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FOREWORD

For the last three years, the interdisciplinary team of research workers of the Faculty of Environmental Engineering and Land Surveying at the University of Agriculture in Krakow has completed a number of research and applied works in the framework of the project “Valorisation and Sustainable Development of Cultural Landscapes using Innovative Participation and Visualisation Techniques – VITAL LANDSCAPES (EU programme CENTRAL EUROPE). The studies concerned broadly-taken subject matter relating to rural space and landscape.

The subject matter of the papers published in this first issue of the Geomatics, Landmanagement and Landscape publication concerns the whole spectrum of the international project realisation. The publications describes in a very interesting and intelligent manner, the historic and current state of Mściwojów village located in the Lower Silesian Voivodship. Papers focus directly on the historic man-made park landscape and the grange of the von Nostitz family.

Remarkable concepts and ideas are represented by the application of spatial management of these objects; these were achieved by using modern planistic and photogrammetric tools. Ground laser scanning was employed to complete a full 3D visualization. In order to perform these complex calculations, the authors programs from the field of spatial management were used. Also, I am very pleased to have received and be able to publish the article by our Austrian and Slovak VITAL LANDSCAPES project partners.

The present scientific issue contains ten (10) papers written in English. These show the results of research and applied works carried out in the scientific, didactic and productive institutions by the representatives of the world of science and practice. It is with great pleasure that, we present onto your hands the first scientific issue of the journal of Geomatics, Landmanagement and Landscape. It contains the authors elaborate research, dedicated to the detail study of question of space and how it is affected by economic, ecologic and landscape factors.

It is hoped by the Scientific Council, who advanced the motion to bring into existence such a journal, that this publication will serve as a platform for the presentation and the serious discussion of this field of work by researchers from home and abroad.

Urszula Litwin
Scientific Editor of the Journal
Chair of the Scientific Board
CULTURAL LANDSCAPE POTENTIAL AND LOCAL STRATEGIES OF RURAL AREA DEVELOPMENT

Maciej Brożek, Marek Możdżeń, Jacek M. Pijanowski

Summary

The article presents results of research and implementation studies conducted at the University of Agriculture in Krakow within the project VITAL LANDSCAPES realized with the support of the CENTRAL EUROPE Programme funded by the EU. The research covered the area of the manor and park complex funded by the family of von Nostitz in Mściwojów. Project activities involved innovative combination of advanced 3D visualizations with the participation of local communities and decision-makers for the valorisation of local cultural landscape assets, which were regarded as important elements of local rural development strategies. Activities towards developing local strategies are now an important trend in Europe. They usually engage local and subregional stakeholders in the development processes in rural areas with special emphasis on the development of strategy concepts, in accordance with the principles of Agenda 21.

Keywords

Landscape • cultural landscape • landscape inventory • development of rural areas • 3D visualisation • social participation • CENTRAL EUROPE • Agenda 21

1. Introduction

The article presents results of research and implementation studies conducted at the Agricultural University in Krakow as part of the VITAL LANDSCAPES project. In the first place, it is important to mention the development of scientific methodology for the creation of innovative 3D visualizations presenting changes in cultural landscapes. The work, which was regarded as quite a novel approach in Poland, was carried out for the manor and park complex von Nostitz in Mściwojów (study object for the project). However the visualisations, was not the sole object of the study. They were part of an advanced methodology for building public participation within the pilot project, with active involvement of local communities and decision-makers. Important elements included were regional seminars organized in Mściwojów and Krakow as well as extensive studies carried out for the needs of 3D visualizations. From a practical point of view, the aspect of public participation is becoming
increasingly important in enabling the implementation of all investment and development plans: such as local infrastructure investments, local spatial development plans or regional investment plans [Litwin and Pijanowski 2008, Meyer et al. 2008, Spiegler et al. 2008]. This constitutes a significant scientific challenge.

An important element of the project was cooperation of the Agricultural University in Krakow with partners from Germany, Austria, the Czech Republic, Hungary and Slovenia. Intensive communication between the project partners and the involvement of local and regional stakeholders will make project results particularly valuable and ensure their long-lasting impact.

Project work described in this article was a scientific contribution to the new approach aiming at the improvement, protection and development of landscape cultural values in Central Europe. Also, it helped to confirm the thesis that the protection of natural and cultural landscape assets is possible only if we manage to maintain and develop traditional local economies in rural areas, bound to this landscape. This is to be accomplished by generating non-farm jobs and developing potential in the region.

2. Objectives and Methods

This article discusses the importance of cultural landscape assets for the creation of local rural development strategies. The recognition of these resources is possible only as a result of an extensive area inventory, while active participation of local communities and authorities is a prerequisite for creating the concepts of local development strategies and applying them. What is important, is the feedback which can make cultural landscape resources the „lever” for the development of specific projects, in which landscape can be used and revaluated, ensuring its conservation or sustainable use.

In terms of methodology, the article is a synthesis of the results of the research and implementation work carried out in Mściwojów during selected VITAL LANDSCAPES project activities. These activities included a broad historical analysis, analysis of the existing situation, creation of the restoration concept for the historic manor and park complex and the surrounding objects in Mściwojów; all with the use of innovative methods of community participation, and advanced 3D visualizations.

3. General description of the community of Mściwojów

The community of Mściwojów is located in the district of Jawor (Lower Silesia), and is geographically located at the Sudeten Foreland, including the so-called Strzegom Hills. The commune covers an area of 71.42 km² and it encompasses 12 villages. Mściwojów is located 5 km south of Jawor, 25 km south of Legnica and 65 km west of Wroclaw. The commune is cut by the Oder tributaries, as well as the river of Wierzbak which flows into the retention reservoir at Mściwojów with an area of 0.7 km².
The community has a population of 4,250 inhabitants. It is a typically agricultural community, mainly because of very good soils (chernozem, podzolic soils, brown and alluvial soils), favourable climatic conditions and the limited number of jobs in other sectors of the economy. Natural resources of the community include extensive deposits of sand and gravel, and rich deposits of granite.

4. General description of cultural landscape assets in Mściwojów

The first mention of Mściwojów comes from the thirteenth century. It was referred to then as: Provin, Profen, Provyn or Profin [Grabier 1930]. The village was originally situated in the former Duchy of Świdnica and Jawor and later in the district of Jawor (Jauer) [Koiwchwitz 1910], as it is today. In the 15th century, Mściwojów and the surrounding areas belonged to the families von Bibran and von Profen, while in the middle of the 17th century it became the property of the family von Nostitz. The most prominent period for Mściwojów began in 1654 and lasted about 300 years. At this time when Baron Otto von Nostitz, the governor of the Duchy of Świdnica and Jawor, founded a large manor-park complex with a conservatory and a vineyard [Brożek et al. 2011].

In 1689, Friedrich Lucae called it one of the finest and largest (9,295 ha) estates in Lower Silesia, along with the gardens of the von Hochberg family in Pełcznica and Ciernie. Nicolaus Henelius described this property at the turn of the 17th and 18th centuries. He especially admired the wonderful and numerous trees and exotic
plants. Also, the garden was adorned with allegorical or mythological sculptures. In the central part of the complex, there was a cave in the form of a rotunda with artificial water equipment, including a fountain and a statue of Diana holding corn flowing with water. In the 19th century, the complex was purchased by Johann Joseph von Nostitz-Reneck and in 1931 it became the property of Konstantina von Pfeil [Jastrzębski 1973].

The complex was considerably devastated during the war and declined. Its condition became deteriorated after the war. In 1953, the manor burnt down under mysterious circumstances and the wonderful garden suffered ultimate devastation.
Attempts to rebuild the complex in the 1970s failed [Brożek et al. 2011]. Despite its major damage and signs of devastation, after the years of being used for the needs of the National Agricultural Holdings (PGR), the entire complex is still impressive. Unfortunately to this day, it has not been restored to its former glory. The project group from the Agricultural University of Krakow conducted intensive research, in order to find comprehensive information about the manor and park complex, along with the vineyard from the time of its prominence. Unfortunately, they encountered a number of difficulties in obtaining historical materials, especially those related to the flora of the park. The main reason for this was the fire from 1953, which destroyed the manorial library.

The most important existing local cultural landscape assets include the following: a part of the manorial garden with the conservatory. (This is well-preserved but rebuild in the period when it was occupied by PGR). The adjacent pond with an island and a pavilion, the ruins of the manor house, church and its surroundings, and the well-maintained farm buildings and remains of the buildings adjacent to the vineyard. Also, the new landscape element is the water reservoir of Mściwojów, which has a strong impact on the character of the area were well preserved.

Unfortunately, Figure 3 presents fragments (mostly hypothetical), of a digital reconstruction illustrating former glory of the manor complex.

5. Creating a local strategy for rural area development based on cultural landscape assets

Most rural communities in Poland suffer from the same socio-economic problem, which is a limited local employment opportunity outside of agriculture. As a result, many people of working age migrate to urban centres in search for work. This is because many of the local decision-makers in Poland perceive development opportunities only in seeking investors in the production, industry or services sector. In peripheral rural areas especially, it is difficult (if not impossible) to find these opportunities. Often local authorities, do not take into account the possibility of using the hidden “potential” inherent in the field of cultural landscape. Often, just as in the case of Mściwojów, decaying cultural objects wait unused for incomprehensible reasons.

Even the most of inconspicuous villages are in the possession of such hidden potential, both in the material and immaterial dimension. They stem from the historical past and are usually difficult to recognize at first glance. Often, due to the poor condition of the buildings, they are not taken into account as a potential tourist attraction at all. However, if the potential of such an object is “excavated” and properly “marketed” it can become a “lever of development” for the community and region. Mściwojów could be an excellent example: at first glance it is a plain, dilapidated, uninteresting village. The perspective changes dramatically, when we look at it through the prism of its history and neglected today its cultural resources. Upon doing that, we see a flourishing village full of life. Nearby, we see a magnificent manor and park complex with a vineyard and a farm.
The project VITAL LANDSCAPES was aimed at building a local rural development strategy for the area in question and for applying an innovative combination of activities involving local communities and authorities. This is quite possible with the most modern techniques of 3D visualization. The main objective was to show, by means of visualizations, the hidden potential in the landscape to the local population and decision-makers (see Figure 3).

Fig. 3. Fragments of the eastern manor elevation (A), the view from the west towards the pond and a pavilion on the island (B) and fragment of the northern elevation of the conservatory (C) in the 1920s and in 2011.
An important element of the study was to create special software VITAL LANDSCAPES Tools which is the product of an extremely innovative design team. The software filled the gap between the existing programs used for building Digital Terrain Models (DTM) and high-end software for texturing and visual exposure in High Definition (HD).

The aim of the working group established at the beginning of the project, was to implement the above methodical assumptions. The team consisted of local community leaders, representatives of community authorities from Mściwojów and experts from the Agricultural University in Krakow. The aim was accomplished through a series of regional seminars, devoted to the following issues:

1) analysis of the Mściwojów area,
2) based on the above, definition of its resources and potential for non-agricultural economic development;
3) based on the above, suggestions of potential development objectives,
4) the conclusion that a renovated manor and park complex with adjacent objects (the farm, the vineyard, and the water reservoir) will be the main development axis for Mściwojów.

The next step, after the working group concluded the concept work, constituted intensive inventory activities focusing on:

- cultural resources of the village, particularly the park and manor complex with adjacent objects,
- spatial patterns of the village and surrounding agricultural grounds.

The inventory confirmed the great non-agricultural potential of Mściwojów, based on the ruins of the old manor house of von Nostitz and the surrounding objects. These could be transformed into a large holiday resort with a hotel and recreational facilities.

The panel of experts conducted all activities in such a way, as to stimulate active participation and initiative in the local inhabitants and authorities. Due to the involvement of experts from Germany and the presentations of similar already implemented concepts, it was finally decided to follow the proposed direction and transform the complex into a recreational facility, on the condition that an external investor is found.

The final concept was to restore the park and manor complex with the vineyard, transform the farm objects into a modern hotel complex and create facilities for sports recreation. This will include a stable and an observation tower. The area would then act as an important weekend recreation centre for the Wroclaw agglomeration (64 km, including 39 km on the highway). Also, with good marketing, it would be in the reach of the Upper Silesian agglomeration population (240 km from Katowice, including 220 km on the highway).

That goal can be achieved only after a detailed examination of possible environmental impact (mainly the water reservoir “Mściwojów”) and the analysis of preliminary actions studies. These reports need to prepare the community infrastructure for
the investment of this size. Good preparation of the report and plan will be crucial for obtaining an external investor.

Consequently, the analysis of hydrological conditions was carried out, including environmental aspects of the water network and the reservoir, as well as accompanying infrastructure, as the key conditions for sustainable development.

It was extremely important to engage local inhabitants and authorities in this process. Social support is the prerequisite for effective activity by the local authorities. In turn, local authorities are usually the ones who are responsible for concept
implementation. This is obtaining an investor, providing support in legal and formal questions related to investment preparation and lastly including changes in the local spatial development plan.

**Fig. 5.** Selected fragments of the 3D visualisation presenting the development concept for the complex in Mściwojów (A – the complex seen from the south, B – recreation area at the water reservoir, C – horse stable between the recreation area and the park, D – observation tower, E – hotel facilities in the former farm buildings)
In this area, the inherent potential was illustrated by the experts by means of advanced 3D visualisations. This increased interest of the local members of the working group. Also, thanks to the visualisations, it was possible to improve the concept along the way and add new elements.

6. Conclusions

The project VITAL LANDSCAPES was aimed at building a local rural development strategy for the village of Mściwojów. The group applied an innovative combination of activities involving local communities and authorities, as well as the most modern techniques of 3D visualization. A special emphasis on the development of strategy concepts in accordance with the principles of Agenda 21 was applied.

It has become an important trend in Europe and it combines the methods of involving local and regional stakeholders into development processes in rural areas.

From a practical point of view, the aspect of social participation is becoming increasingly important, to enable the implementation of all investment and development plans in the area. This applies from community infrastructure facilities to the local spatial development plans and regional investment plans.

Activities described in this article were a scientific contribution to the new approach aiming at the improvement, protection and the development of landscape cultural values in Central Europe. This helped to confirm the thesis that, the protection of natural and cultural landscape assets is possible only if we manage to maintain and develop traditional local economies in rural areas, by generating non-farming jobs and developing potential in the region.

An important element of the project was to create special software VITAL LANDSCAPES Tools, which was the output of an extremely innovative design team. The software filled the gap between the existing programs used for building Digital Terrain Models (DTM) and high-end software for texturing and visual exposure in High Definition (HD).

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ANALYSIS OF LAND CONFIGURATION OF ARABLE LANDS
CASE STUDY OF MŚCIWOJÓW

Jacek Gniadek, Stanisław Harasimowicz, Jarosław Janus,
Jacek M. Pijanowski

Summary
The article contains the results of research on arable land configuration in Mściwojów. To
determine the basic qualities of land configuration the following software was employed:
MKTopo GUTR, Plikpol, Pole. The basic surface elements assumed for research were plots,
defined as continuous parts of cadastral plots utilized only in one way. The analysis covered
spatial parameters of the plots, estimated land configuration related cultivation costs, location
of the land in the village and farm and basic features of the farm. The obtained results allowed
to define the degree of influence of land configuration on the costs connected with cultivation
and to determine if correction of land layout is necessary.

Keywords
land configuration • spatial land structure

1. Introduction
Excessive fragmentation and awkward and incorrectly shape of agricultural lands are
the reason for lower agricultural production efficiency, as compared to lands properly shaped. These have an optimal harvesting area. The existing rural management solutions meant to correct the land layout are usually preceded with evaluation of
the current state, which analyzes the basic spatial parameters of the plots and land
configuration related cultivation costs (land configuration costs). The traditional
methods of researching land configuration are laborious, because they are associated
with determining many spatial parameters for a large number of surface elements.
In order to improve this process, it is necessary to introduce new IT solutions which
automate this procedure and give full information about the area under research.

2. The purpose and methodology of the study
The aim of the article is to analyze the existing land layout in Mściwojów (Jaworski
District in Lower Silesian Voivodeship) which was not the object of land consoli-
The activities were run in the framework of the VITAL LANDSCAPE project (CENTRAL EUROPE EU program). The study used an automated method for assessing the distribution of farmlands. That allowed the analysis of all the plots that make up the existing farms in the area. The basic surface elements assumed for research were continuous parts of cadastral plots utilized only as arable land. The analysis was conducted using the following software: MKTopo GUTR, Plikpol, Pole [Gniadek 2001]. This software uses the data from a digital cadastral map and from the descriptive part of digital land and buildings cadastre to produce results. MKTopo GUTR software enables gaining information concerning plots from digital cadastre map. The next software PlikPol helps in processing of gained source files, and the last software Pole enables determination of plots spatial parameters and cultivation costs which are a function of plots layout. For every plot were established: area, length, width, elongation and distance from the farmer’s habitat. The study of land configuration of arable plots mainly consisted in evaluating particular features of land configuration with the values considered to be proper or optimal, and in analyzing the arrangement of the plots in the village. This was accomplished by determining their location with respect to habitats and the center of the village.

A complete evaluation of land configuration of the plots covered by the study was made using the so called land configuration costs which are the sum of the related cultivation costs and production losses. These costs were estimated under two assumptions: 5 tons per hectare (ha) production and full mechanization.

3. Area and shape of arable lands

The average area of an agricultural land belonging to the residents of Mściwojów is 2.36 ha and varies from 0.02 to 7.51 ha (Table 1).

Figure 1 presents the distribution of the number of arable lands depending on their area in hectares. The graph shows, that the minority of the plots in Mściwojów (about 21%) are no larger than 0.75 ha, and their average length ranges from 80 to 280 m. Utilization of plots that are too small is inconvenient and in case of using tractors leads to high land configuration related costs, which exceed 20 cereal units per hectare. For properly shaped plots for optimal use, these costs should not exceed 5 cereal units per hectare.

About 9% of the plots covered by the study have areas from 0.75 to 1 ha, which do not differ much from the area considered proper for mechanical farming. It is assumed that in case of mechanical farming the minimal area should be 1–2 ha [Cymerman et al. 1982, Pruszczyk and Żurawski 1991, Woch 2001]. The average length of these plots is approximately 300 m, which can be considered proper for mechanical farming. The land configuration costs for these plots are much lower than in the case of the previous group of plots and are about 7 cereal units per hectare. The remaining plots make up 70% of the plots under study and are bigger than 1 ha. Their larger area is caused by the increase to their lengths which range from 300 ha
Table 1. Basic descriptive statistics of considered features of arable plots land configuration in Mściwojów

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Plot area [ha]</td>
<td>2,36</td>
</tr>
<tr>
<td>Plot length [hm]</td>
<td>3,37</td>
</tr>
<tr>
<td>Plot width [hm]</td>
<td>0,68</td>
</tr>
<tr>
<td>Plot perimeter [hm]</td>
<td>8,34</td>
</tr>
<tr>
<td>Number of vertexes</td>
<td>5,78</td>
</tr>
<tr>
<td>Plot elongation</td>
<td>7,32</td>
</tr>
<tr>
<td>Number of plugging strips</td>
<td>0,75</td>
</tr>
<tr>
<td>Length of plugging strips [hm]</td>
<td>0,95</td>
</tr>
<tr>
<td>Land configuration costs without driving to the plot [cereal units per ha]</td>
<td>3,77</td>
</tr>
<tr>
<td>Land configuration costs with driving to the plot (bad roads) [cereal units per ha]</td>
<td>11,69</td>
</tr>
<tr>
<td>Land configuration costs with driving to the plot (good roads) [cereal units per ha]</td>
<td>6,94</td>
</tr>
<tr>
<td>Distance from the nearest vertex of the plot to the farmers' habitat</td>
<td>8,54</td>
</tr>
<tr>
<td>Distance of the plot from the farmers' habitat</td>
<td>10,56</td>
</tr>
<tr>
<td>Distance of the plot from the village center</td>
<td>9,72</td>
</tr>
<tr>
<td>Number of plots at the farm</td>
<td>23,92</td>
</tr>
<tr>
<td>Number of arable plots</td>
<td>13,35</td>
</tr>
<tr>
<td>Number of grassland plots</td>
<td>1,4</td>
</tr>
<tr>
<td>Area of the farm [ha]</td>
<td>32,99</td>
</tr>
<tr>
<td>Area of the arable land [ha]</td>
<td>31,87</td>
</tr>
<tr>
<td>Distance of the farmers habitat from the centre of the village [hm]</td>
<td>7,06</td>
</tr>
</tbody>
</table>
to more than 500 m. This is the reason why the cultivation costs are relatively low. The cost do not significantly exceed the allowable level of 5 cereal units per hectare.

The average plot length is 337 m (Table 1) and is definitely proper for the mechanical cultivation which requires plots longer than 100–150 m. The lengths of considered plots range from 44 m to more than 800 m.

About 9% of plots have short lengths, not exceeding 100 m (Figure 2). The length of these plots is more than three times their width, which is 30 m on average. In case of these plots, cultivation may be troublesome and is indicated by the big land configuration costs. These costs are about 20 cereal units per hectare. Fewer plots (6%) have the length of 100–150 m. The widths of these plots are usually twice as long as in the previous case, about 70 m. Both make lower costs. The length and width of these plots are not a significant difficulty in their agricultural utilization and the cultivation costs are slightly decreased to around 7 cereal units per hectare.

About 85% of plots are longer than 150 m. The increase of the length of the plots is accompanied by a slight fluctuations of their widths and slight fluctuations of cultivation costs. The graph under discussion shows a dominating influence of the length of grasslands and the cost of their cultivation. The shorter the plot lengths are, from the optimal length (100–150 m), the higher the costs.
The average plot width is 68 m. The number distribution shown on Figure 3 shows, that 13% of plots are less than 25 m wide. This results in considerable losses in harvest on the borders of these plots, during cultivation. These are small plots, 0.4 ha, narrow and relatively long. They average at the length approximately 210 m. Therefore, the land configuration costs for these areas are the highest and usually exceed 12 cereal units per hectare. A significant group (33%) of plots are between 25 m and 50 m wide. These plots have the proper length (average about 300 m), which is beneficial for cultivation and keeps the land configuration costs low. On the average, the cost is 7.4 cereal units per hectare. A similar group, in terms of size (32%) are plots whose widths range from 50 m to 100 m. They can be considered sufficiently large for mechanical cultivation [Harasimowicz 2002]. However, the larger widths of these plots, in the range of 360–440 m, are accompanied by increased cultivation costs in the range of 4.9 to 6.0 cereal units per hectare. The remaining group of plots, comprise 21% of the total number of plots covered by the study. In this scope, there is a significant decrease of plot length (from approximately 400 m to 250 m), which corresponds to the increase of cultivated area from 4.4 to 5.9 ha.
The average elongation of plots is around 1:7 (Table 1). This elongation, is the consequence of adequate plot lengths, which is close to the proper value, for the plots bigger than 1–2 ha, as it should be 1:5 [Stelmach 1971].

The number distribution of plots in Figure 4, shows that around 11% of analyzed plots have small elongation, not exceeding 1:2. Considered plots of elongation smaller than 1:2 have the average areas of approximately 3.2 ha and lengths of around 190 m. The faulty elongation of these plots leads to significant increase in cultivation costs which are about 7–8 cereal units per hectare. A large group of plots, covering 21% of their total number, has elongation ranging from 1:2 to 1:4. These plots of area, similar to those whose elongation is the smallest are much longer. They reach on average about 270 m. The land configuration costs of this group of plots is, about 8 cereal units per hectare which exceeds the allowable level of 5 cereal units per hectare. In the area of study, 17% of plots have the proper elongation of between 1:4 and 1:6. They have the optimal areas and their related land configuration related cultivation costs are proper [Harasimowicz 2002]. The rest of the plots have too large elongations for their area.
4. Location of arable lands on farms and in the village

The location characteristics of arable lands on farms were determined by the distance from the closest corner of the plot from the habitat and on the average distance of the middle of the plot from the habitats. In order to establish the location of the plot in the village, the distance of the closest corner from the center of the village was used.

The average distance of arable lands from habitats in Mściwojów is 1056 m. This is approximately 200 m longer from the distance of the nearest corners of plots from the habitats. The distance of arable lands from habitats is very similar to the distance from the center of the village. This is confirmed by the density of buildings in the southern part of Mściwojów. Figure 5, shows the number distribution of plots dependant on their distance from habitats. The first group consists of 22% of the plots. These plots according to Dembowska and Lachert [1974a, b] are properly located with respect to the habitats, which is no further than 500 m. About 77% of plots are located within 1500 m which is the proper distance according to Przybyłowski [1998]. In this interval, the plots have the suitable area of around 1.5 to 2.5 ha and the proper lengths from 230 m to 270 m. The propriety of these parameters is confirmed by the low land configuration related cultivation costs which is no more than 5 cereal units per hectare.

Fig. 4. Number distribution of arable plots depending on their elongation

<table>
<thead>
<tr>
<th>Elongation plots</th>
<th>Land configuration costs (cereal units per ha)</th>
<th>Area of the plots (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length plots (m)</td>
<td>Land configuration costs (cereal units per ha)</td>
<td>Area of the plots (m²)</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>200</td>
</tr>
<tr>
<td>5</td>
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Geomatics, Landmanagement and Landscape No. 1 • 2013
According to Manteuffel [1971], Dembowska and Lachert [1974a, b], Przybyłowski [1991], one kilometer more of distance of lands from habitats leads to an increase in labor from 10% to 25%. This in turn results in lower income from 4% to 25% per one kilometer [Stelmach et al. 1975]. Plots located further than 1500 m from habitats have bigger areas and lengths. However, gradual increase of these parameters is associated with increasing cultivation costs which exceed 10 cereal units per hectare. This group is 23% of all the plots.

5. Land configuration related cultivation costs

The majority of arable lands have cultivation costs which may indicate unsatisfactory land configuration for the object under study, which was not taken into consideration during land consolidation. Average costs incurred on the arable lands are around 7 cereal units per hectare and range from 2.6 to over 30 cereal units per hectare.

The number distribution of arable lands depending on the cultivation costs is shown on Figure 6. The first group of arable lands, 32% of their total number, has cultivation costs below 5 cereal units per hectare. It consists of plots located on average...
600 m from habitats, ergo the closest to the buildings. They have relatively large areas 1.9 ha and lengths close to 400 m. These plots have the largest areas and lengths from all the covered plots. The largest group consists of the plots on which the cultivation costs range from 5 to 10 cereal units per hectare. This group covers about 60% of agricultural lands, whose land configuration is close to average. Their average lengths are 340 m, areas 2.3 ha, and their average distance from habitats is about 1250 m.

Fig. 6. Number distribution of arable plots depending on their exploitation costs connected with land configuration

Around 5% of all the plots covered by this study, have the cultivation costs between 10 and 15 cereal units per hectare. Plots in this group have areas under 0.2 ha, lengths about 150 m and are located in distances under 1800 m from the habitats. The high cultivation costs for this group is associated both with disadvantageous land configuration and too long distance from habitat.

Very few of these plots (around 4%) have land configuration related cultivation costs over 15 cereal units per hectare. Such high cultivation costs occur on plots with the poorest land configuration, whose average distance from habitats ranges from 800 m to 4400 m. The lengths of these plots do not exceed 70 m and their areas are not bigger than 0.2 ha.
6. Summary

Based on the analysis of land configuration of arable lands in Mściwojów, it can be concluded that the majority (around 70%) of plots have area considered to be suitable for mechanical cultivation. The lengths of plots are also acceptable. Nine percent of the plots have lengths which generate high land configuration related cultivation costs, reaching 20 cereal units per hectare. Incorrect widths occur in approximately 46% of plots. A majority of analyzed elements have too large an elongation for their area. In most cases analyzed plots are properly located with respect to habitats, 23% do not. Based on the land configuration related cultivation costs (which are a synthetic measure for evaluating land configuration) it can be concluded that only 32% of plots are within the correct limit of 5 cereal units per hectare in this study. The rest significantly exceeds this value. The results indicate a need for reconfiguration of land which was not the object of land consolidation and exchange. This will contribute to creating much more beneficial economic conditions for their agricultural use.

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DATA PREPARATION FOR THE PURPOSES OF 3D VISUALIZATION

Paweł Gryboś, Marika Kaletowska, Urszula Litwin, Jacek M. Pijanowski, Agnieszka Szeptalin, Mariusz Zygmunt

Summary
The article presents a method of preparing input data for 3D visualizations. The authors implemented the proposed procedure when they were working on a visualization, with use of Autodesk 3ds Max software.

The test object were the ruins of a historic grange that belonged to the Nostitz family in Mściwojów (Mściwojów commune, Jaworski district, Lower-Silesia Voivodeship). After surveying the area and analyzing the data, using MicroStation with a geodetic application MK (Mapa Kontekstowa – context map), a Digital Terrain Model (DTM) was created along with contour lines, with use of Data Acquisition (a tool in some programs of Bentley). Next, the models of spatial objects were created using the authors’ software VITAL LANDSCAPES Tools, developed during the EU CENTRAL EUROPE program. It was the basis for development of a visualization of current land management, using the software Autodesk 3ds Max. This allowed the design of the future land management of the historic grange so that the landscape balance is maintained.

The data processed in this manner can be used for photorealistic visualizations in Autodesk 3ds Max or other graphical software.

Keywords
Digital Terrain Model • cultural landscape • 3D visualization • photorealistic visualization • data conversion

1. Introduction

One of the ways of protecting cultural legacy is proper management of space [Gołuch 2003]. It is getting simpler to protect and manage space, thanks to modern tools such as platforms for modeling and digital visualizations (e.g. Autodesk 3ds Max). They provide the opportunity to develop complex projects related to various areas, for example to model and visualize in photorealistic way the land management [Batty et al. 2000, Drettakis et al. 2006, Pawlak-Jakubowska 2012].
As a part of VITAL LANDSCAPES project, the test object of the ruins of the historic grange of the Nostitz family in Mściwojów, a visualization was made with use of Autodesk 3ds Max software. Spatial (geodetic) data from the measured object and photographic documentation were essential for this purpose [Pundt 2000]. Visualization of the present state allowed to incorporate new infrastructure and to evaluate if, it fits the landscape.

The data from field measurements was processed using MicroStation software (a Bentley product), with a dedicated geodetic tool MK – Mapa Kontekstowa (a product of GeoDeZy company). This set (MicroStation software with MK tool) comprises the basic tool of geodesists, to modify spatial data. Basing on this tools, a Digital Terrain Model was created along with models of buildings in the Data Acquisition application. This was also working in MicroStation environment.

The attempt to export a 3D model from MicroStation to Autodesk 3ds Max confirmed that the input data prepared in a different environment can be inconsistent. This is due to the fact that it contains different kinds of spatial information [Hejmanowska et al. 2008].

Analyzing the inconsistencies that occurred, allowed the development of a procedure for organizing the input data during the process of creating a visualization [Belcher 2006, Bojarkowski and Gościewski 2008, Gläβer et al. 2010]. Also, special software was developed, which assisted with closing the polygons made up of single elements (segments, arcs) and rises the elements to the terrain surface. These are determined by the grid of triangles of the Digital Terrain Model.

2. Research description

The data necessary to make a DTM can be prepared using different measuring methods. This creates therefore different errors. In the studied object of the ruins of the historic grange, the analyzed data was gathered through tachymetric measurements and GNSS (Global Navigation Satellite System). The materials needed to be organized by recognizing the contents of particular layers. This allows for the easy selection of layers, where the objects were contained using these automatic tools. The standard process’s to filter the data from different measurement methods by their usefulness.

2.1. Data Acquisition tool [Kaletowska 2012]

The next stages of work required a tool to construct a Digital Terrain Model (DTM) for Data Acquisition. This is available as software offered by Bentley (PowerSurvey, PowerCivil for Poland, InRoads, GEOPAK, MX). It allows for the import of data originating from various software:

- measured data,
- raster models of spatial data and,
- Digital Terrain Model formats.
Due to this process, all the data is connected and saved in one “*.dgn” file and then can be exported to different file formats.

Preparation of input data, that contain large quantities of elements require carefully distinguishable graphical objects, such as:

- scattered height points,
- discontinuity lines or
- boundaries of the map

are required to be placed on different layers. These layers names would suggest their contents. The layers will serve as a base for a Digital Terrain Model (DTM) that consists of triangles network (TIN – Triangulated Irregular Network) and isolines for the analyzed area. These will be generated automatically using the Data Acquisition tool. The triangles network and isolines are stored on users surface (Surface) in features (Features) of triangles network (Triangles) and isolines (Major and Minor Contours).

Generating a Digital Terrain Model (DTM) in the form of TIN (Triangulated Irregular Network) is an automated process based on the imported data. Input of new elements results in an automatic modification of Triangles and Major and Minor contours.

The generated TIN form is required to be verified by the user, if the triangles form created by the program is correct. At this point, it is possible to modify the selection of points and lines that the TIN and the contours are based upon. Tools for creating a Digital Terrain Model (DTM) also offer additional options, such as defining the maximum length of the TIN. This can eliminate the unreliable propositions of the network, at the stage of creating the model [Majde 2011].
A ready surface in the form of Triangulated Irregular Network (TIN) can be exported to “*.dtm”, a universal format for storing Digital Terrain Model. This also allows for a possibility to save and store the model in a “*.dgn” file.

Using the Data Acquisition tool, the last stage of the procedure is creating the isolines, and then adding the contour lines with a specified interval into the “*.dgn” file. The contour lines are divided into primary and secondary lines. Placing them on different layers, depending on the interval set by the user, allows the user to adjust the clarity of the image. All contour lines below the zero level and their descriptions lay on separate layers.

Source: Gryboś 2012

**Fig. 2.** Output data: network triangles supplemented with contour lines

### 2.2. VITAL LANDSCAPES Tools Application [Gryboś 2012]

In the next stage, with the use of VITAL LANDSCAPES Tools application, the triangles of the network are used to project objects of the map onto the terrain. Meanwhile the contour lines will be the basis for developing a visualization in Autodesk 3ds Max.

VITAL LANDSCAPES Tools, on Bentley’s CAD software was designed and developed as a part of the VITAL LANDSCAPES project, which is a part of CENTRAL EUROPE program. It assists in creating objects by closing the polygons made of single linear elements (segments, arcs) and raising the elements to the level defined by the TIN, of the Digital Terrain Model.

The functions of the VITAL LANDSCAPES application are contained in two windows. The first part of the window is named Object tools (Figure 3a). With its use, one can place selected geometrical forms of an object on a given surface of a Digital Terrain Model. This function requires a previously prepared surface, such as a Triangulated Irregular Network. Due to the function *Lift object options*, the objects
drawn on different heights in project space of the file can be adjusted to any planned surface. This means, that they can be placed to a new height without copying them.

Objects can be moved in two modes:

- **center point** – when lifting the object, only the height of the centroid is taken into account,
- **all points** – each point of a geometrical object is independently lifted to a 3D model.

![Image of Vital Landscapes Tools application: a – Objects tools window, b – Export data window](image)

Source: Gryboś 2012

**Fig. 3. Vital Landscapes Tools application: a – Objects tools window, b – Export data window**

The second part of *Object tools* window – *Create objects* is used to perform the so-called objecting. Objecting is a process by which the user creates one consistent polygon out of many linear elements (segments, arcs). This is accomplished by closing the shortcomings and intersections with a preset tolerance. Dynamic creation of polygons by pointing to linear elements of an area or a shape which will replace the partial elements. This function allows the possibility to model regular objects, such as buildings.

The option **Move new object on level** is used to control the placement of new objects. Depending on the selection in this window, a new element will be placed on a layer, on which the connected linear elements are located or on a dedicated layer, for storing newly created objects. Their location in space is dependent on the settings of active height in the drawing.
At this stage the objects connected by the function *Create objects* and objects created without using this function are flat. In the second window of the application, called *Export data* (Figure 3b), the *Extrude* function allows the creation of solids out of these elements. This means that selected closed elements will be expanded to the 3rd dimension and will have the height determined by the user.

When it comes to exporting different types of objects, it is best to do it by incremental steps. This allows for the proper assignment of height to buildings, depending on their type. Additionally, approximate heights of forests are modeled.

Objects created in such a manner, will be stored in a special text file with “*.dat” extension. As the format developed by participants of the project, shown below. The scheme of objects in a file is shown on Figure 4.

Source: Szelest 2012

**Fig. 4.** Scheme of objects in file

Special characters used in this format are described in Table 1.

**Table 1.** Special characters [Szelest 2012]

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The formats used to exchange data between Bentley applications and *Autodesk 3ds Max* are listed below:
DATA PREPARATION FOR THE PURPOSES OF 3D VISUALIZATION

• The highest level objects:
  #SCENE – scene type object,
  #SPLINE – spline type object,
  #MESH – mesh type object,
  #CELL – point object (cell),
  #EOF – end of file.

• Parameters:
  @NAME – name of an object,
  @KNOT – knot,

• Type {korner, bezier},

• Points [x, y, z],

• Access path to the object:
  @TopVector [x, y, z] – zenith vector of an object ascribed to the knot,
  @MeshType – net side type (3 triangle, 4 quadrangle),
  @SplineClosed (true/false) – automatic closing of a spline,
  @Color [r, g, b] – object color,
  @Extrude [h] – height of closed objects (buildings, forests).

2.3. Autodesk 3ds Max application

Thanks to the application and use of the procedure the objects of the model were successfully imported into Autodesk 3ds Max (Figure 5). This was the goal of the procedure.

Source: Inspired by U. Litwin, developed in 3ds Max by P. Szelest

Fig. 5. Initially processed data in Autodesk 3ds Max views
The model was expanded during the processing (with use of Surfer software) to the neighboring areas which provides the illusion of a remote horizon [Zygmunt 2012]. Creating a model in a presented way does not require additional data, however, shows the outside of the area in a simplified manner.

Terrain model preparation was the basis for the photo – realistic visualization, but it is needed for landscape to show the designed object in its real environment. (e.g. to compose new infrastructure elements based on old ones and terrain). That’s why photogrammetric method was used to get the DTM (Digital Terrain Model).

After creating DTM, the model was textured. The buildings were textured with ground-based photographs and the terrain was textured with aerial photographs, including area outside of the test object. Next, a model of firmament was added and energy balance was directed. This gives the shading effect.

The picture above (Fig. 6) shows a photo-realistic visualization made using photogrammetric tools [Mitka, Szelest 2012]. The same effect can be achieved as a result of the suggested by authors procedure.

At the stage of designing new infrastructure, a photorealistic visualization allows the possible addition of modern buildings such as an observation tower or sport objects, without destroying the harmony of the landscape (Figure 6).

3. Conclusions

Preparing the data for the purpose of 3D visualization is a very complex procedure. The authors suggest the following sequence of actions to make it simpler:
• Prepare the input data and arrange the "*.dgn" file containing spatial information about the analyzed area in Bentley software.
• Create a Digital Terrain Model (DTM) with use of the Data Acquisition tool.
• Place the objects on the terrain model with the use of the Vital Landscapes Tools for MicroStation application.
• Close the polygons and the spatial modelling of them with the use of the Vital Landscapes Tools for MicroStation application.

Data prepared in this manner can be used for making a 3D visualization in software dedicated for such purposes. For the purpose of VITAL LANDSCAPES, a photorealistic visualization was made in Autodesk 3ds Max. Any of all these tools can be used in the process of creating more complex visualizations.

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THE APPLICATION OF GROUND-BASED AND AERIAL PHOTOS IN SURVEYING AND VISUALIZING ARCHITECTURAL OBJECTS IN MŚCIWOJÓW

Bogusława Kwoczyńska

Summary

The article presents the possibility of using pictures taken with aerial and ground-based metric measuring cameras in surveying and visualizing architectural objects. The areas of interest include historic and damaged buildings belonging to the farm complex in Mściwojów, in Lower Silesia. To prepare vector architectural drawings, digital photogrammetric station Delta, as well as a digital autograph VSD were used. The digital terrain model was generated on the basis of aerial photographs, and the visualization of the whole village with the body of water in Mściwojów was developed using MicroStation software.

Keywords

architectural survey • visualization • ground and aerial photo

1. Introduction

Surveying historic buildings involves creating the fullest documentation of objects possible, but it also involves the use of advanced equipment and technology allowing the restoration and reconstruction of object shapes in a precise manner. This is possible by using the knowledge and experience of many specialists, including surveyors specializing in photogrammetry. Surveying boils down to a collection of documents produced as a result of research, detailed measurements and analysis conducted by conservators and specialists in various fields of science and art. Surveying is the foundation and initial condition for protecting monuments from destructive forces of nature and man, and reconstructing them in the event of damage [Zawieska 2008]. Because of the created documentation, surveying is important in conducting maintenance of monuments. Its basic component is architectural survey, which includes:

• horizontal projections,
• facades – external wall plans (mostly photographic maps),
• documentation of the roof truss.
Short-range photogrammetry plays an important role in the process of creating this documentation. Photogrammetric documentation presents the spatial state of an object and allows for performing measurements on the created model. It is the basis for monument reconstruction and can also be used for comparison in reconstruction of a similar object. This is common in the case of no original documentation being available. Such issues has been handled by CIPA for many years [Lerma García 2002, Kasser and Egels 2000, Kasser and Egels 2001, Patias and Karras 1995, Batic et al. 1996].

Photogrammetric works try aiming to survey architectural monuments by the careful documentation of a present state. Photographs of buildings taken for this purpose can not only be used in cartometric studies but they can also be the basis of such documentation. Photogrammetry allows to obtain the needed material in a remote way and it is therefore often irreplaceable in measuring unreachable elements. It can be freely used for the measurement of highly irregular components. Photogrammetric studies also have another important use. The final effect of photogrammetric works, often created in 3D, can be posted on websites allowing everyone to see remote and sometimes difficult to access places and enjoy the sights unavailable for everyone. Often such websites are created precisely to promote these places and encourage tourists to visit them.

Source: http://www.msciwojow.pl/

Fig. 1. Aerial view of Mściwojów
2. Research object characteristics

Architectural objects covered by the study are located in the municipality of Mściwojów in the central part of the province of Lower Silesia in the Jawor county. In the village Mściwojów there is a historic mansion from the 17th century along with a complex of farm buildings, a tower and a wall (Figure 1).

3. Research methods

To perform studies on architectural objects which employ photogrammetric methods, most often digital photographs are used. These are photographs obtained either directly from digital cameras or scanned from analog photographs taken mostly by metric or semimetric cameras. Sample studies are based on photographs taken by metric cameras UMK 10 and RC 20.

Ground-level images were taken as normal (optical axes of cameras were also approximately perpendicular to the facades of the buildings) and the basic length of the photographs was assumed taking into account both precision of the study and stereoscopical observation conditions.

The stereograms were aligned using natural characteristic points which were background details for the objects under study. The coordinates of these points were measured independently from the photogrammetric methods (using reflectorless total station in case of the tower in Mściwojów), and also some of the coordinates were obtained analytically (by adjustment of photogrammetric network – in case of the farm building façade).

Elaboration of tower in Mściwojów

The historic tower along with a wall is located near an orangery belonging to the mansion houses in Mściwojów. Its north and south facades were elaborated photogrammetrically with use of two different tools (VSD digital autograph and Delta digital station). The photographs were taken in the year 2008 using UMK 10/1318 camera and then were scanned with the resolution of 24 µm (Figure 2).

The description of the tower required internal alignment and interalignment on the VSD digital autograph to be performed beforehand. The precision of the results can be supported by the achieved results in which the average coordinate errors of photopoints are: \( m_x = 0.01 \) m, \( m_y = 0.02 \) m and \( m_z = 0.01 \) m. In the case of the south façade the description was based on Delta digital station. Surveying of the object was possible after previous alignment of the model for which the photopoints and following RMS values were achieved: \( m_x = 0,01 \) m, \( m_y = 0,02 \) m i \( m_z = 0,10 \) m.

Description of the south facade of the farm building in Mściwojów

In the central part of Mściwojów next to the garden formed in the 17th century belonging to the von Bibran family there is a complex of farm buildings (Figure 3). Nowadays these buildings are damaged and require renovation. Some of them are residential buildings, the others are farm buildings.
Surveying of the south facade of the farm building was performed based on the ground-based photographs taken with UMK 10/1318 camera in the year 2008. The photographs were scanned in the resolution of 24 µm per pixel on the Digital Photogrammetric Scanner Delta 2 by GeoSystem.
The elongated shape of the building required eight photographs and due to this terratraiagulation was used. The object was described in the local coordinate system, assumed for the central base of shooting. The surveying was performed using a digital photogrammetric station Delta. Because the scales of the photographs were similar, conducting the terratriangulation was comparable to the process of aerotriangulation performed on aerial photos. Employing terratriangulation allowed adjustment of the block of all photos in GeoSystem MSG program. Adjustment was performed on 12 natural photopoints. As a result of adjustment of the block of photos the following average errors of photopoint coordinates were achieved in the XY plane $m_{XY} = 0.08 \text{ m}$ and in case of height, $m_{Z} = 0.14 \text{ m}$.

**Application of aerial photos in creating a 3D model of Mściwojów**

Nowadays, technological development in the IT industry offers many possibilities of application of aerial photogrammetry products. Basing on the Digital Terrain Model or Digital Surface Model with application of suitable graphical tools one can create 3D visualizations of objects like for example models of cities or towns. Such models are numerical, three-dimensional (3D) representations of selected elements of urban space, integrated with the library of descriptive data.

Depending on their complexity models can include buildings, rivers, road, railroad networks, bridges, lakes, forts, graveyards, forests, wooded areas and sport facilities, high industrial buildings, district borders, allotments, and so on. The more elements, the more faithful the representation depicted. The objects can be placed in the Digital Terrain Model and also descriptive data can be attached to them. Thanks to such actions a complete 3D model of an area can be obtained, and it would show most realistically the spatial representation of the terrain. Such visualizations are nowadays one of the basic products of photogrammetry.

The 3D model of Mściwojów was developed using data obtained using a digital photogrammetric station Delta basing on aerial photos taken in the year 2004 in the scale of 1 : 26000. They were panchromatic pictures taken using RC 20 camera, which were scanned with the resolution of 14 µm per pixel. The measurement was performed basing on a block of photographs covering the terrain within the boundaries of Mściwojów.

Alignment of the pictures was performed in the process of digital aerotriangulation with the use of natural photopoints obtained from the topographical maps in the scale of 1 : 10000. As a result of the alignment such average errors were achieved in the XY plane $m_{XY} = 0.77 \text{ m}$ and in case of height, $m_{Z} = 0.56 \text{ m}$.

4. Research results

Facade models (wiremesh and solid) and vector drawings obtained during photogrammetric works are often used by architects and conservators to create architectural documentation for historic buildings of religious or secular value. They serve as source of information necessary to recreate for example the precise state of the
object from before the renovation, creation of orthoimaging of the object or a very precise sections [Kędzierski et al. 2008].

The sections are often accompanied by computer made models of objects with use of CAD software. 3D reconstruction of an object is nowadays a very popular presentation of architectural documentation and photogrammetry. As a source of data for this purpose, it is still one of the best methods to use.
The model of the tower in Mściwojów was created as a result of surveying both north and south facade of the object. All the losses in plaster as well as any other damage were marked on it (Figures 4 and 5). The graphical vector description is a result of the previously created stereomodels and always contains less information than the models themselves. It is visible, especially on the descriptions of complex forms and shapes, which are often subjectively represented, depending on the skills and resources of the specialist. Working on a stereomodel allows the specialists to faithfully recreate the geometry and to analyze more fully the style and characteristics of the object under research [Gołka et al. 2000].

During the survey of the farm building in Mściwojów, close attention was paid to the damaged parts of the facade and the roof. After vectorization, the drawing was saved in DGN format, which allowed to create a 3D model of the south part of the façade of the farm in MicroStation software. The final effect is visible on Figure 6.

In order to obtain the Digital Terrain Model many situational and height measurements were performed for the infrastructure of Mściwojów (buildings, roads, body of water) as well as for the terrain itself (slopes, trenches) marking the boundaries of excluded areas (forests, orchards, shrubbed areas) and discontinuity lines. Vectorization of the object was performed in 15 layers. The result is visible in Figure 7.

Height measurements, lines of terrain discontinuity and exclusion borders were used to generate the Digital Terrain Model (DTM) in the form of a grid with unit 10 m. The DTM of Mściwojów generated on the photogrammetric digital station Delta was then exported to a format that allowed its further processing in MicroStation software. Then a TIN model (triangle model) was created along with grid models of buildings. In order to visualize the Digital Terrain Model and the buildings rendering with artificial textures were used. A file containing the buildings was then attached to the file containing the terrain data, in order to visualize in 3D the whole town. The end effect is visible on Figures 8 and 9.
Fig. 7. Mściwojów. A vector drawing

Fig. 8. Visualization of a part of Mściwojów
5. Summary

Employing photogrammetric methods in surveying and describing buildings is a very good solution. Once made stereograms can be processed in steps depending on the needs, ergo an object partially developed can be furtherly developed at a later date so that it suits the current needs. It allows to significantly lower the costs of surveying and conservation of buildings [Kwoczyńska 2012]. Creating 3D models of single objects and complete towns and cities is very popular nowadays. 3D visualizations can be simplified models of areas. These can be later used for animations. They are very helpful in creating full architectural documentations.

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APPLICATION OF SURFER SOFTWARE IN DENSIFICATION OF DIGITAL TERRAIN MODEL (DTM) GRID WITH THE USE OF SCATTERED POINTS

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Summary
This article explores the problem related to preparing the digital data used for 3D visualizations on big areas. Because of the frequent problem of having only a small amount of such data the authors introduce a technology allowing densification of the data that make up the Digital Terrain Model. This is where SURFER software finds its application. These methods are sufficient to generate images for landscape visualization.

Keywords
landscape • visualization • Digital Terrain Model (DTM)

1. Introduction
1.1. Data
Landscape visualization is one of the specific tasks of 3D modeling. This problem requires preparation of data that allows visualization of very big areas. An additional obstacle in data preparation is the necessity to “grasp” the horizon, not only from the point of view of an observer on the ground, but also from the bird’s eye view. We do not always have the possibility to collect satisfying data which would reflect the realism of the space surrounding us [Wytyczne... 2003a, b]. However, we very often have partial data. Data can be obtained in different ways. In cases where no digital data is available, it can be obtained directly from analog maps. In such situations there is a necessity to prepare the materials in a manner that would prevent the 3D model of the space surrounding us, from having unnatural terrain forms such as sudden terrain shifts or terrain discontinuities. One of the better solutions is densification of terrain points with “artificial” coordinates, calculated basing on the XYZ data. It can be performed in many ways. In this article, the suggested solution is the use of SURFER software.
1.2. Description of SURFER software

SURFER software is a product of Golden Software, Inc. and finds its use among others in creating representations of terrain surface. With its use, one can for example generate isoline maps, 3D maps, create sections of 3D maps, and calculate volumes and surface areas. Generation of such maps requires an algorithm, which will prepare the data for 3D visualization in a form of a map, basing on the input data (in most cases measured XYZ coordinates of points).

SURFER software uses a regular grid of points called GRID. This feature is used for processing insufficient amounts of input XYZ data and preparing them for later use in visualization module.

During data preparation there is a possibility to preview an approximated form of a 3D map.

![Fig. 1. An example of XYZ measurement data](image)

The SURFER package offers many methods of interpolation to determine the elevation of grid nodes. The adapted calculation algorithms allow choosing the most suitable ones, depending on the XYZ input data, its quantity, density or distribution.

1.3. Regular grid of values

SURFER software operates on a regular grid of XYZ values. This means that the interval of grid's element in the direction of the X axis is always constant. This is
The main goal of developing a GRID is to establish a surface composed of regularly distributed XYZ points in such a way that the input points would be contained within.

The most important task is determining the vertical coordinate. This is done by using the interpolation or extrapolation method. Interpolation can be done in many ways.

Unfortunately, extrapolation does not always give the desired results. However, in the case of preparing the required data for visualization on big areas, we have to use this method. This limits the number of ways in which the regular grid of values can be created.

A significant part of the job is developing a GRID. One of the key parameters is the investigated range of node surroundings, which implies selection of the points in the set of input data. To calculate the vertical coordinate in the grid eye, the key data (apart from the point elevation) is its distance from the node.

It determines the degree in which the value of the function, in the point of input data is reflected on the point elevation in the grid node.

Fig. 2. An exemplary file containing coordinates Number X Y Z

Source: own study

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The value of the function in the node point located in \((i, j)\) position can be expressed by the following formula:

\[
Z_{i,j} = w_1 \cdot z_1 + w_2 \cdot z_2 + w_3 \cdot z_3 + w_4 \cdot z_4
\]

where:
- \(Z_{i,j}\) – value of the function in the node located in \((i, j)\) position,
- \(z_1-4\) – value of the function in exemplary points 1–4, taken from the input data set,
- \(w_1-4\) – weight coefficients in the points 1–4, taken from the input data set.

The weight coefficients determine the influence of the elevation taken from the data points on the value of the function on the calculated node located in the position of the \(Z_{i,j}\) point of the GRID.

For the purposes of this study the assumed test quantity of the points is 4. It can be selected in a wider range. However, one should remember the calculations will be much longer in case of very big areas that contain a large number of nodes.

1.4. Input data verification

A separate problem is the process of data filtering. Its aim is to eliminate incorrect points from the set of input data. To verify the set of input data it is recommended...
in the beginning to generate a report regarding the basic statistics of the data. Then, based on the report, we can determine if the set of input data contains potentially incorrect information.

Because there is a possibility of errors that are duplicated X Y coordinates, the program eliminates them. This is a necessary step for algorithms for GRID development. Another possibility is having incorrect data in the set because of the range of investigation. The program also offers a possibility to filter the coordinates with an option to determine the acceptability of the data.

The data excluded from the interpolation can be later defined according to X, Y and Z axes. The rules of exclusion are defined as complex logical operations.

2. GRID generation

2.1. Selecting the interpolation method

Properly prepared and verified input data is the basis for creating a regular grid of values GRID. The SURFER software offers 12 methods of grid generation to choose from. Because of the large number of interpolation methods, one should keep in mind a few basic criteria while choosing, such as: number of input points, area of elaboration or necessity of extrapolation. Additionally, each of the methods has its own set of parameters [Galon 2009].

For the purposes of the presented method of calculating data for densification of grid XYZ points, we are basing the GRID on the Kriging method, as a default method of GRID development. However, another criterion that had to be taken into account was the amount of input data. In case of insufficient data, a more reliable interpolation method would be used, for example the Polynomial Regression method.

While creating a GRID, the SURFER software can take into account the edges of discontinuity. The program offers two methods: Breaklines and Faults. Both are used for the same purpose.

The Faults method sharpens the generated model while Breaklines generates smoother forms. During calculations the Faults algorithm does not intersect the edges of discontinuity, it omits them instead. This results in an increase of the distance between the determined grid point from the known point. It decreases the weight of this point which influences the final calculation of the vertical coordinate.

The Breaklines algorithm uses the elevation obtained from intersecting the edge of discontinuity with the line drawn from the grid node which has known coordinates. Both of these methods require different input data formats. For the Faults method the XY coordinates of the edge are sufficient. The Breaklines method requires in addition defining of the vertical Z coordinate.

All this information has to be loaded into the program in a form of a text file, in which we define the coordinates of the edge of discontinuity of the terrain. Unfortunately, not all of the interpolation methods allow for applying the technology of defining areas of discontinuity. Lack of it results in flattening of the model, which
in case when very faithful representation of the area is desired, limits the selection of interpolation method.

2.2. Interpolation quality evaluation

When we have to test several interpolation methods in order to select the best one or to select the proper parameters, we can use the interpolation evaluation [Longley et al. 2006]. The main idea is to build a grid and then to interpolate the heights for data points basing on the generated grid. The deviations from the real values inform us about the precision of the generated model.

We can test all the points or only a part of them. For large sets of data it is recommended to test only a part of them by providing proper information in the field *Number of random points to validate*. There is an additional filtering option, which allows limiting the range by minimum and maximum coordinates X, Y, Z – *Select validation points within these limits*. The results of the report are saved in a text file.

The basic parameters for the grid interpolation are:
- the average error,
- the standard deviation,
- the variance.

2.3. Interpolation grid data

Using the program options we have a possibility to change the density of grid elements. The software automatically calculates the range of minimal X and Y coordinates. One should remember to operate these parameters in balanced way. This data will be used later for creating the DTM in the following steps of the developed technology.

A grid that is too dense can contribute to a necessity of using fast computational units and a large amount of operational memory. To use the GRID in generating a DTM in different systems we have to be able to use its data. The simplest way is to save it in a text file with a space separator.

2.4. A quick preview of the results of calculations

Before exporting the data to a text file, it is recommended to use the results of calculations to visualize the grid (3D Wireframe feature in the SURFER software). Quite frequently, such a procedure gives us sufficiently reliable information about the applicability of the performed calculations. The presented model can be scaled, zoomed-in, rotated. Basing on the previews, we can determine if the input data contains major errors. Elimination of such errors should be performed before the final processing in graphical software.
Source: own study

**Fig. 4.** A quick preview of a grid

Source: own study

**Fig. 5.** A quick preview of a grid with visible results of incorrect input data
Source: Galon 2009

**Fig. 6.** A map before and after smoothing
2.5. Modifying the GRID

While using the program we can encounter a situation, in which the generated grid does not meet our expectations related to its later application for the purposes of landscape visualization. The SURFER software offers a way to correct it. It can be done using filters. The general rule of filtering is calculating the height of the analyzed node using the heights of the neighboring nodes. The process is based on algorithms which are most commonly used for image processing [Tadeusiewicz and Kohorda 1997]. We can choose from convolution filters:

- low-pass,
- high-pass,
- first order differential with edge detection,
- second order, calculated basing on Gaussian and Laplacian,
- gradient and other.

To obtain the required effect, the filter has to be averaging. The range of the analysis of neighboring nodes is selected in the program settings.

3. The results of using the SURFER software in a 3D visualization of the grange in Mściwojów

The described procedures were applied in practice during an international project: VITAL LANDSCAPES which is a part of the EU program CENTRAL EUROPE. One of the main goals of the project was to create a 3D visualization of a test object – a complex of historic ruins of the grange belonging to the Nostitz family in Mściwojów (Mściwojów commune, Jaworski district, Lower Silesia Voivodeship).

Source: own study

Fig. 7. A top view of the terrain model of the test object in an orthogonal projection
After creating the terrain model for the test object, it was noticed that it looked unnatural during manipulation in the 3D view. The reason for this is the concavity of the polygon defining the range of the study (see Figure 7) and the lack of continuation of similar surface outside of this area.

Supplementing the data around the area under discussion and using any geodetic method is time-consuming, and is not necessary for obtaining the satisfactory visual effect. For the purpose of visualization, the model of the object was placed in hypothetical surroundings. They were generated by densification of data using the GRID with the application of SURFER software. The Kriging algorithm was used with the default settings. The distance between nodes was set to 10 meters. Spreading the grid outside the visualized area, smoothed the image and removed the illusion of a chasm outside of its boundaries. These illusions are clearly visible while manipulating the object and observing it in 3D. This is the reason why the comparison of the effects of visualization was presented in an oblique projection (Figures 8 and 9). In this view, we can clearly see, that the generated grid adapts seamlessly to the boundaries of the model.

![Source: own study](image1.png)

**Fig. 8.** An oblique projection of a part of the model

![Source: own study](image2.png)

**Fig. 9.** An oblique projection of a part of the model of the extended area with the generated grid of points outside of the studied area
To obtain the best visual effect one should generate the grid of points in a wide area in such a way, that the effect of a far horizon is observable. As we get further from the modeled object, a flattening of the terrain model will happen. Applying a wide range of additional points will let us view the modeled objects conveniently from different perspectives, including those further away.

4. Conclusions

The issue of landscape visualization is connected with the necessity of preparing data on large areas. As such data may be incomplete, we are forced to look for substitute solutions. The technology employing the SURFER software is sufficient for these purposes.

Preparation of the data is quick; moreover the data is verified. This applies to both input data and the final results: a terrain coverage grid. This technology can be freely used for such purposes.

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LANDSCAPE DIALOGUES – DISCUSSING LANDSCAPE ISSUES WITH LOCAL PEOPLE

Lukas Löschner, Georg Neugebauer, Gernot Stöglehner

Summary

Human impacts on landscapes pose serious threats to Central European landscapes (e.g. urban sprawl, land consumption and loss of landscape diversity and biodiversity) and consequently, influence quality of life as landscapes are a key factor in individual and social well-being and affect everybody. Therefore, public participation is an issue of great significance when elaborating visions and action plans for sustainable landscape development. In order to implement participatory discussion of landscape issues, “landscape dialogues” in the Austrian LEADER region Mühlviertler Kernland were organised in the framework of the VITAL LANDSCAPES project. The introduced method proved to be an adequate instrument to create awareness and to give local people a forum to elaborate on visions and concrete actions for sustainable landscape development. In the course of the “landscape dialogues”, complex issues of landscape development, e.g. the renewal of village cores, the cultivation of low-productive grasslands, the management of small-structured landscape elements as well as the increase of renewable energy use were addressed and gave impulses in some involved municipalities to continue the discussion in communicative and participatory planning processes within the Local Agenda 21 framework.

Keywords

Landscape development • public participation • Local and Regional Agenda 21 • European Landscape Convention

1. Introduction

Cultural landscapes in Central Europe are endangered although they are of great value as evidence of our natural and cultural heritage (ELC). This is often associated with loss of diversity caused by urbanisation, increased accessibility and globalisation [Antrop 2005]. Considering that landscapes are a key factor for physical, intellectual and spiritual well-being of individuals and societies [Dejeant-Pons 2006], a loss of landscape diversity will also cause a substantial loss of quality of life. Landscapes have an impact on the regional and local identity of the people and the potential to be relevant for sustainable landscape development [Meier et al. 2003] for which reason public participation is an issue of great significance to reach sustainable land-
scape development [Jones 2007, Sevenant and Antrop 2010]. Therefore, objectives for participation should include awareness raising that our everyday actions have an impact on landscape development, visioning for sustainable landscape development and action planning to elaborate concrete implementation measures.

Consequently, the ELC (Art. 2A) deals with the question of public awareness calling for a stronger valuation of landscapes, such that landscape issues are established and raised in the societal value base. The communicative planning paradigm that perceives planning as a consensus and democracy-oriented process between citizens, decision-makers and planners [Healey 1997, Müller 2004, Selle 2004] is suitable to reach common ground for the inclusion of landscape issues in the societal value base. A central part of communicative planning processes is to express the value base as visions which are placed in the centre of the respective planning process. In doing so, participatory planning can make an important contribution to an improved and more comprehensive decision-making [SGP 2010]. It supports the generation and formulation of a clearly defined and transparent value base as a precondition for traceable decision making [Stöglehner 2010].

From a learning theory perspective, such a process can be understood as a collective learning process that can induce two ways of learning by reflecting on the consequences of recent developments and proposed actions [Argyris 1993, cited by Innes and Booher 2000, Stöglehner 2010]. In single loop learning, a reflection of the consequences of proposed actions leads to adaptations of an action programme (including mitigation and compensation measures) without questioning the vision and the underlying values of the planning/development process. In contrast, double loop learning also questions the values and vision and therefore, undesired consequences might induce a general change of the vision. In terms of sustainable landscape development, it is not only necessary to mitigate or compensate for negative impacts on landscape “end of pipe” but to change societal processes that shape landscapes. This calls for double loop learning in communicative planning processes with participation of the wider public.

This theoretical framework grounds the approach of “landscape dialogues” as a participatory method developed and tested in the Austrian “Vital Landscapes” (www.vital-landscapes.eu) pilot project. The “landscape dialogues” aim to (1) create awareness by local and regional people that everyday actions shape landscapes, (2) to give the local and regional people a forum to elaborate on their visions concerning landscape development and the position of landscape in the local and regional value base, (3) to think about actions, how to put these visions into practice. In the following pages, the concept of “landscape dialogues” based on the application in the Austrian pilot region Mühlviertler Kernland is described, followed by a discussion of the approach.

2. Landscape dialogues
The Austrian “Vital Landscapes” project team conceptualised and introduced “landscape dialogues” as a two-part workshop series, based on the Local Agenda 21

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approach. This was to implement participatory discussion of landscape issues with the local and regional population. In this activity the authors representing Academia were supported by the SPES-Academy, a company that inter alia, is specialised in guiding and moderating community development processes like Local and Regional Agenda 21. Accordingly, from September 2011 to April 2012, eight workshops in four locations in the LEADER region Mühlviertler Kernland (two single municipalities and two co-operations of municipalities) were organised involving altogether eight municipalities. The aim of the “landscape dialogues” was the involvement of the

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Fig. 1. “Landscape dialogues” process scheme (continuous border line, shaded – community action; dashed border line – desktop work of process attendants)
public, in the elaboration of visions and goals for sustainable landscape development, as well as concrete implementation measures. The participation process comprised the following steps (see Figure 1).

During the starting phase, municipalities selected by the authors, in cooperation with the LEADER region, could be sensitised and interested in active participation in the VITAL LANDSCAPES project, via discussions in the respective municipal councils or responsible committees (e.g. spatial planning committee). When the decision to participate was taken basic information on the current landscape situation in the respective municipalities was gathered in a preparatory meeting with local stakeholders and municipal representatives. This was done in the form of a discussion session. Subsequently, a short visit of the municipal territory together with the mayor provided an insight into the landscape so that the process attendants could get an overview of the current situation in the respective municipality. Based on this information and a desktop analysis, the contents of the first “landscape dialogue” were elaborated. The public was invited to participate via municipal newspapers and websites, conventional and electronic mailing as well as personal invitations. “Landscape dialogue I” was focused on problem description applying the Group InVENTion Method (GIVE) by SPES (Stöglehner et al. 2006) and goal definition with the aid of the fruit-tree-method [SPES 2006]. The GIVE method is a tool to collect ideas in groups of people in a very efficient way. As a first step, the workshop participants give their personal answers to several questions, written on a flip-chart. In a second step, a prioritisation is done where the participants have the possibility to show their own priorities giving three points for each flip-chart (question). In the second part of “landscape dialogue I”, small working groups of participants focus on the goal formulation for vital landscapes related to landscape issues outlined on several flip-charts of the GIVE method. Each working group composes a fruit tree, in assembling fruits (= goals), blossoms (= implementation measures) and leaves (= framework requirements). On the basis of the evaluation of the first workshop evening, several topics for the discussion in the second “landscape dialogue” were selected, after consultation of the municipal representatives. Marketing activities were carried out in the same way as for the first workshop. “Landscape dialogue II” aimed at the elaboration of concrete implementation measures. Together with the workshop participants several out of the agreed-in-advance topics were chosen for a discussion in greater depth in the second workshop evening, applying the 10-finger-check according to Hujber [2007]. This method supports the elaboration of clear project plans, along a set of ten key points: data (thumb), clarity of goals (index finger), obstacles (middle finger), tour guides (ring finger), small steps towards to great success (pinkie), dialogue and marketing (thumb), cooperation (index finger), mentor (middle finger), bill (ring finger) as well as bits and bobs (pinkie). Finally, the evaluation of both “landscape dialogues” was incorporated into the formulation of landscape quality objectives as well as concrete implementation measures. This

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1 In German, the first letter of each key point corresponds with the name of the finger.
provided the municipalities and the LEADER region a basis for their further work on municipal and regional level.

3. Results

The “landscape dialogues” provided insights regarding the public perception of landscape in the respective municipalities participating in the VITAL LANDSCAPES pilot process. This enabled a critical reflection of ongoing landscape developments. Based on these findings, the authors formulated landscape quality objectives for the LEADER region, providing a normative framework for future landscape development. With “landscape quality objectives” the competent public authorities shall express “the aspirations of the public with regard to the landscape features of their surroundings” for each specific landscape (Art. 1 ELC). Landscape quality objectives could be defined as objectives related to landscape development that define the future state within certain areas, and the timeframes within these states should be reached [Neugebauer and Stoeglehner 2012].

On the one hand, the “landscape dialogues” indicated a high level of satisfaction with regard to the current state of the landscapes in the Mühlviertler Kernland region which many participants judge to be “predominantly intact”. On the other hand, the residents see the current state of the landscapes under threat. Changes in land-use (e.g. urban sprawl), structural changes in the primary sector (e.g. a trend towards more efficiency and bigger plots) as well as changes in the system of energy supply (e.g. land-use for the production of renewable energy) were identified as relevant influencing factors.

Due to a generally high level of satisfaction with the current state of the landscape, the landscape quality objectives overwhelmingly have a conservatory character (e.g. “preserve landscape diversity” or “maintain small-scale farming”). However, several landscape quality objectives (e.g. “develop public recreation areas” or “increase the use of renewable energy sources”) indicate that landscape development is acknowledged to be a dynamic process and subject to change and outside influences [Löschner et al. 2012]. The individual objectives and their interrelations (see Figure 2) constitute the region's principal landscape quality objective, to preserve and develop the variety of the Mühlviertler Kernland landscape encompassing the following aspects:

- varied and highly structured landscapes including well-preserved landscape elements,
- a high diversity of plant and animal life,
- diverse landscape capacities (e.g. for recreation or agrarian and energy production),
- varied but balanced land-uses, preserving favourable farming areas and allowing for controlled settlement development,
- a socio-spatial diversity, which allows for a sustainable life style in central and peripheral regions.
Human beings are intrinsic parts of the landscape [Linehan and Gross 1998, Matthews and Selman 2006] laying several claims to the system “landscape”. Consequently, the above mentioned landscape quality objectives address all three essential landscape benefits, according to Simmen and Walter [2007], Knoepfl and Gerber [2007], Rodewald and Knoepfl [2006]: these are aesthetic, sociocultural as well as ecological landscape qualities.

4. Discussion

We start this discussion with learning and planning theory and end with practical issues concerning participation, landscape definitions, as well as expected and achieved outcomes.

In terms of a social learning process, the “landscape dialogues” are intended to activate both behavioural modifications (single-loop-learning) and a discourse about context and goals (double-loop-learning), broadening the spectrum of supposable implementation measures throughout the reflection of action strategies and governing

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**Fig. 2.** Landscape quality objectives for the Austrian LEADER region Mühlviertler Kernland"
values. Also, a discussion about landscape and local/regional identity could be started and a general awareness that landscape is a feature of quality of life could be created. From our experiences, we can state that “landscape” often is simply “there” and given no special attention. In the process, with the simple questions asked, people started to think about the special qualities and features of their landscapes and their “value” for their quality of life. By the moderation techniques chosen, it was guaranteed that visions were elaborated that proved to be stable in the ongoing process. They were also well embedded in the overall value frame of the respective municipalities. Partly, “inherent” values to societies were expressed as visions, especially applying the “fruit-tree-method”. Awareness emerged in the landscape dialogues that buying locally/regionally creates (regional) income and economic activity. This automatically leads to landscape management. Consequently, the regional population proposed to strengthen and increase projects like farmers shops and markets, use of regional renewable energy sources, creating touristic offers with respect to landscape management, and to support existing civil-society based initiatives for landscape management.

The “landscape dialogues” proved to be an adequate method to involve the interested public in the discussion of landscape issues, although via such workshops and other interactive methods, normally only a certain, but not very large share of the population can be reached. On the average, approximately 20 persons attended each of the eight “landscape dialogues” in the Mühlviertler Kernland. Overall, we experienced a significantly more male than female participation and that the youth were not present at all. For teenagers, we created a separate school action that is not the subject of this paper.

Our experience is that “landscape” is a complex and awkward topic to discuss with the general public. To find a common understanding of landscape, takes time. Classical landscape definitions work on an academic scale, but with the general public, a more practical understanding has to be gained. Visualisation of landscapes and landscape elements, e.g. by showing pictures or drawing maps about special landscape features together, supports a jointly agreed concept of “landscape”. Both the open landscapes and the build structures were in the local/regional landscape perception with a predominance of agriculturally used areas and old town/village cores with historical buildings. Finally, new settlement developments, especially sprawl and big infrastructures were often perceived as “necessary” disturbances. This can be seen on the highway project S10, the landscape change is perceived partly negatively, most people are still in favour of the project, because of expected positive economic incentives, improvements for commuters and the expected population stabilisation or even growth in a structurally weak rural region.

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1 See e.g.: The European Landscape Convention defines landscape as “an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors” (Art.1 ELC). Tress et al. (2000) outline a similar understanding of landscape, that “the physical processes and the human actions together with the thinking of humans are shaping and creating the landscape. The three fields (the physical geosphere, the biosphere and the mental noosphere) are closely related and influence each other mutually”.

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When we started the process, we expected to come up with more concrete projects and single, event-like actions, e.g. the planting of hedgerows, tree-cutting in sensitive landscape sceneries. However, we experienced that people wanted to tackle complex issues, such as ongoing landscape management strategies, the renewal of town/village cores etc. Consequently, two out of the eight municipalities participating in the “landscape dialogues”, have started a full Local Agenda 21 process, with two more municipalities thoroughly considering Local Agenda 21 in the near future. From this perspective, we can firmly state that the experience of taking part in participatory planning methods created awareness for the benefits of participatory planning by the respective municipal decision makers.

5. Conclusions

Summing up the results of the “landscape dialogues”, it can be stated that on the one hand “landscape” as such, is a difficult issue to be discussed with local people as the general concept of landscape is not very tangible to the broad public. On the other hand, if certain areas or landscape features are discussed, where a personal affection is present, people intensively engage in discussions and show some willingness to implement action. We can state that in some municipalities, the “landscape dialogues” created more need, understanding and enthusiasm for communicative and participatory planning processes, which should address very complex issues of landscape development that cannot be sufficiently handled in the short-intensive layout of the “landscape dialogues” and need a longer process. When addressing landscape, people engaging themselves are not only interested in single actions, but also in long-term processes, like the renewal of village cores, the cultivation of low-productive grasslands, the management of small-structured landscape elements, the increase of renewable energy use and many other activities. These actions can be linked to sustainable landscape development, taking economic, social and environmental issues into account.

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Digital photogrammetry is a field of photogrammetry in which aerial and ground photographs, obtained either directly from digital cameras or from scans of photogrammetric photographs. These photographs are processed by special software. Digital photogrammetry is an important step in the development of this field, because of the application of computers. Photogrammetric methods make working with an object more comfortable, as no direct contact with the object is required. Methods and solutions employed by today’s photogrammetry have become very useful in many engineering and industrial aspects (measurements of deformations, surveying measurements).

Keywords
digital photogrammetry • surveying

1. Introduction

The aim of the work is surveying. This determines the dimensions, shape and location of the object in space and other given qualities of the object identified on ground-based images. Another aim of surveying is to design and develop a digital relational databases of historic objects, which may contain information beyond the description of objects geometry. A photograph is a source of a huge amount of information regarding the object under research. Despite its possible disadvantages (e.g. not capturing all the details precisely because of the bad shape of a surface), it has big informational potential. It allows the performance of many measurements in a disproportionately short time. Therefore it is not surprising, that photographs are treated as documents and are included into the further surveying files. Diversity and flexibility of measuring tools that are available nowadays enables one to find an optimal solution. Multiplicity of technological variants makes it possible to adjust both technical and economical parameters to suit current conditions and needs.
2. The aim of surveying

In order to standardize the methods of measurement and the technical documentation, technical guidelines, the G-3.4 were created: “Surveying of urban areas, green areas and architectural objects”. An official document containing the official and aims of surveying was issued on April 11th 1980, by the president of The Head Office of Geodesy and Cartography:

„The aim of surveying is to depict existing spatial configuration, functional and technical structure and décor of elaborated objects.”

According to technical guidelines (G-3.4), surveyings has in view obtaining complete materials and information, which represent current state of the object. It is to be a historic document as well as a source material for further research, technical and design elaboration. The materials are used first of all by protection of the objects, their adaptation and for very important – revaluation. It covers the whole of conservation activities, which have in view restoration of former historical and artistic value for antiques and historic monuments. In the case of objects of art and old buildings, surveying is performed mainly when the object exists, but the design documents are missing.

Before surveying, it is necessary to check any existing materials, their usefulness and if possible use them in the course of work. The obtained set of information is presented in graphical, description and photographic way [Czokański and Przewłocki 1990].

3. The range of architectural surveying according to technical guidelines of G-3.4

Architectural surveying includes:

• objects of brick (stone) architecture,
• objects of wooden architecture,
• interiors,
• details of architectonic decor (interior and exterior),
• objects of small architecture.

Objects of so called small architecture are included as well in urban survey elaboration, and in architectural elaborations as well. Qualification in this case is dependent on needs of performed project [Technical guidelines G-3.4 1981].

The range of urban and architectural survey, may be supplemented with a survey of technical aboveground and underground infrastructure including water-sewage, gas, electricity, telecommunications, central heating installations [Sitek 1991].

4. Photographic survey

Photographic survey is very important from the use of photographic point of view. It may be used in the frame of architectural, urban and construction surveying, or
as a separate service. Created photographic documentation constitutes illustrating material which is a supplement of graphic materials and helps by mapping. Such issues has been involed by CIPA from many years [Lerma García 2002, Kasser and Egels 2000, Kasser and Egels 2001, Patias and Karras 1995, Batic et al. 1996].

Photographs which are part of the documentation, should present photographed object with small deformation and perspective exaggeration:
1) the whole object,
2) parts of the object,
3) elevations,
4) elements of architectural decor,
5) details,
6) distinctive construction elements.

All data concerning the way and accuracy of performing photos, used photographic equipment, lighting and other technical details are given by the instruction. Photographic documentation of architectural decor details should include photographs of decor elements (stone, wooden, painted, ceramics, stucco work etc.), grates, balustrades and stained-glass windows.

The range should be in details settled with the customer. Professional photographic survey is necessary in the course of detailed project analysis, renovation planning, decor and adaptation planning, technical state of the object determining, for archival purposes, documentation of the state of works (e.g. before sale or lease), prior to beginning of an investment, for judicial expertise (photograph is treated as an independent piece of evidence – it possesses evidence power after experts opinion), specialists, heritage conservation, etc. Photographic documentation will register all plaster damages and stains, caused by atmospheric, chemical and biological factors. It shows color changes on metal elements, caused by rust [Przewłocki 2008].

5. Historic object surveying

Surveying is a complex process, which is based on registered picture(s) of a measured object. It begins with setting up and measurement of a geodetic and photogrammetric control network. Next, photographs are taken, and on the basis of them, study works are initiated [Boroń et al. 2007]. Up to now analog cameras were used (for example UMK 10/1318), whose principle of operation is based on picture recorded by light on photosensitive material. The quality of photographs depends on the proper choice of photosensitive material, correct exposition and proper realization [Augustynowicz 2008]. At present, digital cameras are commonly used, with established elements of internal orientation (calibration), parameters of lens distortion [Boroń et al. 2007]. They register spectral shapes in the form of matrix. Each pixel has a number attributed, which determines the value of spectral answer.
A digital image gives additional advantages i.e. possibility of processing images in real time, or obtaining multispectral imageries. However, it has a much smaller resolution in comparison to an analog one. What has influence on a smaller accuracy of measurements (photograph from analog camera corresponds to several dozens of digital photographs with respect to resolution). An important aspect is the angle of view of the lens: cameras with long focal length give higher accuracy of flat coordinates than their wide angle equivalent, when making photos from the same distance, and the radial displacements are smaller.

The choice of method and specification depends greatly on complexity of the object. Photographs made by metric camera, can be recognized as an ideal central projection, however existing deformations resulting from the fact that the object is not flat, can not exceed established accuracy. It is the condition of considering the documentation as metric.

Surveying is usually performed in a local reference system. Processing a single photographs and stereoscopic elaborations, requires the adjusting of points with known positions in space (photopoints). Photopoints are indicated in a special way or chosen as characteristic points on the object, or natural details of terrain and registered on photographs. Their number and layout are adapted to the specific object and demanded accuracy. Survey of photopoints is performed by the polar method, or by angular forward intersection. Points which are hard to access, or impossible to access are surveyed using reflectorless total station [Augustynowicz 2008]. Registration of photographs for stereograms is seldom performed with use of analogue equipment. Technical progress in electronics and informatics caused great changes in the study works. Digital images processing software, replaced old analogue converters, and digital photogrametric stations took place of mechanic autographs. The final phase of survey consists in printing documentation in appropriate scale and archiving of digital originals [Boroń et al. 2007].

6. Own investigation
6.1. Choice and characteristic of the investigation object

In investigations of photographs of elevation of historic elevation of grange annexe in Mściwojów village (Figure 1).

Mściwojów village is situated in Lower Silesia Voivodeship, Jaworski district. The settlement is located at the foot of the northern arm of Strzegomskie Wzgórza at the height 190 m over the sea level. Wierzbak river of the Odra hydrographic basin flows across the village.

Natural and cultural heritage of the village

Mściwojów village offers many natural qualities and interesting historic monuments. Some of them are as follows:

- Roman Catholic Church of Holy Mary the Virgin built in baroque style in 18th century, number of register 149/L,
• parish Cemetery, Roman catholic parish in Mściwojów, number of register 843/L,
• grange annexe, number of register 215/L (Figure 2),
• decorative garden (commonly called Mściwojów park), number of register 559/L,
• water pond, „Mściwojów” of 57 ha area,
• documented archeological finding of Łużycka culture.

Source: www.msciwojow.pl

Fig. 1. Aerial photograph of Mściwojów village

Source: Plan of Revitalization of Mściwojów Settlement 2009

Fig. 2. Part of historic grange annexe
6.2. Source materials and method of their obtaining

Field work, was divided into two phases: a) geodetic and b) photogrammetric. First, surveying the control network was designed for the creation of conditions for supplementary surveys. The network had 17 points, located around surveyed grange building. All points were stabilized in terrain. For all the points of the network; topographical descriptions were prepared. Control network was linked to the network of III class, to adjust it and calculate coordinates X, Y, Z in a proper national coordinates system. The software, *Winkalk* was used to do it.

Calculated coordinates were used to create a land survey and height map by the method of direct measurement. Next, the survey of grange building was performed including accurate measurement of small architecture elements. Windows, doors and ceilings were measured. As a result, 3D information of the object was obtained. Additional source material to photogrammetric elaboration were analogue photographs made using UMK 10/1318 measuring camera, and next scanned on Geo-System Digital Fotogrametric Scanner ”Delta – 2”, with resolution 1058 dpi. (Figure 3).

![Image](image_url)

*Fig. 3. The left photograph of stereogram*

The project of making photographs included: selection of the UMK camera position (stereogram), selection of stereograms kind (horizontal) and the focus of UMK camera lens (100 mm). The most advantageous for the future elaboration was performing frontal photographs, facing the plain of the object.

From among the taken photographs, those which enabled full coverage of the facade, and those which provided established resolution on the whole picture were selected. Additionally those which did not fullfil conditions of joining in stereo pairs,
were removed. To obtain full information about elevations, selected photograms were set together in stereo pairs. Next signalization, selection and measurement of photopoints were performed. On accessible walls of building, photopoints were marked by small, stuck on crosses.

6.3. Creation of thematic levels and their vectorisation

After orientation phase, the next phase was digitalisation – mapping of the research object. To obtain full survey of the grange building elevation, vector levels were created, with suitable attributes: name, color, line weight.

Following levels were created:
1) roof (color: yellow),
2) elevation (color: fuchsia),
3) windows (color: green),
4) doors (color: blue),
5) chimney (color: aqua).

![Image]

Source: own investigation

**Fig. 4.** Window of data accumulation. Digitalization of the object. Partially covered elevation

Figure 4 shows weak points of the method. Thick bushes on the right side of the building, cover a great part of the elevation. Additional obstacles, in fact make the access to the windows difficult. The last window in the building was practically impossible to measure, and was omitted from the measurements. There were some obstacles in the case of doors, partially covered with bushes.
7. The results of investigations

In elaborate surveys of complex architectonic documentation, unified land surveying and photogrammetric methods are irreplaceable.

The present paper contains a profile of information connected with surveying. Different kinds of surveying were presented. Specification of presented methods, and their applications for different surveys, adequate situations and conditions.

In the photogrammetric methods last years have become appreciated not only by surveyors. Their popularity growth and the number in their application is broadening. Contemporary methods are used in technical sciences, like engineering, architecture, geodesy, or the described above surveys, and also in medicine, and tourism.

Photogrammetric methods provide objectivity and richness of details. Photograph contains a lot of information, registered in a very short time. Time aspect is a significant factor for accuracy of measurements.

Measurement of an unlimited number of points can be repeated several times. Additional asset is the fact of registration of points which are unaccessible to direct measurement.

Photogrammetry does not require direct contact with object. Problem of elements, which can be dangerous for surveyor (very tall, or unstable buildings), or inaccessible points can be solved by this method. Application of photogrammetric methods has influence on limitation to minimum burden some fieldwork. Measurements which are usually time consuming and dependent on weather conditions have been moved to comfortable office conditions.

Highly developed technology, enabled automation of the photographs processing. Results of elaboration should be supplied in digital form. This enables their interactive use by different specialists.

References


CIPA Supported Publications


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EVALUATION OF SOIL WATER EROSION RISK IN THE MŚCIWOJÓW WATER RESERVOIR DRAINAGE BASIN ON THE BASIS OF NUMERIC MODELLING

Jacek M. Pijanowski, Artur Radecki-Pawlik, Andrzej Wałęga, Jakub Wojkowski

Summary

The paper presents the evaluation of soil water erosion risk of the Mściwojów water reservoir drainage basin. In the present study, modelling with the use of GIS (Geographical Information Systems) and RUSLE (Revised Universal Soil Loss Equation) erosion models were exploited. Values of topographic factor (LS) were calculated after formulas proposed by Moore et al. [1991] as well as Desmet and Govers [1996]. The results of erosion prognosis by means of RUSLE method after Moore’s formula are by 40% higher than values evaluated after Desmet and Gover’s formula. Eroded soil mean mass from area unit during the year is estimated at the level of 10.35–14.53 Mg ∙ ha⁻¹ ∙ year⁻¹, depending on computable formula used. Results of this research enabled to divide the drainage basin area into soil water erosion intensity zones based on predicted soil loss values according to Marks et al. [1989]. The study shows that water erosion risk of soil in the Mściwojów water reservoir drainage basin is very high. Almost one third of its area is located in the high and very high class of erosion risk.

Keywords

soil water erosion • RUSLE • GIS • spacial modelling • the Wierzbiak River • the Mściwojów water reservoir

1. Introduction

Proper recognition of spacial arrangement of water erosion size of soil is a necessary condition for effective drainage basin management and the conducting a rational water economy. Identification of areas which in the extreme contribute to surface water pollution with eroded soil material simplifies decision making in planning activities that restrict that process.

Negative effect of soil water erosion on natural environment concerns not only the place or area where it takes place. The results of that process have got much bigger spacial range and can strike areas that are considerably distant from places
where soil material diminution is observed. Knowledge of spacial arrangement of soil water erosion size is especially important in context of quality of surface water which supply retaining water reservoirs. Because in these water basins, sediments transported by supplying water are stopped. It may take effect in water pollution and eutrophication and in the course of time also in decreasing of disposable capacity of reservoirs.

The example of area that is greatly endangered by soil water erosion is The Wierzbiak River drainage basin, placed in Lower Silesia Voivodeship, which supplies Mściwojów retaining reservoir with water. Initial recognition of water erosion risk at the phase of reservoir’s designing and some years after its starting showed that in the space of reservoir drainage basin intensive surface erosion could take place [Czamara 2002]. However, these researches were not the type of spacial analysis and their results were only partially published [Kasperek and Wiatkowski 2008].

Gaining reliable spacial information about soil erosion size on the basis of nothing but in situ measurements is practically impossible. In that case, Geographical Information Systems (GIS) prove to be helpful as they make natural processes modelling possible and they enable gaining information about spacial diversity of potential and real erosion size.

Pilot project of the European Regional Development Foundation (ERDF), named VITAL LANDSCAPES, that is carried out by Agriculture University in Cracow workers’ team became occasion to conduct many complex studies in the region of the Mściwojów water reservoir. Some of them concerned the problem of soil water erosion. Their aim was to evaluate the degree of risk of the Mściwojów water reservoir drainage basin both in quality (classification of risk degrees) and quantity (evaluation of eroded material size) aspects. To reach that aim, modelling with use of GIS and RUSLE (Revised Universal Soil Loss Equation) erosion models were exploited.

2. Characteristics of research area

The research area is placed in Sudeckie Foothills macroregion (332.1), in Strzegomskie Hills mesoregion 332.1 [Kondracki 1998]. It possesses features characteristic for a piedmont area. Mściwojów reservoir drainage basin is the hilly space and almost all area is occupied by farming grounds with dominance of arable land. The Wierzbiak River is a right-bank tributary of the Kaczawa River in the Odra River basin. In the upper section of the Wierzbiak River, in the neighbourhood of Mściwojów town, water reservoir was built and came into use in 2000 [Szafranński and Stefanek 2008]. Its main purpose is agricultural usage of stored water and fire protection. Apart from the Wierzbiak River there is left-bank tributary named the Kałużnik which flows into the Mściwojów water reservoir. Total surface of the Mściwojów water reservoir drainage basin at the mouth of the river from the water basin is 49.12 km², from which 35.72 km² falls on the Wierzbiak River and 13.40 km² – on the Kałużnik River one. The drop of drainage basin is 160.6 m and its mean fall is 11.5%.
3. Materials and methods

To estimate valuation of the degree of soil water erosion risk in Mściwojów reservoir drainage basin, database of spacial data was built. It was composed of:

- digital terrain model (DTM) with resolution of 25 m,
- soil-agronomic vector map in scale 1 : 25 000,
- topographic objects database (TBD) in scale 1 : 10 000,
- vector map of level 2 (VMapL2) in scale 1 : 50 000,
- topographic map in scale 1 : 10 000,
- map of Polish hydrographic partition (MPHP),
- ortophotomap.

Digital Terrain Model (DTM) was elaborated on the support of photogrammetric surveying of black and white air-images in scale 1 : 26 000 that were performed within the framework of PHARE project. It was prepared on the basis of height points network with a 25-m hole. Its height accuracy is 1.5 m on the flat areas and to 2.5 m on hilled and mountainous ones. DTM was used to appoint direction of water confluence, to estimate confluence of accumulation size, to shape hydrographic net and partial drainage bases delimitations as well as to evaluate so called secondary topographic factors. Height data and course of rivers net from the map of Polish hydrographic partition (MPHP) were verified and corrected on the basis of topographic objects database (TBD) in scale 1 : 10 000 and topographic map in scale 1 : 10 000.

Soil-agronomic map in scale 1 : 25 000 was used to design the map of soil kinds in studied drainage basin (Figure 1) whereas the map of land cover of the Mściwojów water reservoir drainage basin (Figure 2) was prepared on the basis of data from TBD and vector map of level 2 (VMapL2) in scale 1 : 50 000. Covering data were verified in the basis of ortophotomap and topographic map in scale 1 : 10 000.

The method proposed by Józefaciuk and Józefaciuk (1996) is commonly used in Poland for evaluation of soil water erosion risk. It enables to estimate erosion risk only in quality aspect which means classification of risk degree. Estimation of not only eroded material quantity but also its quality is possible by means of USLE method (*Universal Soil Loss Equation*) elaborated by Wischmeier and Smith (1978) on the basis of long-standing experimental studies. USLE model is an empiric equation that describes mean annual losses of soil in the result of surface and linear erosion:

\[
A = R \cdot K \cdot L \cdot S \cdot C \cdot P
\]  

(1)

where:

- \(A\) – mean annual soil loss per unit of area, Mg \(\cdot\) ha\(^{-1}\) \(\cdot\) year\(^{-1}\),
- \(R\) – rainfall-runoff erosivity factor, MJ \(\cdot\) ha\(^{-1}\) \(\cdot\) cm \(\cdot\) h\(^{-1}\),
- \(K\) – soil erodibility factor, Mg \(\cdot\) ha\(^{-1}\) \(\cdot\) (MJ \(\cdot\) ha\(^{-1}\) \(\cdot\) cm \(\cdot\) h\(^{-1}\))\(^{-1}\),
- \(L\) – slope length factor, non dimensional,
- \(S\) – slope steepness factor, non dimensional,
In the present studies, spacial arrangement analysis of soil water erosion process was performed by means of its modified version of RUSLE model (Revised Universal Soil Loss Equation) (Renard et al. 1997). RUSLE model modification relates to the way of evaluation of non dimensional factor of length \( L \) and slope steepness \( S \). In RUSLE model both factors were combined into one non dimensional topographic factor \( LS \). Spacial data indispensable for modelling were submitted to rasterisation process to spacial resolution 25 m and recorded in geodetic coordinates system ’1992’. Hydrographic analysis and hydrologic modelling was done by means of Arc Hydro Tools instrument which works in range of ARC GIS software from ESRI company. Topographic factor calculation \( LS \) as well as RUSLE model implementation for estimations was made with help of SAGA GIS software.

\[ C \quad \text{cover management factor, non dimensional,} \]
\[ P \quad \text{support practice factor, non dimensional.} \]

Fig. 1. The map of soil kinds in the Mściwojów water reservoir drainage basin: 1 – loess, 2 – silty clay loam, 3 – loam, 4 – loamy sand, 5 – sand, 6 – silty clay, 7 – silt loam, 8 – sandy loam, 9 – loamy very fine sand, 10 – sandy clay loam
4. Results

Rainfall-runoff erosivity factor ($R$)

Rain erosion factor describes drop rain capacity to loosening and transportation of soil bits. It was calculated on the basis of Fournier index in modification suggested by Arnoldus [1997]. Its usage in evaluations made with use of SI system units needs multiplying by 17 [Drzewiecki and Mularz 2005]:

$$R = 17 \sum_{i=0}^{12} \frac{p_i^2}{P}$$

where:

- $R$ – rainfall-runoff erosivity factor, MJ·ha$^{-1}$·cm·h$^{-1}$,
- $p_i$ – rainfall sum in $i^{th}$ month, mm,
- $P$ – annual rainfall sum, mm.
Rain erosivity factor \( (R) \) estimated on the basis of mean monthly sums of falls (1961–1995), that was registered in the meteorological observation post IMGW in Jawor, amounted to 957 MJ \( \cdot \) ha\(^{-1} \) \( \cdot \) cm \( \cdot \) h\(^{-1} \).

**Soil erodibility factor \( (K) \)**

Soil erodibility factor expresses eroded soil mass from the unit of model field. It can be evaluated after Renard et al. [1997]:

\[
K = 0.0034 + 0.0405 \cdot \exp \left( -0.5 \cdot \left( \frac{\log D_s + 1.659}{0.7101} \right)^2 \right) \tag{3}
\]

when:

\[
D_s = \exp \left( 0.01 \cdot \sum_{i=1}^{n} f_i \cdot \ln \frac{d_i + d_{i-1}}{2} \right) \tag{4}
\]

where:

- \( K \) – soil erodibility factor, Mg \( \cdot \) ha\(^{-1} \) \( \cdot \) \( (\text{MJ} \cdot \text{ha}\(^{-1} \) \( \cdot \) \text{cm} \cdot \text{h}^{-1})^{-1} \)
- \( d_i \) – upper limit of fraction range, mm,
- \( d_{i-1} \) – lower limit of fraction range, mm,
- \( f \) – mass fraction content, %.

Studied drainage basin is mostly covered with loess soil and loess formations (83%) (Figure 1). According to the soil-agricultural map, medium clays account for 7%, light clays – 5% whereas flour claystones and loose sands 3% of cover, each.

Values of soil susceptibility to water erosion factor \( (K) \) that were estimated for analyzed drainage basin varied from 0.0123 to 0.0421 Mg \( \cdot \) ha\(^{-1} \) \( \cdot \) \( (\text{MJ} \cdot \text{ha}\(^{-1} \) \( \cdot \) \text{cm} \cdot \text{h}^{-1})^{-1} \). For the whole tested drainage basin, mean surface value of \( K \) factor was 0.0386 \( (\text{MJ} \cdot \text{ha}\(^{-1} \) \( \cdot \) \text{cm} \cdot \text{h}^{-1})^{-1} \).

**Topographic factor \( (LS) \)**

Topographic factor \( (LS) \), which is also called sediment transportation ability factor, is characterized by erosive potential. It is determined by relationship between size of the area that takes part in surface confluence (fragment of drainage basin) and value of its slope. In the present study, formulas proposed by Moore et al. [1991] as well as Desmet and Govers [1996] served to evaluate \( LS \) factor. Both teams of scientists proved that area shape influence on behaviour of water floating at its surface would be described in better way when the length of a slope in \( LS \) factor would be replaced by float area or actually by value that is quotient of contributing area and length of given slope fragment (so called unit upslope contributing area). According to Moore et al. [1991] topographic factor \( (LS) \) is calculated on the basis of the below formula:

\[
LS = 1.4 \left( \frac{A_S}{22.13} \right)^{0.4} \cdot \left( \frac{\sin q}{0.0896} \right)^{1.3} \tag{5}
\]
where:
- \( LS \) – topographic factor, non dimensional,
- \( A_s \) – local upslope contributing area from flow accumulation raster, \( \text{m}^2 \),
- \( q \) – slope angle.

Values of topographic factor \( (LS) \) calculated after Moore et al. (1991) formula for analyzed drainage basin varied from 0 to 30.55. Territorial mean of the factor \( (LS) \) for the whole tested drainage basin was 2.44.

According to Desmet and Govers (1996), topographic factor \( (LS) \) is calculated on the basis of the below formula:

\[
LS = \frac{(A_s + D^2)^{m+1} - A_s^{m+1}}{x^m \cdot D^{m+2} \cdot (22.13)^m} \cdot S
\]

where:
- \( LS \) – topographic factor, non dimensional,
- \( A_s \) – local upslope contributing area from flow accumulation raster, \( \text{m}^2 \),
- \( D \) – raster resolution, \( \text{m} \),
- \( x \) – coefficient that corrects the length of flow way through a raster cell, non dimensional,
- \( m \) – index of slope's length factor, non dimensional,
- \( S \) – slope steepness factor, non dimensional.

Index of slope's length factor \( (m) \) can be calculated by McCool et al. [1989] from formula:

\[
m = \frac{\beta}{\beta + 1}
\]

when:

\[
\beta = \left( \frac{\sin q}{0.0896} \right) \cdot \frac{1}{3(\sin q)^{0.8} + 0.56} \cdot r
\]

where:
- \( q \) – slope angle,
- \( r \) – usage factor: forests – 0.5, rural areas – 1.0, built-up areas – 2.0.

Slope steepness factor \( (S) \) can be evaluated after Renard et al. [1991] from formulas:

\[
S = 10.8 \sin q + 0.03 \text{ dla } q < 9\%
\]

\[
S = 16.8 \sin q + 0.5 \text{ dla } q < 9\%
\]
where:

\[ S \quad \text{slope steepness factor, non dimensional,} \]
\[ q \quad \text{slope angle.} \]

Values of topographic factor \((LS)\) evaluated for analyzed drainage basin according to Desmet and Gover's formula (1996) varied from 0.03 to 16.21, whereas area mean for the whole examined area was 1.72.

**Cover management factor \((C)\)**

Cover management factor \((C)\) is a relation of the soil quantity that eroded from the field with specified flora and way of usage to the soil eroded from the model field in black fallow with up and down slope ploughing [Jozafaciuk and Jozafaciuk 1996].

In covering and usage structure of examined drainage basin (Figure 2) the biggest share belongs to farmlands (70%) and forests (15%). Grasslands compose 8%, built-up areas 4% and wastelands 2%. On the basis of covering and land usage map that was elaborated for analyzed drainage basin, values of \(C\) factor were estimated. Their appropriate values were accepted after Koreleski [1992]: wastelands – 0.350, farmlands – 0.240, grasslands – 0.020, forests – 0.003, built-up areas and surface waters – 0.000.

Values of plant covering and way of usage factor \((C)\) appointed for analyzed drainage basin fluctuated within limits from 0 to 0.35 whereas area mean for the whole drainage basin was 0.18.

**Support practice factor \((P)\)**

Support practice factor \((P)\) characterizes importance of using procedures that limit water erosion intensity. It is a relation of soil losses while using anti-erosion procedures to those from model fields on which cultivations along the slope angle are conducted. As there is lack of data of such kind, lack of anti-erosion procedures (value of factor \(P = 1\)) was accepted for modelling needs.

**Mean annual soil loss \((A)\)**

As a result of conducted modelling of water erosion, information about spacial distribution of soil losses size in the tested drainage basin was obtained (Figure 3). Mean quantity of eroded soil in the drainage basin was calculated following Moore's formula and amounted 14.52 Mg ∙ ha\(^{-1}\) ∙ year\(^{-1}\) whereas according to Desmet and Gover's formula it was 10.35 Mg ∙ ha\(^{-1}\) ∙ year\(^{-1}\). Total annual mass of eroded soil from the drainage basin calculated after Moore's formula (68 622 Mg ∙ year\(^{-1}\)) is almost 40% bigger than the values obtained by means of Desmet and Grover's formula (49 147 Mg ∙ year\(^{-1}\)) (Table 1). It results from different way of topographic factor \((LS)\) determination.

Modelling also allowed to determine the level of contribution of particular drainage basins to the total mass of eroded soil material (Table 1). Together with surface flow, 63% of that mass finds its way to Mściwojów reservoir from the Wierzbias
River drainage basin whereas from the Kalużnik River drainage basin – 27%. The rest 10% relates to surface flow from areas that are directly adjacent to Mściwojów reservoir which is partial drainage basin between the section from the Wierzbiak and Kalużnik Rivers’ mouths to the reservoir and the section on the outlet of the Wierzbiak River from the reservoir.

Table 1. Eroded soil mass evaluated for Mściwojów reservoir drainage basin

<table>
<thead>
<tr>
<th>Model</th>
<th>Mean annual soil loss (A) [Mg · year⁻¹]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wierzbiak River drainage basin</td>
</tr>
<tr>
<td>RUSLE after Moore et al. [1991]</td>
<td>43 269</td>
</tr>
<tr>
<td>RUSLE after Desmet and Govers [1996]</td>
<td>30 934</td>
</tr>
</tbody>
</table>

On the basis of predicted soil loss (Figure 3), research area division into water erosion risk zones was performed on the grounds of criteria proposed by Marks et al. [1989] (Table 2). Classification map of erosion risk is presented on the Fig 4.

High and very high erosion risk is predicted on the area that makes up 31% of analyzed surface, small and medium one on 20%, whereas very small risk or lack of it can be found on 51% of that surface (Table 2).

Table 2. Classification of erosion risk criteria according to Marks et al. [1989]

<table>
<thead>
<tr>
<th>Risk class</th>
<th>Erosion risk</th>
<th>Annual soil loss [Mg · ha⁻¹]</th>
<th>Contribution of risk classes [%]</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Wierzbiak River drainage basin</td>
</tr>
<tr>
<td>1</td>
<td>lack</td>
<td>&lt; 1</td>
<td>33</td>
</tr>
<tr>
<td>2</td>
<td>very small</td>
<td>1–5</td>
<td>18</td>
</tr>
<tr>
<td>3</td>
<td>small</td>
<td>5–10</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>average</td>
<td>10–15</td>
<td>9</td>
</tr>
<tr>
<td>5</td>
<td>high</td>
<td>15–30</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>very high</td>
<td>&gt; 30</td>
<td>15</td>
</tr>
</tbody>
</table>

Taking categories of covering and usage of the area into consideration, the biggest loss of soil material concerns arable lands, grasslands as well as wastelands and post-drift areas. Their proportional contribution in the total area of examined drainage basin is presented in Table 3. What results from Table 3, 28.2% of arable lands, 1.4% of wastelands and 0.4% of grasslands are exposed to high and very high erosion risk.
Fig. 3. Spatial distribution of eroded soil mass [Mg · ha⁻¹ · year⁻¹]

Table 3. Proportional contribution of usage of the area categories in erosion risk classes

<table>
<thead>
<tr>
<th>Risk class</th>
<th>Contribution in whole examined area [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Arable lands</td>
</tr>
<tr>
<td>1</td>
<td>13.2</td>
</tr>
<tr>
<td>2</td>
<td>11.7</td>
</tr>
<tr>
<td>3</td>
<td>9.2</td>
</tr>
<tr>
<td>4</td>
<td>7.8</td>
</tr>
<tr>
<td>5</td>
<td>13.9</td>
</tr>
<tr>
<td>6</td>
<td>14.3</td>
</tr>
</tbody>
</table>
5. Summary and conclusions

RUSLE model used in the present research is commonly applied in the world method of soil erosion risk evaluation. Its usage prevalence enables possibility to compare gathered results of modelling with the other authors’ researches results which were conducted in different parts of the country or the world [Kowalczyk and Twardy 2012, Mularz and Drzewiecki 2007, Jianguo 2001, Auerswald 2006, Gumiere et al. 2009, Ranzia et al. 2012]. Beside many advantages of RUSLE model, its disadvantage is lack of the possibility to take into account the areas of deposition of eroded soil material. In situ measurements reveal existence of quantity restraint of soil material which can be transported together with surface flow [Mitasova et al. 2005, Pistocchi et al. 2002].

On the basis of conducted modelling, following conclusions can be presented:

1. Water erosion risk of soil in the Mściwojów water reservoir drainage basin is very high. Almost one third of its area is located in the high and very high class of erosive risk.

Fig. 4. Erosion risk classification: 1 – lack, 2 – very small, 3 – small, 4 – average, 5 – high, 6 – very high
2. Results of erosion prognosis by means of RUSLE method after Moore’s formula are by 40% higher than values evaluated after Desmet and Gover’s formula.

3. Eroded soil mean mass from area unit during the year is estimated at the level of 10.35–14.53 Mg · ha⁻¹ · year⁻¹, depending on accepted computable method.

4. Total mass of eroded soil which can annually flow into the Mściwojów water reservoir is evaluated at 49 147–68 622 Mg · year⁻¹, depending on computable formula used.

References


IMPACT OF DISPARITIES IN SETTLEMENT AND POPULATION DEVELOPMENT ON CULTURAL LANDSCAPE

Peter Podolák

Summary

The paper is focused on the selected problems of the cultural landscape in the attractive hinterland of Bratislava, in the region under the slopes of the Little Carpathian Mountains. The principal turn in the migration balance of the largest cities is one of the most typical traits of the change that has manifested in the spatial movement of population after 1990. Bratislava, with the concentration of almost all basic human activities in the area, has become much lower in density due to intensive migration. This change is due to suburbanisation and deconcentration of the regional population. The building of large concentrations of new residential areas in the hinterland, is in many cases, in contradiction with values of traditional cultural landscape. The quoted example would be adjust to historical vineyards.

Keywords
cultural landscape • costs, region • building

1. Introduction

Types and structures of cultural landscape are among the key factors of the Central European cultural identity, combining the natural and the cultural components into one. There remain relatively few intact or whole natural landscapes in Central or Western Europe. The prevailing regions are covered by cultural landscapes in various degrees of recreation, conservation and functionality. Even with numerous ecological, aesthetic, and economic assets, cultural landscapes in Central Europe are still underestimated. Landscapes are under constant pressure due to economic activities and are continuously fragmented and destroyed. One reason for such an undesirable development, is the lack of awareness in terms of landscape and assets cost. Moreover, cultural landscape is normally less efficiently protected than the natural landscape. The legal, planning and executive processes in this area(s) are prepared and applied on a much higher qualitative level. The awareness in the field of environmental protection is also higher than in the case of the cultural landscape [Podolák et al. 2011].
Individual authors interpret the notion of cultural landscape differently. For a fraction of them, cultural landscape is synonymous to cultural superstructures, cultural heritage projected onto the landscape. The approach, where, the notion of cultural is equal to civilized by man, has recreated a denatured landscape. This is quite different as it also includes a disturbed, disharmonic and devastated landscape(s). As Hanušin et al. [2000] assert, cultural landscape is an originally natural landscape, recreated by human activities. Along with natural processes, such as economic and social activities, laws are also applied to the cultural landscape. Humans have created the secondary landscape structure via anthropic effects. Different types of landscape, such as agricultural, urban and industrial landscape are discerned, according to the level of recreation and the prevailing functions.

2. Suburbanization and cultural landscape of the Sub-Little Carpathian Region

Links between population and landscape are of key importance, in the complex process of the development. Humans live, work, relax and pursue many varied activities in the landscape. Humans are capable of accomplishing their own plans on the appearance of cultural landscape, hence they decide about changes and realize them. The number, structure and distribution of population and its relationship to the cultural landscape in a given landscape are also vitally important. An area in Slovakia where the characteristics of cultural landscape can be studied best is the Sub-Little Carpathian Region, part of the hinterland to the capital of Slovakia, Bratislava. The Region consists of three towns (Pezinok, Modra, Svätý Jur), two marginal city parts of Bratislava (Rača, Vajnory) and 19 villages with the total population of about 92,000 (2011). Situated on the foothills of the southern Little Carpathian slopes, in the attractive hinterland of the capital, this setting in many ways has determined the economy and demographic development of the Region.

The vine-growing tradition, as pursued by the population of small towns and villages, on slopes of the Little Carpathians, dates back to the 13th century. During these centuries, the Region became the largest centre of viticulture in Slovakia. The trend survived into the second half of the 20th century, as did the conservation of the traditional assets of the cultural landscape at a relative satisfactory level. Simultaneously, under the general tendency of the population’s concentration in cities, daily commuting to Bratislava in the pursuit of professional, educational and other activities, including services of supra-regional nature, increased in the 1970s. Daily commuting decreased the rate of emigration from rural areas to cities. In spite of this, the rural population diminished in the 1970s and 1980s.

The size of a population, living and acting in a particular area and its spatial distribution may greatly influence the functioning and development of the cultural landscape. This can occur in both a positive or negative way. The basic feature of population development in the Region, is its (close) proximity to Bratislava, the largest settlement agglomeration in Slovakia. The extensive phase of the urbanization of
Slovakia peaked (characterized by the mass exodus of rural population to the cities), during 1970s. In the 1980s, the trend reversed. During the second half of the 1990s, the cities began to lose population due to emigration back towards suburban areas. Rural municipalities in the hinterlands of cities, became the most attractive destinations. From this point of view, the municipalities of the Sub-Little Carpathian region are the most attractive in the country, as a whole [Podolák 2006, 2007].

![Fig. 1. Sub-Little Carpathian Region in South-Western part of Slovakia](image)

The processes of suburbanization and deconcentration of population, in connection with the increased socio-economical differentiation in society, have become more intensive in the second half of the 1990s and significantly more so in 2000–2002. Beside other trends, this Slovakian transformation in society has resulted, in income differentiation and diversification of the real estate market. This has determined the basic setting for such a development.
Table 1. Population development (1970–2011)

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Budmerice</td>
<td>1913</td>
</tr>
<tr>
<td>Častá</td>
<td>2222</td>
</tr>
<tr>
<td>Dolany</td>
<td>1198</td>
</tr>
<tr>
<td>Dubová</td>
<td>1135</td>
</tr>
<tr>
<td>Limbach</td>
<td>955</td>
</tr>
<tr>
<td>Modra</td>
<td>7149</td>
</tr>
<tr>
<td>Pezinok</td>
<td>12123</td>
</tr>
<tr>
<td>Plá</td>
<td>410</td>
</tr>
<tr>
<td>Slovenský Grob</td>
<td>2276</td>
</tr>
<tr>
<td>Svätý Jur</td>
<td>5286</td>
</tr>
<tr>
<td>Šenkvic</td>
<td>4238</td>
</tr>
<tr>
<td>Štefanová</td>
<td>423</td>
</tr>
<tr>
<td>Viničné</td>
<td>1758</td>
</tr>
<tr>
<td>Vinosady</td>
<td>1110</td>
</tr>
<tr>
<td>Višňovce</td>
<td>1794</td>
</tr>
<tr>
<td>Rača</td>
<td>17450</td>
</tr>
<tr>
<td>Vajnory</td>
<td></td>
</tr>
<tr>
<td>Chorvátsky Grob</td>
<td>2080</td>
</tr>
<tr>
<td>Borová</td>
<td>480</td>
</tr>
<tr>
<td>Dlhá</td>
<td>491</td>
</tr>
<tr>
<td>Dolné Orešany</td>
<td>1644</td>
</tr>
<tr>
<td>Horné Orešany</td>
<td>2160</td>
</tr>
<tr>
<td>Lošonec</td>
<td>738</td>
</tr>
<tr>
<td>Smolenice</td>
<td>2656</td>
</tr>
</tbody>
</table>

Remark: In 1980, Dlhá was the administrative part of Košolná and Lošonec was part of Smolenice.

This fact is obvious, based upon the differentiated demands and possibilities of the various social groups, also in the quality and location of their living place are concerned. Suburbanization brings changes, not only in population distribution or spatial structure of large areas in city hinterlands, but simultaneously, it also brings the changes in social structures and life patterns of populations, in source and destination communes. Moving out to the countryside is often connected with ambitions,
not only to improve housing conditions, but to preserve the benefits both of the urban and rural life as well.

**Table 2.** Selected characteristics of suburbanization

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Total population change 2001–2011 (in %)*</th>
<th>Immigration from Bratislava (in %)**</th>
<th>Change in number of new flats 2001–2008 (in % to 2001)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Budmerice</td>
<td>12.3</td>
<td>28.0</td>
<td>9.2</td>
</tr>
<tr>
<td>Častá</td>
<td>4.5</td>
<td>29.7</td>
<td>6.0</td>
</tr>
<tr>
<td>Dolany</td>
<td>3.3</td>
<td>29.8</td>
<td>8.2</td>
</tr>
<tr>
<td>Dubová</td>
<td>6.7</td>
<td>29.7</td>
<td>6.8</td>
</tr>
<tr>
<td>Limbach</td>
<td>41.0</td>
<td>54.0</td>
<td>23.4</td>
</tr>
<tr>
<td>Modra</td>
<td>3.0</td>
<td>28.5</td>
<td>7.4</td>
</tr>
<tr>
<td>Pezinok</td>
<td>0.9</td>
<td>31.0</td>
<td>9.7</td>
</tr>
<tr>
<td>Píla</td>
<td>18.1</td>
<td>23.5</td>
<td>13.6</td>
</tr>
<tr>
<td>Slovenský Grob</td>
<td>17.3</td>
<td>44.8</td>
<td>10.8</td>
</tr>
<tr>
<td>Svätý Jur</td>
<td>12.5</td>
<td>51.5</td>
<td>7.2</td>
</tr>
<tr>
<td>Šenkvice</td>
<td>6.7</td>
<td>22.3</td>
<td>6.7</td>
</tr>
<tr>
<td>Štefanová</td>
<td>–4.5</td>
<td>12.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Viničné</td>
<td>32.6</td>
<td>24.4</td>
<td>23.1</td>
</tr>
<tr>
<td>Vinosady</td>
<td>22.6</td>
<td>18.9</td>
<td>12.2</td>
</tr>
<tr>
<td>Višňovce</td>
<td>–0.8</td>
<td>33.7</td>
<td>4.0</td>
</tr>
<tr>
<td>Rača</td>
<td>1.8</td>
<td></td>
<td>5.0</td>
</tr>
<tr>
<td>Vajnory</td>
<td>29.1</td>
<td></td>
<td>21.7</td>
</tr>
<tr>
<td>Chorvátsky Grob</td>
<td>85.0</td>
<td>66.6</td>
<td>94.8</td>
</tr>
<tr>
<td>Borová</td>
<td>17.2</td>
<td>16.3</td>
<td>13.0</td>
</tr>
<tr>
<td>Dlhá</td>
<td>14.1</td>
<td>5.9**</td>
<td>7.6</td>
</tr>
<tr>
<td>Dolné Orešany</td>
<td>6.9</td>
<td>10.4**</td>
<td>9.1</td>
</tr>
<tr>
<td>Horné Orešany</td>
<td>5.0</td>
<td>10.4**</td>
<td>7.0</td>
</tr>
<tr>
<td>Lošonec</td>
<td>1.3</td>
<td>6.9**</td>
<td>8.6</td>
</tr>
<tr>
<td>Smolenice</td>
<td>4.2</td>
<td>8.0**</td>
<td>10.6</td>
</tr>
</tbody>
</table>

Remark:
* The number indicates the average total annual population change per population 1.000 in the municipality in 2001–2011.
** The number indicates the percentage of immigrants from Bratislava in total immigrants to the municipality in 2001–2008. In municipalities marked **, migration from Trnava (more intensive than in case of Bratislava) dominates.
The level of total population changes depends on two components:
A) The natural component of total population increase after 2000 is very low; fewer children were born in the majority of municipalities than the number of deaths.  
B) The migration balance often amounts to multiples of the natural increase values, that mostly influences the total population increase.

The villages that benefit most from migration are Chorvátsky Grob, Limbach, Viničné, Vinosady and Vajnory. These were relative large newly built dwelling quarters. These villages are also characterized by the highest level of the total population increase (Table 2).

3. Consequences of suburbanization for cultural landscape of the Sub-Little Carpathian Region

Suburbanization creates important changes in use of cultural landscape. Farming, vine-growing and related activities are traditional functions of cultural landscape. These are substituted by dwelling and commercial activities on an area of considerable size in the cultural landscape. Along with single-family homes, hypermarkets, shopping centres, industrial zones with warehouses, distribution and lastly production facilities are also constructed. Also, residential suburbanization assumes the form of refurbishment of houses in older zones of municipalities or construction of extensive compact quarters on formerly green areas. These are sometimes isolated from the older communal fabric.

Rural municipalities, in the hinterland of the capital became attractive for new dwellings. The largest city Bratislava and partially the town of Trnava (in the north of the Region) had enough population and financial resources for migration to the cultural landscape of the Sub-Little Carpathian region. The studied municipalities are among those with the highest population increase and with relatively better living conditions. This is in terms of the educational level of the population and the dwelling quality indicators as compared to the rest of the country. An above-average rate of increase of the dwelling population pool (compared to the Slovakian average) with the corresponding impacts on cultural landscape assets, have been observed in the Region. Residential suburbanization contributes to the change of the traditional socio-spatial structure of the settlements. Due to migration, suburban zones increase population with higher income and higher education. The migrating population, who build their residences in suburban zones are, as a rule, well-to-do members of higher social strata looking for a higher living standard and a higher environmental quality with good transport connections to the nearest city. Under the intensive migration, other characteristics of the social structure of population are also changing. The social status of newcomers’ households is often in a sharp contrast with that of the native population.

Suburbanization as a very complex process with multiple factors of different nature, has both positive and negative aspects. In the study area, part of the
capital’s hinterland with the highest socio-economic level in the country, for which consequences of this process for the cultural landscape assets, fully manifested their impact. Distinct increase of the dwelling quality, satisfaction of thousands of home-buyers and in some cases the improvement of the aesthetic quality of the environment are some of the positives. Also, an important phenomenon seen in the Region, is represented by the activities connected with the development of domestic and international tourism (Sub-Little Carpathian Wine Route is a positive example).

On the other hand, this process is also accompanied by negative phenomena such as the list below. Unfortunately, in Slovakia these are rather unrestrained.

- Deep changes in the use of cultural landscape: areas of farming, forestry and recreation plots have diminished and transformation of the arable land pool is practically irreversible.
- Destruction of the traditional cultural landscape often cause many environmental problems.
- The rapid increase of individual car transport and missing solutions for public transport links, connections and communications; the actual physical vicinity of the city does not corresponded to real time accessibility.
- Missing sufficient communal infrastructure and amenities. This reduces the quality of the dwelling environment.
- Missing power of local administration (territorial plans) over investors, adaptation to interests of investors and lack of public spaces.
- Not fully utilized cultural landscape potential for the residential environment – suburban planning and architecture of many new houses (groups of houses) does not respect the landscape. Negative examples of such use listed below:
  - Extreme individualism – gated communities, separated from the rest of the municipality.
  - Civil disengagement and communal life – reduced social contacts between native population and newcomers.
- Official statistical records of population: many immigrants living in newly built houses in hinterland of Bratislava have kept their former addresses in the capital as permanent domicile.
- Lower tax base: municipalities lose the corresponding taxes in this manner, revenue that could be invested in improvement of the communal infrastructure.

4. Conclusions

The outlined rate of pressure concerning the settlement-population development in the Sub-Little Carpathian region, is striking and unmatched by any other in Slovakia. From this example, municipalities in the hinterland of other Slovak cities, may learn a lesson about the negative and positive effects of suburbanization pressure on cultural landscape assets. Presumably, some of these noted impacts will
sooner (or later) appear in other Slovak regions with varied rates. The distinct factor of any commune’s attractiveness is the activity of local self-administration which determines the conditions for migration. Although strategies of developers also play a role. It may contribute to the increased attractiveness of the place (area). The immediate future will reveal, to what extent people are willing to accept the negative effects (transport stress due to under sized transport infrastructure) of their decision to move to the countryside. There are indications of slowing emigration to the hinterland of Bratislava. These may not be so much due to the negative factors of suburbanization as by financial problems, due to the financial crisis (or by high prices) of houses in some localities. So far, it seems that people who’ve decided to move to the attractive Sub-Little Carpathian hinterland of the capital, accept the positive sides of their decision and tolerate the negative. Perhaps, some problems of the suburbanization pressure in the hinterlands’ of Bratislava, will soon be overcome by construction of public spaces within walking distance. The would be items such as pavements, playgrounds, shops, etc. in otherwise hastily built residential compounds. Meanwhile, the permanent consequences of these mass processes on the traditional cultural landscape and the natural landscape, in the hinterland of the capital, will soon be clear as well. Obviously, the natural development and satisfaction of people’s ideas of their new dwelling via a progressive transformation of cultural landscape is one thing. Some of today’s irreversible decisions over nature in terms of cultural landscape is another.

Acknowledgements

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References


ASSESSMENT OF WATER INFLOWING, STORED AND FLOWING AWAY FROM MŚCIWOJÓW RESERVOIR

Agnieszka Policht-Latawiec

Summary

The hydrochemical analyses of water inflowing, stored and flowing away from Mściwojów water reservoir were conducted from April to November 2012. Measured were 27 physico-chemical indices of surface water sampled at 8 dates from four measurement-control points. Analysis of results revealed that water inflowing into Kalużnik river was the best quality – corresponded to class III, but only due to nitrate nitrogen. In the water Wierzbiak from the river, only two from among 16 indices exceeded class II (nitrate nitrogen and phosphates). Water in the reservoir was classified to quality class III because of the temperature and BOD₅, similar as water flowing away from the reservoir. Moreover, the paper assessed usable values of inflowing water, stored in the reservoir and flowing away from it. On the basis of the analysis, it was stated that water cannot be supplied to people since it does not meet the requirements stated in the Minister’s regulations concerning the conditions of the natural habitat of cyprinids and salmonids.

Keywords

water quality • Wierzbiak river • Kalużnik river • usable values

Introduction

In view of the subject of on paper presented, it is necessary to state and assess changes of quality (features) of water flowing in the main watercourse but also water from the tributaries immediately feeding the reservoir. Generally, the current quality status of surface waters in Poland, particularly rivers is considered as poor. It is usually, the outcome of unbalanced water resources management, particularly the supply untreated or insufficiently treated sewage into rivers [Szczykutowicz et al. 2003, Krzanowski et al. 2005].

Water degradation is apparent as unfavourable changes of their physicochemical and biological features, both owing to introduction of excessive amounts of organic and inorganic substances and heated water discharge, or radioactive substances [Dobrzańska et al. 1997]. In result, the balance between pollutant concentrations caused by human activity and potential of self-purification of water environment...
become disturbed. This was the cause of destruction and annihilation of numerous aquatic biocenoses, excessive increase in productivity and eutrophication of waters [Pawelk 2002].

Surface and underground waters are also polluted with other substances coming from various sources. These are both natural sources, such as: geological substratum, vegetation or atmosphere [Rajda et al. 2002] and anthropogenic. This would be connected with life and economic activities of humans [Rajda and Kanownik 2005]. Natural sources of pollution are less dangerous for water purity than anthropogenic ones. In villages, and farms the most dangerous are household wastewater and animal excrements (manure, slurry or liquid manure) but also landfill sites. Agricultural lands are perceived as one of the basic sources of area pollution [Taylor 1988, Ilnecki et al. 2002, Rajda and Kanownik 2007]. In these areas surface waters are polluted mainly due to the application of excessive doses of nitrogen and phosphorus fertilizers [Pawlik-Dobrowolski 1983, Grunert et al. 2004].

At the initial stage of operation, Dam reservoirs accumulate chemical substances inflowing from the catchment, including biogens. These may also function as a kind of treatment plants, biologically favourably changing physical features and chemical composition of waters below the reservoir. The result, water flowing away is generally more deficient in biogens but richer in organic matter. However, with time, the result of chemical elements release from bottom sediments, water reservoirs may become a hazard to the natural environment [Kostecki 1992].


Concentrations of chemical elements and basic physical properties of water sampled from watercourses and the reservoir are assessed in the paper. On the basis of the data, on water quality indices, an attempt was made to assess the quality of water inflowing, stored and flowing away from Mściów reservoir.

2. Material and methods

Quality of water in the Wierzbiak and Kałużnik rivers and in Mściów reservoir were assessed on the basis of the Author's own physiochemical analyses. These were conducted during the period from April to November 2012. Water for analyses was sampled at one month intervals, on randomly chosen days, in measurement-control points situated in the following cross sections (Figure 1):

• inflow to the reservoir: the Wierzbiak river – point No. 1, the Kałużnik river – No. 2,
• outflow from the reservoir – point No. 3,
• outflow from the reservoir below the dam – point No. 4.

Assessed were 27 physicochemical indices. The temperature and oxygen saturation were measured on site by means of CO–411 oxygen meter, water reaction by means of CP–104 pehameter and electrolytic conductivity (EC) by CC–102 conduc-
In the laboratory, total suspended solids (TS) were determined using the gravimetric method, total dissolved solids (TDS) by evaporation, concentrations of Ca$^{2+}$, Na$^{+}$, K$^{+}$, Mg$^{2+}$, Mn$^{2+}$ ions and content of Cr, Zn, Cd, Cu, Ni, Pb and Fe$_{\text{org}}$ were assessed by means of atomic absorption spectrometry on UNICAM SOLAR 969 spectrometer. Concentration of ammonium nitrogen (N-NH$_4^+$), nitrite (N-NO$_2^-$), nitrate nitrogen (N-NO$_3^-$), PO$_4^{3-}$ and Cl$^-$ were determined by means of flow colorimetric analysis on FIAstar 5000 apparatus. Concentration of SO$_4^{2-}$ was assessed using precipitation method, BOD$_5$ by Winkler’s method while COD$_{\text{Mn}}$ (oxidability) was determined by means of permanganate method [Hermanowicz 1999]. Also chlorophyll “a” was determined in water.

Minimum and maximum values were established for all indices and then arithmetic means were calculated. Water quality was assessed on the basis of the previous Regulations of the Minister the Environment, dated 20 August 2008. On the method of classification of the status of surface water bodies (Dz. U. Nr 162, poz.1008) because the new Regulation of the Minister of the Environment, dated 9 November 2011, is less exacting than the one mentioned above. Water usable values were estimated from the perspective of potable water supply [Rozporządzenie... 2002] and as fish habitat under natural conditions [Rozporządzenie... 2002].

Prepared by J. Wojkowski

Fig. 1. Localization of measurement-control points
Table. Range and mean values of physicochemical features of inflowing waters (1 – Wierzbiak river, 2 – Kałużnik river), stored (3 – main reservoir) and flowing away (4 – Wierzbiak river) and assessment of its usable values.

<table>
<thead>
<tr>
<th>Index</th>
<th>Maximum–Minimum Average</th>
<th>Water quality class [8]</th>
<th>Usefulness of surface water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>salmonids</td>
</tr>
<tr>
<td>Temperature [°C]</td>
<td>2.9–21.2 12.1</td>
<td>3.0–19.0 11</td>
<td>2.6–27.5 15.1</td>
</tr>
<tr>
<td>pH</td>
<td>7.00–7.98 7.49</td>
<td>7.04–8.01 7.52</td>
<td>7.20–8.72 7.96</td>
</tr>
<tr>
<td>EC µS · cm⁻¹</td>
<td>296–578 437</td>
<td>360–490 425</td>
<td>288–560 424</td>
</tr>
<tr>
<td>BZT₅ [mg O₂ · dm⁻³]</td>
<td>2.9–4.0 3.5</td>
<td>3.0–4.6 3.8</td>
<td>2.6–6.8 4.7</td>
</tr>
<tr>
<td>ChZT₅ [mg O₂ · dm⁻³]</td>
<td>3.1–9.0 6.1</td>
<td>3.0–6.0 4.5</td>
<td>2.9–11.0 7.0</td>
</tr>
<tr>
<td>O₂ %</td>
<td>55–75 65</td>
<td>53–64 59</td>
<td>47–80 64</td>
</tr>
</tbody>
</table>

| Measurement-control points   |                          |                          |                             | salmonids                  | cyprinids                     |
|                              |                          |                          |                             |                           |                              |
| 1                            |                          |                          |                             |                           |                              |
| 2                            |                          |                          |                             |                           |                              |
| 3                            |                          |                          |                             |                           |                              |
| 4                            |                          |                          |                             |                           |                              |

**Note:** The values in the table are taken from the original source, and the table is presented in a readable format. The assessment of usability is based on the referenced criteria.
| Dissolved solids | 76–458 mg ∙ dm⁻³ | 85–428 mg ∙ dm⁻³ | 135–442 mg ∙ dm⁻³ | 188–408 mg ∙ dm⁻³ | I | I | I | I | I | I | I | I | A1 | A1 | A1 | A1 | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
|------------------|------------------|------------------|------------------|------------------|---|---|---|---|---|---|---|---|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Total suspended solids | 1–2 | 1,5 | 3–5 | 0–0,6 | 0,3 | 2–3 | 2,5 | I | I | I | I | A1 | A1 | A1 | A1 | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| N–NH₄⁺ | 0,04–0,05 | 0,04–0,453 | 0,08–0,10 | 0,09 | 0–0,09 | 0,05 | I | I | I | I | – | – | – | – | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| N–NO₃⁻ | 0,28–5,26 | 0,34–14,78 | 0,0–0,10 | 0,05 | 0,03–0,07 | 0,05 | III | III | I | I | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| NO₂⁻ | 0,04–0,19 | 0,03–1,87 | 0,00–0,03 | 0,01 | 0,00–0,04 | 0,02 | – | – | – | – | – | – | – | – | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| PO₄³⁻ | 0–0,42 | 0,11–0,27 | 0,05–0,26 | 0,16 | 0,04–0,27 | 0,16 | III | II | II | I | A2 | A1 | A1 | A1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| P total | 0–0,24 | 0,04–0,09 | 0,02–0,08 | 0,05 | 0,01–0,09 | 0,05 | II | I | I | I | – | – | – | – | no | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| SO₄²⁻ | 31–109 | 43–111 | 27–110 | 69 | 32–105 | 69 | I | I | I | I | A1 | A1 | A1 | A1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Fe²⁺/³⁺ | 0,11–0,21 | 0,09–0,15 | 0,05–0,08 | 0,07 | 0,03–0,05 | 0,04 | – | – | – | – | A1 | A1 | A1 | A1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Mn²⁺ | 0,03–0,06 | 0,02–0,03 | 0,04–0,05 | 0,05 | 0,00–0,02 | 0,01 | – | – | – | – | A2 | A1 | A1 | A1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Ca²⁺ | 16–62 | 15–60 | 20–57 | 39 | 30–56 | 43 | I | I | I | I | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Mg²⁺ | 2–16 | 3–12 | 4–5 | 5 | 5–17 | 11 | I | I | I | I | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Cl⁻ | 14–54 | 5–38 | 10–62 | 36 | 11–61 | 36 | I | I | I | I | A1 | A1 | A1 | A1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |

EC – Electrolytic conductivity, A1 – water requiring simple physical treatment, A2 – water requiring typical physical and chemical treatment, A3 – water requiring high-performance physical and chemical treatment
3. Results

Considering their thermal characteristics, the analyzed water samples were classified to quality class III (points 3 and 4), except points 1 and 2, where water was in class I (see Table).

Values of the natural river water reaction, oscillate around neutral. It is connected with calcium concentrations in water, which are small at high but big at low CaCO$_3$ content [Chełmicki 2002]. In the Wierzbak and Kaluznik rivers (direct tributaries to Mściwój reservoir), water pH ranged from 7 to 8.01, i.e. in class I. Water in the reservoir revealed the reaction similar to alkaline (8.72) but already on the outflow from the reservoir the reaction was alkaline (9.09). Therefore, this classifies the water to class III according to the regulation of 2008 [Rozporządzenie... 2008]. In neither of the investigated points, electrolytic conductivity exceeded 1000 µS ∙ cm$^{-1}$ – i.e. the value permissible for I class quality. BOD$_5$ concentrations in the Wierzbak and Kaluznik river waters were similar and placed them in II quality class, whereas water stored and flowing away from the reservoir to class III. The degree of oxygen saturation, dissolved solid concentration, total suspended solids and ammonium nitrogen corresponded to water quality class I in all studied points. Regulations of 2008, which takes into consideration nitrate nitrogen, classifies waters of the Wierzbak and Kaluznik rivers as quality class III. Phosphate concentrations placed water at all points to class II, except point 1, where the concentration exceeded values permissible for class III. The total phosphorus concentration slightly exceeded the limit for class I only in point 1, whereas in the other points in remained on the level of class I. Water assessment in the analyzed points, conducted on the basis of minerals values (sulphates, chlorides, magnesium and calcium) revealed that they did not exceed permissible values for water quality for class I on any date of measurement (see Table).

According to the regulations in force, on water usability for potable water supply, three out of 12 analysed indices (temperature – point 1,2, water pH and BOD$_5$ – point 4) do not meet the requirements stated for these categories in the regulations of 2002 [Rozporządzenie... 2001] (see Table). Water in measurement-control point 3 was classified to A3 category because of BOD$_5$ concentrations, whereas to A2 category due to concentrations of manganese and phosphates in point 1, degree of oxygen saturation (in points 2 and 4) and water pH only in point 3. Values of the other indices were in the A1 category. Summing up: when analyzed water was to be used for water supply, it should be taken only from points 1 and 2 and only used after typical physical and chemical treatment appropriate for A2 category.

Water analyzed in measurement-control points, does not meet the requirements for salmonid or cyprinid fish habitat. According to the regulations of 2002 in-force [Rozporządzenie... 2002], BOD$_5$ and nitrite concentrations exceeded values permissible for both fish species in almost all analyzed points, except points 1 and 2 for the oxygen index and point 3 for nitrates (see Table). Considering living conditions for salmonids, in points 1 and 3, only four among 7 analyzed indices meet the standards, five indices in point 2 and three indices in point 4. On the other hand, considering cyprinids, water of the studied river section in points 1,2 and 3 might provide a viable habitat for them due to six indicators and in point 4 – due to four indicators.
Average content of chlorophyll “a” in the Wierzbiak river water (point 1) was 2.4 µg · dm$^{-3}$, 0.2 µg·dm$^{-3}$ in the Kałużnik (point 2), 73.4 µg · dm$^{-3}$ in the reservoir (point 3) and 35.52 µg · dm$^{-3}$ on the outflow from the reservoir (point 4).

4. Conclusion

Water quality and the resulting usable values change with the changing anthropogenic pressure in the catchment area [Rajda and Kanownik 2007, Ilnicki et al. 2002]. Pollution may be counteracted through sanitation of settlement areas. This would require construction of sewerage system and efficient sewage treatment plants [Ostrowski et al. 2005]. Quality of water in Mściwój reservoir was affected mainly by surface runoffs from the nearest reservoir catchment which comprise forests, arable fields, meadows and pastures and also by precipitation.

Analysis of the research results, revealed that water flowing with the Kałużnik river was of the best quality – categorised to class III but only due to nitrate nitrogen. In the water of the Wierzbiak river, only two (nitrate nitrogen and phosphates) among 16 indices exceeded values for class II. Similarly in the reservoir, where the temperature and BOD$_5$ water was classified to quality class III. On the outflow from the reservoir, the water was revealed the worst quality because of its temperature, pH and BOD$_5$ – class III. All inflowing water should be monitored because it feeds the Mściwojów water reservoir. The which fulfils numerous functions, including a recreational one. Moreover, it also provides a refuge for avifauna [http://lto.most.org.pl] and habitats of rare wetland and aquatic plants. The waters flowing away from the reservoir should also be monitoring. They affect the quality of the Wierzbiak river water below the reservoir.

Studies on usable values of water inflowing, stored and flowing away from the reservoir demonstrated that they cannot be used for water supply because of high temperature and water pH and BOD$_5$ concentration. Moreover, on the inflow to the reservoir, the Wierzbiak river does not meet the requirements for natural salmonid habitat because of BOD$_5$, nitrites and total phosphorus. The Kałużnik river only exceeded concentrations of nitrites and total phosphorus. Waters of the Wierzbiak and Kałużnik rivers may provide natural habitat conditions for cyprinids due to six indices: the temperature, BOD$_5$, total suspended solids, ammonium, nitrate nitrogen and total phosphorus. One of the analized indices, did not meet the requirements posed in the regulations in force of 2002 [Rozporządzenie... 2002]. Conclusion, each analysed point values permissible for fish habitats as stated in the regulation in force, were exceeded.
References


Rozporządzenie Ministra Środowiska z dnia 9 listopada 2011 r. w sprawie sposobu klasyfikacji stanu jednolitych części wód powierzchniowych (Dz. U. Nr 257, poz. 1545).

Rozporządzenie Ministra Środowiska z dnia 27 listopada 2002 r. w sprawie wymagań, jakim powinny odpowiadać wody powierzchniowe wykorzystywane do zaopatrzenia ludności w wodę przeznaczoną do spożycia (Dz. U. 2002 Nr 204, poz. 1728).

Rozporządzenie ministra środowiska z dnia 4 października 2002 r. w sprawie wymagań, jakim powinny odpowiadać wody śródlądowe będące środowiskiem życia ryb w warunkach naturalnych (Dz. U. 2002 Nr 176, poz. 1455).

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