documentation),

the digital map of changes in a way of land use in the form of ESRI Shapefile, made in 2011 on the base of high resolution satellite photos dated 1986–2011, of terrain resolution 30 m and 5 m (source: Voivodeship Centre for Geodesic and Cartographic Documentation),

the map of land inventory and the map of the land and property register of scale 1 : 2000,

abridged copies of data from the land and property survey,


The obtained vector layers were subjected to a topology and attributes control in the software ESRI ArcGIS. The analyses were carried out in the coordinate system of “1992” of GRS 80 system, created on the basis of mathematically unequivocal assignment – according to the Gauss-Krüger cartographic projection theory – of the points on the surface of the Earth to adequate points on a plane.

On the basis of the information obtained in the land inventory, on the land and property register map of scale 1 : 2000, covering the total area of 7765 ha, the forests not revealed in the land and property survey, devastated, neglected areas, tree and shrub planting of between-fields, roadside and along ditches were marked. The currently non-existent roads, revealed in the land and property survey, were indicated as well as existing roads, not revealed in the land and property survey, and roads’ technical condition and the kind of their surface together with technical condition of ditches were also determined. Moreover wetlands and water holes were localized and photographic documentation of the above-mentioned areas was made.

On the basis of the inventory of the status quo and conclusions drawn from the analysis of environmental conditions of agricultural production space as well as the socio-economic conditions, the technical infrastructure and the agricultural production environment of the commune the following issues were worked out:

1. Directions of agricultural production environment development.

The connections between the programme of rural management works and other planning studies for the commune were demonstrated. Weaknesses and strengths of agricultural production environment were shown as well as threats and opportunities for the commune development. The need for rural management works, their scope and kind was determined.
2. Water management (basic and specific land reclamations).
3. Landscaping (or landscape modelling: natural and landscape values, afforestation, trees and shrub planting).
4. Land management and improvement of agricultural structure (exclusion of lands from use for agricultural purposes, development of area structure of farms).
5. Improvement of agricultural land layouts (lands consolidation, rural roads).
6. Directions of agricultural production development (crop and animal production).
7. Comparison of planned rural management works (determining the kind and scope of essential proceedings, assessment of the demand for the works, their general cost and sources of their financing).

In the preliminary selection of areas, where the reasonable arrangement of agricultural production environment would be most appropriate, the following factors were taken into account:
• the opinions of local community leaders,
• the number of farms in a village,
• the mean number of land plots (parcels) in a farm,
• the quality of soils,
• unfavourable shape of land plots,
• the need for road network management,
• land plots without road access,
• the current state of land use.

3. Results

The land inventory showed that the environment of arable lands, in relation to data derived from land register, has diminished in total by 320 ha in all studied precincts, except for the Kozłów village. The biggest depletion of arable lands was noted in Przysieka (64 ha), Kępie (59 ha), Karczowice (52 ha) and Przybysławice (43 ha). The space of grasslands has increased by 170 ha. The biggest increase of grasslands was observed in Przysieka (6 ha). The space of orchards has diminished by 89 ha, of which the least decrease was noted in Wierzbica, and the biggest loss – in Kozłów. Woodlands and tree-covered areas have expanded by 273 ha. The biggest increase took place in Kępie, Przybysławice, Marcinowice and Bryzdyn (Table 1).

As a result of the comparison of data gathered from land inventory with land and property register data the following can be noted:
• arable lands are smaller by 320 ha (about 5%),
• grasslands are bigger by 170 ha (about 22%),
• orchards space has diminished by 89 ha (about 58%),
• woodlands and tree-covered areas have expanded by 273 ha (about 30%).
Table 1. Comparison of land inventory with land register data

<table>
<thead>
<tr>
<th>Precinct</th>
<th>Arable land</th>
<th>Grasslands</th>
<th>Orchards</th>
<th>Woodlands and tree-covered areas</th>
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<tbody>
<tr>
<td></td>
<td>Difference [ha]</td>
<td></td>
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<tr>
<td>Bogdanów</td>
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<td>273</td>
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</table>

Source: Program prac urzędzeniowo-rolnych... 2011

The changes in the size of agricultural lands result mostly from transformation of arable lands to grasslands or from natural succession.

The large part of arable lands in the Kozłów commune are still cultivated in accordance with their intended use. The biggest area of lands not used for agricultural purposes has been noted in the villages of Kępie and Marcinowice (in total about 155 ha), and a part of these lands was afforested or became subject to natural succession of forest flora – a result of prolonged non-usage of lands and proximity of forests. The largest areas of lands that became subject to a process of natural succession were in Przybyslawice, Marcinowice and Kępie, and of afforested lands – in Marcinowice and Przybyslawice. The smallest share of lands excluded from cultivation was noted in Karczowice (0.7% of arable lands), the biggest share – in Przybyslawice (over 14%). Therefore, to sum up the data gathered in the study, one can conclude that only less than 9% of agriculture lands of the Kozłów commune is excluded from agricultural use. In the commune many naturally valuable areas were found, which should be covered by legal protection. More than 60% of rural roads in the commune do not meet technical requirements that would allow the use of modern agricultural machinery. Therefore it can be said that the whole network of rural road transport should be comprehensively modernized. Post-consolidation management, being a part of consolidation and exchange of lands, is an opportunity for improvement of roads quality and land reclamation structures [Program prac urzędzeniowo-rolnych... 2011]. It should be noted however that rational planning of new layout of land plots can considerably shorten
the length of roads needing modernization, which would allow for creating modern
network of agriculture transport during the post-consolidation arrangement. Data
analysis gathered from the land and property register showed that around 10% of land
plots in the Kozłów commune do not have access to public road. Moreover, the current
condition of open ditches was judged as bad – needing maintenance or reconstruc-
tion. Undoubtedly it is related with the increasing threat of inundations during heavy
rainfalls. And it means that there is an urgent need to take actions to avert the danger
[www.kozlow.pl/strategiczne.php].

Within the commune small farms up to 5 ha prevail and they constitute 84% of all
farms. The mean size of a land plot is 0.72 ha and the mean size of a farm is 2.95 ha.
The number of farms in the precincts is within 48–239 range. Within the Kozłów
commune there are 12 775 land plots, of which only 8367 belong to family farms and
the rest are not part of farms. The largest number of those belonging to family farms
was counted in Kępie – 1877, Kozłów – 1209, Wierzbica – 1146, Bryzdzyn – 1142,
whereas the smallest number of them in the villages of Rogów – 220 and Bogdanów –
227. The mean number of land plots in a farm ranged from 2 to 11.

Based on the results of the land inventory, land register map and valid Study of
conditions and directions of spatial development of the Kozłów commune, an agricu-
lultural-forest boundary line was suggested and grasslands as well as forest complexes
were marked off, which included afforested areas, areas undergoing natural succession
and areas proposed for afforestation.

By taking into account the results of the analysis, three priority precincts for
rural management works within the Kozłów commune were identified, namely:
Przybysławice, Bryzdzyn and Wierzbica.

In the Przybysławice precinct the most important arguments for carrying out the
works are:
1. An opinion of soltys (village leader) of Przybysławice, who said that there was
   a need for consolidation works in at least part of the precinct.
2. High land fragmentation (Table 2).
3. Unfavourable shape of land plots (elongated, narrow land plots prevail in part of the
   complexes).
4. Insufficient road network and bad technical condition of roads.
5. Substantial percentage of land plots without road access (81 land plots).
6. Demand for anti-erosion protection.

The factors that prove the need of the consolidation works in Bryzdzyn and
Wierzbica are:
1. High land fragmentation and unfavourable shape of land plots (Table 2).
2. Insufficient road network and bad technical condition of roads.
3. Substantial percentage of land plots without road access (136 in Bryzdzyn and 58 in
   Wierzbica).
Table 2. The area structure of farms and the number of land plots in the Kozłów commune

<table>
<thead>
<tr>
<th>Precinct</th>
<th>Total number of farms</th>
<th>Mean size of a farm [ha]</th>
<th>Number of land plots</th>
<th>Mean number of land plots</th>
<th>1–5 [ha]</th>
<th>5–10 [ha]</th>
<th>10–15 [ha]</th>
<th>15–50 [ha]</th>
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<td>Number</td>
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Source: Program prac urzędzeniowo-rolnych... 2011
The results of the analysis show that the above-mentioned precincts recommended for rural management works are areas that need these works most urgently. Undoubtedly the remaining precincts in the commune also strongly need this kind of works. The main reasons for planning and carrying out these actions are the observed adverse phenomena which can only be corrected as a result of the works. These phenomena are most of all: land fragmentation and unfavourable shape of land plots, poor condition of road network in rural areas, lack of road access to land plots, large areas that require the regulation of hydrographic conditions.

4. Discussion

One of the most fundamental goals of spatial planning is the development of spatial order on all levels of aggregation: on the level of the whole country, on the level of regions, cities, communes or small spatial units, such as precincts.

The agricultural structure order can be corrected by using a geodesic and rural management tool such as land consolidation and land exchange works, which are essential to comprehensive development of villages, farms and to protection and modelling of the natural environment. The most important task of Voivodeship authorities is the adequate and justified indication of areas that most urgently require this kind of
rural management works. Taking into consideration the great demand for structural changes in Małopolska Voivodeship and high costs of land consolidation works and post-consolidation proceedings, which are defined by separate regulations, one has to deliberately and responsibly determine what should be done.

References


www.kozlow.pl/strategiczne.php

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The Importance of the Objective Functions and Flexibility on Calibration of Parameters of Clark Instantaneous Unit Hydrograph

Andrzej Wałęga

Summary
The paper compares the results of automatic calibration of Clark's synthetic unit hydrographs. Optimal values of model parameters were determined by the objective functions: percentage error in peak flow (PEPF), percentage error in volume (PEV), peak-weighted root mean square error (PWRMSE), sum of absolute residuals (SAR) and sum of squared residuals (SSR). The last part of the analysis assesses the flexibility of studied model. The research was performed in the upland watershed of Grabinka – left tributary of the Wisłoka river located in Southern Poland. The analysis reveals that the smallest differences between the maximum flow in the observed and calculated flood culmination were obtained when applying PWRMSE function. This paper also indicates, that Clark's model was efficient for describing the analyzed floods.

Keywords
flood wave • calibration • elasticity • modeling • rainfall

1. Introduction
The parameters of a hydrological model are estimated in the calibration process, which involves minimization of variation between the observed and calculated values [Henrichs et al. 2008]. The previous “manual” calibration technique, which involved adjusting model parameters and verifying the simulation results, has been replaced with algorithms enabling automation of the process, e.g. Monte Carlo method [Bahremand and De Smedt 2008, Di Pierro 2005, Papadopoulos and Yeung 2001]. The model is considered to be effective, if the calibration process provides a set of parameters that will eventually allow obtaining the result of simulation that is similar to the observation. Selection of automatic calibration algorithm depends on the criterion adopted for qualitative assessment of the model. The first stage of the process is the analysis of model errors. In practice, the applied methods involve comparing the observed and calculated values. The resulting measurement error of the calibration process is necessary to evaluate the model – it reflects the quality of model results' adjustment.
to the observation. One can distinguish two basic measures: mean square error (MSE) and sum of squared residuals (SSR) [Kamali 2009]. Another common measure used in hydrology is the Nash-Sutcliffe efficiency coefficient, a normalized MSE, which is defined as [Nash and Sutcliffe 1970]:

$$E = 1 - \frac{MSE}{s_o^2},$$

where:

$s_o$ – standard deviation of observed discharges.

The next stage of the calibration process is a sensitivity analysis. The sensitivity analysis allows examining the interactions between model parameters and obtained simulation results. This analysis enables, among others, to determine the contribution of individual parameters or combinations thereof in the final outcome of the simulation. Automatic calibration process is frequently supplemented by a selection of algorithm to optimize the parameters. This is a very important phase of calculations as, if properly completed, it allows obtaining optimal parameter values and thus achieving the best adjustment of the model to the actual course of the analyzed phenomenon.

Unfortunately, the need to conduct a full process of model calibration in practice is often forgotten. In effect, the results obtained from the calculations do not always properly reflect the reality. Often the calibration process is based primarily on the global assessment of quality of model results’ adjustment to the observations using a single measure. In practice, algorithms for the calculation of different objective functions and searching for their minimum at which the most optimal set of parameters is obtained are well recognized. On the other hand, there is not enough research that compares different measures of model quality and evaluates their usefulness in the calibration process.

Sensitivity analysis results can be used to decide on which parameters the model calibration efforts should focus, or even as an analysis tool to test if the model behaves according to underlying assumptions [Castings et al. 2009]. Ultimately, sensitivity methods should serve as diagnostic tools that help to improve mathematical models and potentially help us to identify gaps in our knowledge that are most severe and affect prediction uncertainty the most. The characteristics of different methods for model sensitivity analysis (for example Sobol analysis, Kullback-Leibler entropy, Morris method or regression analysis) are describes by Pappenberger et al. [2008]. Model sensitivity analysis allows assessing its uncertainty, which is the result of data input errors as well as improper model structure and errors in determining its parameters [Sikorska et al. 2012].

One of the methods of model sensitivity analysis is the determination of its flexibility. Even though this method allows assessing the impact of model input parameters on the results of calculations, it has not been widely adopted. It has been described only in the paper [Maidmend and Hoogerwerf 2002], where it has been used in the analysis of an NRCS-UH (National Resources Conservation Service – Unit Hydrograph) model.
The aim of this paper was to evaluate the impact of the calibration process, using a variety of objective functions, on the accuracy of the phenomenon's description by the model. The Clark Instantaneous Unit Hydrograph models were used in the analysis of discharge floods in the upland watershed. Choosing the objective function significantly affects the efficiency of the applied model. The study used a novel approach to calibrate hydrological models, taking into account also a sensitivity analysis using the coefficient of elasticity in addition to the minimization of the objective function itself.

2. The study area

The analyses were performed in the watershed of Grabinka – the left secondary tributary of the Wisłoka river (Figure 1) located in the southern part of Poland (Podkarpackie voivodeship). The area of the watershed is 218.68 km², the average watershed slope equals 5.46‰, and the length of the main watercourse is 32.82 km. In the analyzed watershed quaternary deposits lay on the Miocene clays: sands with boulders, boulder clays and fluvial sands (Podział hydrograficzny Polski 1983). The average annual rainfall in the watershed is approximately 650 – 700 mm [Lorenc 2005]. The watershed is dominated by permeable soils and the land cover is mostly represented by agricultural land and forests.

Source: author’s study

Fig. 1. Watershed of Grabinka
3. Material and methods

The analysis was based on the highest daily precipitation recorded at the Tarnów precipitation station and the corresponding flood hydrographs observed in the cross-section of Głowaczów water gauge, which closes the Grabinka watershed. The analysis was based on the episodes of 1980, 1981, 2004 and 2006. The selection of data for the analyses was caused by their availability. These data originated from the archives of Institute of Meteorology and Water Management, National Research Institute.

Due to the availability of point-only precipitation data, before the analysis has started, it was transformed into precipitation distributed on the watershed area. Transformation was based on the precipitation reduction curves as functions of duration and watershed area, presented by Ponce [1989]. The division of total hydrograph into direct and basic discharge was based on a recession curve. Effective precipitation, which describes direct discharge, was determined by SCS (Solid Conservation Service) method. In the presented study the value of CN (Curve Number) parameter was determined by optimization using the observed rainfall-discharge phenomenon. The Clark's model based on synthetic unit hydrographs was subjected to the calibration process. Clark developed a method for generating a watershed's unit hydrograph that is based on the relationship between time of concentration and the watershed area, and uses a theory of a single linear reservoir to transform effective precipitation into discharge. Treating the watershed as a linear reservoir allows for including the phenomenon of retention in the watershed. Clark's method is an attempt to link geo-morphological characteristics of the watershed with its reaction to precipitation [Cleveland et al. 2008]. In Clark's method the watershed retention described by a single linear reservoir is expressed by the equation:

\[ S = R \cdot O \]  

(2)

where:
- \( S \) – the volume of retention in the watershed,
- \( R \) – watershed retention coefficient,
- \( O \) – volume of discharge from the watershed.

In the first stage of the calculations, model parameters were automatically calibrated based on the following measures (objective functions): percentage error in peak flow (PEPF), percentage error in volume (PEV), peak-weighted root mean square error (PWRMSE), sum of absolute residuals (SAR) and sum of squared residuals (SSR). All characteristics are specified with the equations [Cunderlik and Simonovic 2004]:

\[ \text{PEPF} = 100 \left[ \frac{Q_o - Q_s}{Q_o} \right] \]  

(3)

\[ \text{PEV} = 100 \left[ \frac{V_o - V_s}{V_o} \right] \]  

(4)
The importance of the objective functions and flexibility...

\[
PWRMSE = \sqrt{\frac{\sum_{t=1}^{N} (Q_O(t) - (Q_s(t))^2 \cdot \frac{Q_O(t) + Q_{ave}}{2Q_{ave}}}{N}}, \quad Q_{ave} = \frac{1}{N} \sum_{t=1}^{N} Q_O(t) \tag{5}\]

\[
SAR = \sum_{t=1}^{N} |Q_O(t) - Q_s(t)| \tag{6}\]

\[
SSR = \sum_{t=1}^{N} [Q_O(t) - Q_s(t)]^2 \tag{7}\]

where:

- $Q_O(t)$ and $Q_s(t)$ – observed and simulated flow in time $t$,
- $Q_{ave}$ – average observed flow,
- $V_O$ and $V_s$ – volumes of observed and simulated wave.

Automatic calibration of model parameters was based on iterative selection of the parameters until the minimum of the objective function. In order to minimize the objective function (3) to (7) a uniform gradient method was applied. This involves estimating the value of one parameter while maintaining the remaining stable.

The final evaluation of the calibration process was based on Nash-Sutcliffe efficiency coefficient $E$ [1970], commonly used in hydrology:

\[
E = 1 - \left[ \frac{\sum_{i=1}^{N} (Q_O - Q_s)^2}{\sum_{i=1}^{N} (Q_O - \overline{Q}_O)^2} \right] \tag{8}\]

where:

- $N$ – the number of hydrograph ordinates,
- $i$ – the index changing from 1 to $N$,
- $Q_O$ – the $i$th ordinate of the observed hydrograph,
- $Q_s$ – the $i$th ordinate of the simulated hydrograph,
- $\overline{Q}_O$ – the average of the observed hydrograph ordinates.

After the model calibration process, its sensitivity to changing parameters was analyzed. Sensitivity of a model was characterized by its flexibility, which is a measure of impact of one parameter on another. It is a non-unitary parameter, which is calculated as the ratio of the percentage change in the output characteristics to the percentage change in input parameter [Maidment and Hoogerwerf 2002]. If values of
this parameter are higher or equal to 1, then the parameter is “flexible”; in other words, the dependent variable is very sensitive to the size of independent variable. Otherwise, when flexibility is lower than 1, the parameter is “inflexible” and the dependent variable is not sensitive to the change of independent variable. The aim of the sensitivity analysis was to determine the effect of the time of concentration and retention coefficient in Clark’s model on the variability of culmination flow in a simulated hydrograph. The analysis consisted on setting different values of parameters and calculating $Q_{\text{max}}$ flow. Based on such analyses it was possible to determine the flexibility of a given parameter.

4. Results and discussion

4.1. Calibration of parameters

Calculations have shown that by using the objective function described by formula (3) one can obtain complete consistency between culminations of calculated and observed waves (Table 1). This is a typical feature of this statistic, where the only criterion for searching the model parameter values is to minimize the difference between these culminations [Cunderlik and Simonovic 2004]. A similar principle shall apply in the case of the other measure – PEV, except that in this case, the model tends to minimize differences in the volume between the compared waves. Unfortunately, adopting these criteria has negative impact on the shape of the calculated wave.

<table>
<thead>
<tr>
<th>Wave</th>
<th>PEPF [%]</th>
<th>PEV [%]</th>
<th>PWRMSE [%]</th>
<th>SAR [m³·s⁻¹]</th>
<th>SSR [–]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>0.0 (0.0)*</td>
<td>0.0 (14.7)</td>
<td>8.6 (–13.5)</td>
<td>61.2 (–30.9)</td>
<td>819.7 (–34.4)</td>
</tr>
<tr>
<td>1981</td>
<td>0.0 (0.0)</td>
<td>0.0 (–45.1)</td>
<td>4.7 (–13.0)</td>
<td>42.0 (–86.8)</td>
<td>423.9 (–49.8)</td>
</tr>
<tr>
<td>2004</td>
<td>0.0 (0.0)</td>
<td>0.0 (–7.1)</td>
<td>1.0 (0.8)</td>
<td>28 (–3.4)</td>
<td>29.7 (–1.1)</td>
</tr>
<tr>
<td>2006</td>
<td>0.0 (0.0)</td>
<td>0.0 (–68.5)</td>
<td>5.3 (–23.4)</td>
<td>76.7 (–37.7)</td>
<td>562.5 (–35.2)</td>
</tr>
</tbody>
</table>

* In brackets are percentage difference between peak flows in observed and simulated wave

Source: author’s study

The best calibration results were obtained using PWRMSE (omitting the PEPF function). Figure 2 compares the observed waves of 2004 and waves obtained from Clark’s model using automatic calibration with PWRMSE. The smallest difference between calculated and observed $Q_{\text{max}}$ was obtained for the episode of 2004 and the worst results (the highest values of objective functions) – for the wave of 2006. The worst results of the simulations were obtained when the model parameters were optimized using SAR; the difference between $Q_{\text{max}}$ calculated and observed reached almost – 87%.

Similarly to PEPF, null values were obtained also in the second criterion (PEV), but the shapes of simulated hydrographs considerably differed from the observed hydrographs. Moreover, apparent disparity between $Q_{\text{max}}$ in culminations between observed
and calculated waves were observed from about −7% to over −68%. For Clark’s model lower values of objective functions were observed for the waves of 1981 and 2004. In most cases the value of $Q_{\text{max}}$ was underestimated. The most common cause for generating the largest errors in calibration was inconsistency between the flow of culmination and different course of the ascending part of calculated and simulated wave (more rapid increase of calculated wave).

Flow residues defined as the differences between the calculated and observed instantaneous flow, where the objective function is described by the equations from (3) to (7). The course of residues is similar for either of the objective functions. Times to culminations of calculated waves in all analyzed cases coincide with the time to culmination of the observed wave. Positive values indicate that for calculated waves flows were higher than for the observed waves. This is due to the adopted model of effective precipitation, which determines the center of gravity when calculating the concentration and lag time [Sikorska and Banasik 2008]. Minor errors are generated in the zone of flow recession curve. Undoubtedly, the initial values of variables play a significant role in the correctness of calibration procedure and thus affect the size of errors generated by the model [Velez and Frances 2005].

![Fig. 2. Comparison of the observed wave of 2004 with the wave calculated from Clark’s model using calibration with PWRMSE](image)

Source: author’s study

### 4.2. Quality of models

The next stage of the calibration of model parameters is the general assessment of the quality, which was performed using the coefficient of efficiency $E$. The results are presented in Table 2.
Table 2. Values of the coefficient of efficiency $E$ [%] for each objective function and analyzed wave

<table>
<thead>
<tr>
<th>Wave</th>
<th>Clark IUH</th>
<th>PEPF</th>
<th>PEV</th>
<th>PWRMSE</th>
<th>SAR</th>
<th>SSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>24.9</td>
<td>39.7</td>
<td>39.6</td>
<td>49.4</td>
<td>49.4</td>
<td>49.4</td>
</tr>
<tr>
<td>1981</td>
<td>37.2</td>
<td>54.8</td>
<td>45.2</td>
<td>35.3</td>
<td>52.5</td>
<td>52.5</td>
</tr>
<tr>
<td>2004</td>
<td>82.3</td>
<td>89.1</td>
<td>95.9</td>
<td>95.8</td>
<td>96.6</td>
<td>96.6</td>
</tr>
<tr>
<td>2006</td>
<td>0.8</td>
<td>-13.7</td>
<td>80.2</td>
<td>83.8</td>
<td>82.8</td>
<td>82.8</td>
</tr>
</tbody>
</table>

Source: author’s study

The lowest efficiency of model was obtained when parameters were optimized using PEV and PEPF functions. Generally, when comparing both objective functions, slightly better results were obtained by optimizing the model parameters using PEPF. Approximated values of the coefficient of efficiency $E$ were obtained when optimization of model parameters was performed using the other objective functions. This follows from the fact that the error values are calculated for the entire course of the hydrograph and not for its selected parts. Generally, high values of coefficient $E$ in optimizing the parameters with PWRMSE, SAR and SSR were obtained for two waves: of 2004 and 2006. Similarly, high efficiency of Clark’s model was showed by Straub et al. [2000] when analyzing IUH (Instantaneous Unit Hydrograph) in small agricultural watersheds in Illinois, U.S. Verification of this model revealed that in 21 of 29 analyzed watersheds the flow error did not exceed 25%. Values of coefficient of efficiency $E$ in the vast majority exceeded 90%.

4.3. Flexibility analysis

The final element of the model parameter calibration was the flexibility analysis.

Clark’s model is inflexible to the change of the following parameters: $T_c$ – time of concentration and $R$ – retention factor. The calculated coefficient of flexibility for $T_c$ was – 0.26 and for $R$ – 0.74. As a result of increasing time of concentration the size of flows is gradually reduced and the hydrograph is postponed (Figure 3a). The increase in concentration time extends the reaction of watershed to precipitation, which delays discharge and slightly reduces flows. Increasing the retention factor $R$ also contributes to reducing the size of flows, but without changing the shape of the hydrograph. The lower the value of this parameter, the greater the amount of precipitation is collected in the watershed area and thus the discharge increases (Figure 3b). The analysis revealed that Clark’s model is significantly more susceptible to the change of the $R$ parameter, than to the change of concentration time. These results coincide with those observed by Ahmad et al. [2009]. According to these authors the phenomenon of discharge wave diffusion in Clark’s model dominates over the effect of discharge delay.
Fig. 3. Effect of the change of time of concentration $T_c$ (a) and retention factor $R$ (b), on the shape of discharge hydrograph in Clark’s model.
5. Conclusions

The following conclusions were reached as the result of conducted analyses:

1. The smallest differences between the maximum flow in the culmination of observed and calculated waves were obtained using PWRMSE. This follows from the fact that in the optimization procedure higher weights were assigned to the errors of flows located closer to the culmination flows. This measure should be used for the calibration of model parameters.

2. The weakest calibration effects were obtained using PEPF and PEV measures. This is caused by the fact that the sole criterion for searching of model parameter values is to minimize the difference between culminations and volumes of calculated and observed wave.

3. Considering the coefficient of efficiency $E$, Clark's model was efficient in the description of the analyzed floods. This is due to the fact that transformation of effective precipitation into discharge in Clark's model is carried out regarding the retention process in the watershed and translation in the watercourse bed. This indicates that Clark's model may be applied in precipitation flood simulations in upland watersheds.

4. Clark's model is inflexible to the change of both its parameters – the time of concentration and the retention coefficient.

5. Sensitivity analysis is a novel approach to the analysis of uncertainty related to hydrological models. Its inclusion in the calculation will reduce the error generated by the model with the correct estimation of the key parameters which will influence the accuracy of the description of reality by model.

References


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