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COMPARISON OF SEALING SURFACE DEGREE ASSESSMENT BASED ON ORTHOPHOTOMAP AND LIDAR DATA

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Abstract
The following article compares the methods and the results of sealing surface degree assessment. In the described experiment/research, orthophotomap and point cloud obtained from airborne laser scanning were used as input for the analysis. In this paper, apart from the statement and comparing the results, the problems and limitations of using different research methods are also listed.

Keywords
sealing surface, image classification, orthophotomap, airborne laser scanning, land use

1. INTRODUCTION

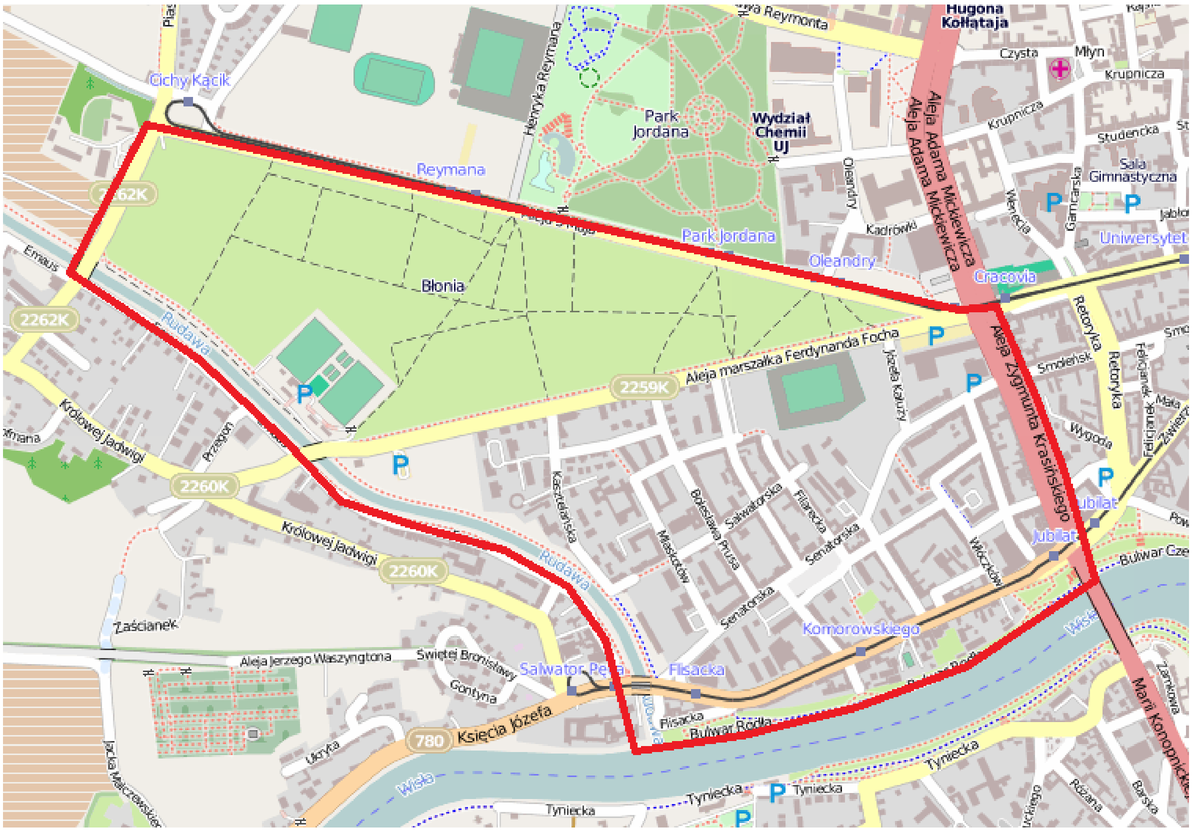
The sealing degree of a catchment area, which specifies the part of the total catchment area constituted by an impervious area, is a fundamental parameter determining the structure and outflow time from a catchment area. This parameter is particularly important in urban catchment areas where a low percentage of biological activity is observed. Actions that expand a sealing surface result in less infiltration of water into soil and its greater outflow from the area. The increase in sealing areas, the improper outflow and management of discharge water, chocked or unadapted drainage systems in terms of surface run-off, negligence in operation and investment in drainage equipment constitute factors which can cause submergence resulting in significant losses in urban areas (Bzymek, Jarosińska 2012). The sealing degree of catchment areas also influences results concerning the calculation of water outflow from catchment areas and the shape of models of the storm and combined sewers catchment areas (Skotnicki, Sowiński 2011). Determining the water outflow from a catchment area requires that the sealing degree for all analysed sub-catchment areas be assessed. In order to carry out detailed calculations and to create mathematical models, it is necessary to provide information about the structure of the sealed surface areas. Valid values for determining the sealing degree of a catchment area is a key element when designing drainage systems, wastewater treatment systems, storm water transfer networks or the revitalization of urban areas (Zawilski, Wierzbicki, 2005). In addition, this indicator should constitute an important element for the management of urban spaces while establishing spatial zoning plans and flood protection. Its determination is also necessary while implementing sewage infrastructure management systems (from English. *Real Time Control*).

Ascertaining the sealing degree of a catchment area is not an easy task, especially in urban areas. It is mainly based on the appropriate classification of source material (maps, photos, point clouds). Specialist literature describes many classification methods using a broad spectrum of image processing technology, as well as methods of statistical classification – they include: the classification of satellite images and aerial photographs, the segmentation of areas using the method of chromatic moments, texture classification using the Markov random field method and the classification of areas based on aerial photos using neural networks (Kubik et al. 2008).

Currently, the most common material used for surface cover analysis and for determining the sealing degree of a catchment area is an ortophotomap. However, it should be remembered that by the end of 2014, data obtained from aerial laser scanning carried out over more than 60% of the entire surface of Poland, involving more than 200 urban areas of the ISOK Project (Information system of national protection against extraordinary risks) will be made available. Thanks to the easy access to data (provincial geodetic-cartographic data) and the relatively low cost of its acquisition, the results of classification carried out on the basis of an orthophotomap and point cloud obtained through aerial laser scanning were compared.

2. RESEARCH METHODS

The experiment was carried out on a part of a Kraków with a total surface of 1.2 km^2 on an estuary of the Rudawa River to the Wisła River (Fig.1). The area includes heavily urbanized sites with high-density housing (areas between the Wisła as well as the Rudawa and Aleja Zygmunta Krasińskiego as well as Aleja Focha) with green elements (a stadium, many squares, boulevards of the Wisła River), as well as a large green space (Krakowskie Błonia). The choice of the area was dictated by the diversity of its land usage, as well as the lack of significant changes in this area in the period between the experiment and when airborne scanning and aerial photographs were taken, which could falsify the results and hinder their interpretation.



Source: Open Street Map.

Fig. 1. The area for which an assessment of catchment area sealing has been carried out

An assessment of the sealing degree of the catchment area was made on the basis of a supervised and unsupervised raster classification (orthophotomaps) and the classification of a point cloud obtained as a result of airborne laser scanning.

The experiment used the ortophotomap (RGB model) at a scale of 1:10 000, prepared on the basis of aerial photos taken in 2009, its pixel terrain resolution was 0.25 m. In order to carry out the supervised and unsupervised classification, MicroDEM software (in version 16.0) was used.

The point cloud obtained as a result of airborne laser scanning, was made available by the Biuro Planowania Przestrzennego Urzędu Miasta Kraków (Spatial Planning Office of the Krakow Municipal Council). The study was made in 2006. It used a helicopter with the measuring system Fli-Map 400; the average height of flight trajectory was 350 m. The density of points of the analysed cloud is variable and ranges from 11 to 30 points per m^2, in total the entire cloud has nearly 20 million points. The data was provided in ASCII format, which means that in each row coordinates are stored (consecutively: X, Y, Z). The provided point cloud is presented in the Kraków local flat rectangular coordinate system (KUL).

In order to process the lidar data, the study used commercial software from the Finnish Company, TerraSolid Ltd., working as the MDL application for MicroStation.

In the first place in the analysed area, the land use classification was performed using three methods: raster supervised classification, raster unsupervised classification and point cloud classification. Four classes of land usage were found:

- buildings (roofs)
- bituminous roads
- unpaved surfaces
- parks, gardens, green squares

3. RESULTS

3.1. Unsupervised classification

The unsupervised classification was carried out several times, each time increasing the number of classes and comparable results with the ortophotomap. A variety of roof cover meant that to obtain results, data had to be divided into twelve classes, however: four classes were classified as green, two as bituminous roads, one as an unpaved surface and five as roofs. Figure 2 shows the effect of the classification, obtained before the aggregation of classes and after its completion.

Table 1 shows results which were obtained for each land usage classification in connection with performing the unsupervised classification.

3.2. Supervised classification

Supervised classification was carried out on the basis of standards indicated in the programme, so-called training fields, according to which the programme classifies the raster surface.

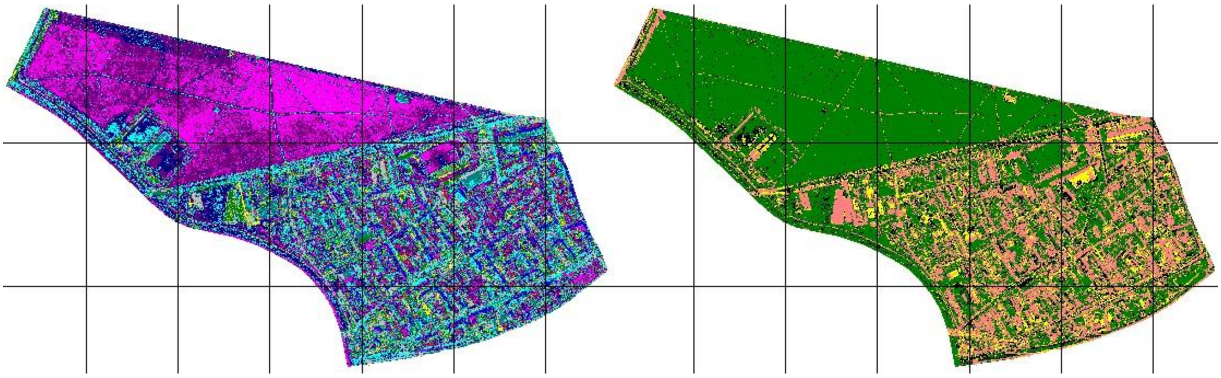
The results obtained from the supervised classification are presented in Table 2.

Table 1. Land usage - results of unsupervised classification.

Type of usage	Share,%	Area, km²
Bituminous roads	12.7	0.15
Buildings	18.1	0.22
Unpaved surfaces	8.9	0.11
Green areas	60.3	0.72

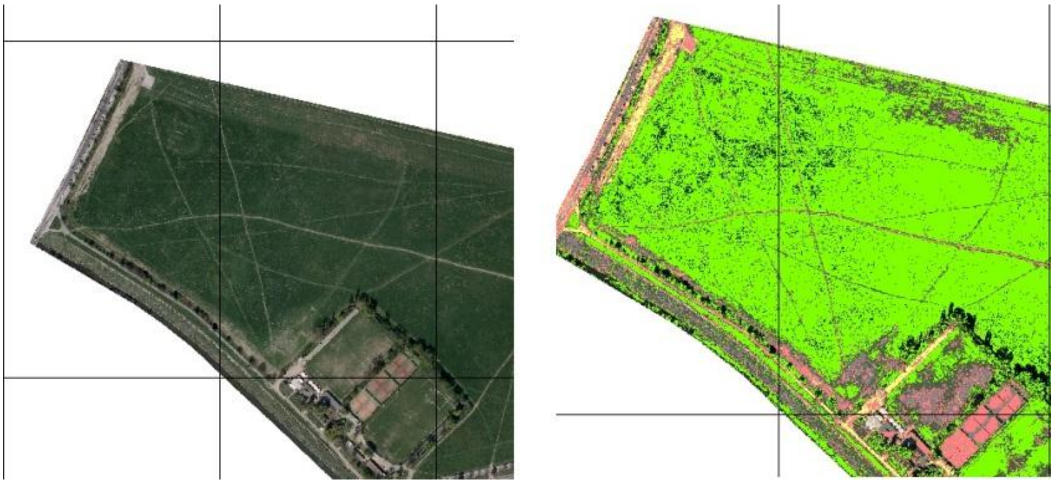
Table 2. Land usage - results of supervised classification.

Type of usage	Share,%	Area, km²
Buildings	14.4	0.17
Bituminous roads	22.7	0.27
Unpaved surfaces	6.6	0.08
Green areas	56.3	0.68



Source: Own elaboration.

Fig. 2. Supervised classification before the aggregation of classes and after its completion

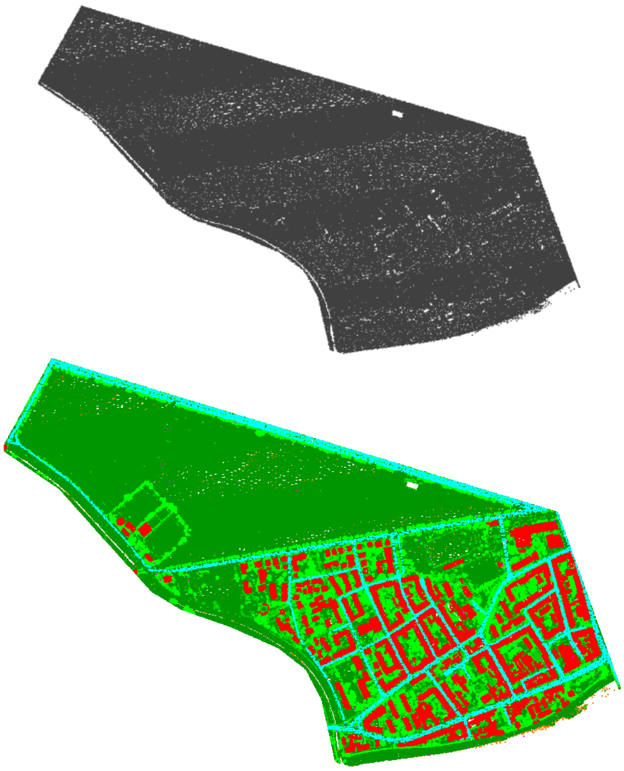


Source: own elaboration.

Fig. 3. Supervised classification - unbuilt fragments of area

3.3. Filtration and classification of the point cloud

Grouping points into certain layers, such as: area, vegetation and buildings is divided into 2 stages: filtration and classification. The first process, i.e. the filtering of the lidar data, consists of finding points which are reflected only in the area. For this process the Digital Terrain Model (DTM) is built as it is indispensable for classifying the point cloud. The classification divides the lidar data into layers dependent of the heights to which the assigned reflected points e.g. from vegetation and buildings can automatically be assigned. During the research, filtration using the TIN (Triangulated Irregular Network) active model algorithm was used. *(Axelsson 2000).* The idea of filtration is based on determining the initial surface when it is found lower than the measurement points, and then on binding this surface with the area points with the help of so-called binding points, meeting defined conditions – iterative distances and iterative angles. Iterative distance is the distance between the point which is proposed as the binding point and the triangle surface in the given stage of the operation, whereas the iterative angle is the maximum angle between a straight line going through a binding point and a proposed point as the binding point and the projection of this straight line on the triangle's surface. Having obtained area points from the point cloud, one can classify the rest of the points in terms of height. In the classification for this area, height of 0 is taken, with regards to which one can group the rest of the points according to the set conditions. For this research, the following height ranges were adopted: 0-1.0 m-low vegetation, 1.0-3.0 m-medium vegetation-, >3.0 m-high vegetation. In the next step, points reflected on roofs of buildings are searched. In this case, the algorithm searches for points from the layer of "high vegetation" and chooses the ones at which there is no area point. The identification of the above mentioned layers is done automatically. A problem arises when one extracts bituminous roads and unpaved surface. If, in the first case, one can find points in a semi-automatic way, using information regarding the intensity or the echo of pulse reflection, unpaved surfaces are chosen manually. In this research, due to the absence of additional information stored in the cloud, in both cases, points were manually selected based on the vector maps of roads and the ortophotomap.



Source: own elaboration.

Fig. 4. Point cloud classification- raw point cloud on left , classified point cloud on right

Table 3 summarizes the final results of the classification carried out on the basis of point cloud.

Table 3. Land use - results of point cloud classification

Type of usage	Share,%	Area, km^2
Buildings	15.8	0.19
Bituminous roads	19.2	0.23
Unpaved surfaces	7.5	0.09
Green areas	57.5	0.69

Results obtained on the basis of the ortophotomap during both the supervised and unsupervised classification as well as from the point cloud differ from each other to a very small degree. This also includes results for green areas and for individual categories of sealed areas (Fig. 5).

4. PROBLEMS IDENTIFIED IN THE CLASSIFICATION

4.1. Ortophotomap

While the land cover classification, on the basis of the orthophotomap was made using both supervised, as well as unsupervised classification, three fundamental problems were identified:

a. disturbances associated with shadows visible on the ortophotomap
b. difficulties in identifying buildings with black roofs
c. areas covered by tree crowns

The most important of the identified problems is the one connected with shadows being visible on the ortophotomap. These shadows intensively interfere with the unsupervised classification method. They are classified as a separate category and at the same time they obscure actual land usage.

Two other problems associated with tree crowns and black roofs apply to a similar degree to supervised and unsupervised classification.

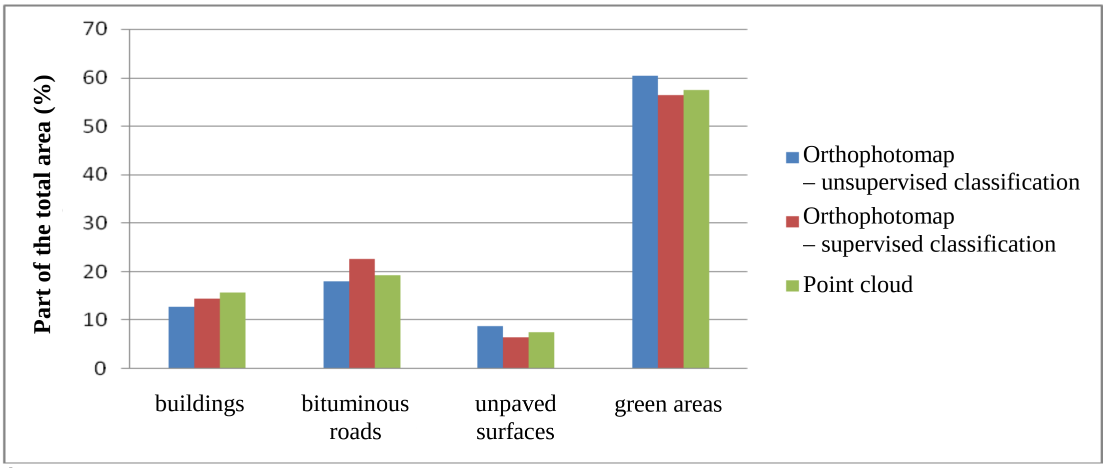
The problem connected with covering the terrain surface with trees is particularly troublesome in the case of avenues of trees being located along roads – tree crowns provoke too much green area share in relation to the total area and they impede the identification of the main directions of water runoff from catchment areas.

In case of black roofs, the fact that these roofs are often identified as green areas constitutes an obstacle to the appropriate classification. This situation has also been observed in the undertaken experiment (Fig. 7).

4.2. Point cloud

In order to correctly classify the lidar data, it is necessary to carry out proper filtration to build the correct Digital Terrain Model (DTM). Searching points reflected in the area is done automatically but sometimes a manual adjustment of the terrain model is necessary. The biggest risk of errors concerns data describing points that build a terrain model and that are located far below the terrain. Such cases occur most often in the vicinity of buildings.

Classification in terms of height is performed on the basis of the Digital Terrain Model. In the undertaken research it was not necessary to build layers of low, medium and high vegetation but it was done in order to determine points that identify buildings. Searching for buildings in the "high vegetation" layer reduces the scope of the task, so the algorithm runs faster and more efficiently. The problem regarding the correct building classification in the automatic way appeared when there were high trees present in the vicinity (Fig. 9). In such cases, it was necessary to manually reclassify points.



Source: own elaboration.

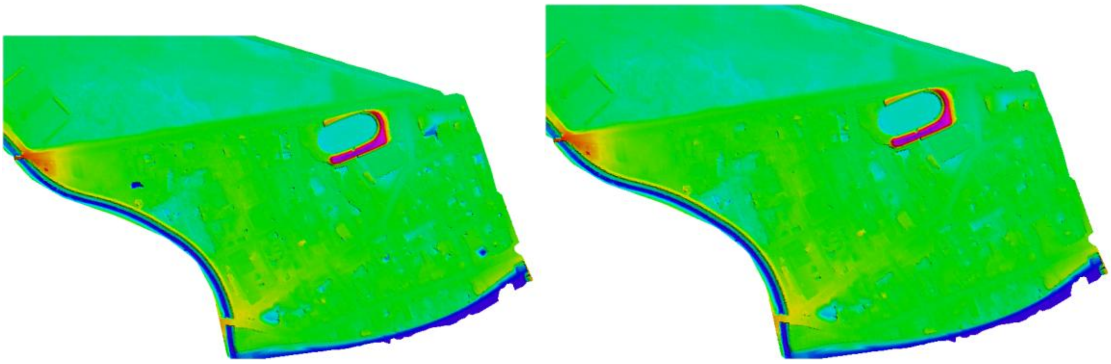
Fig. 5. Comparison of results obtained using three methods

Source: own elaboration.

Fig. 6. Classification of "shadows" as a separate land cover class

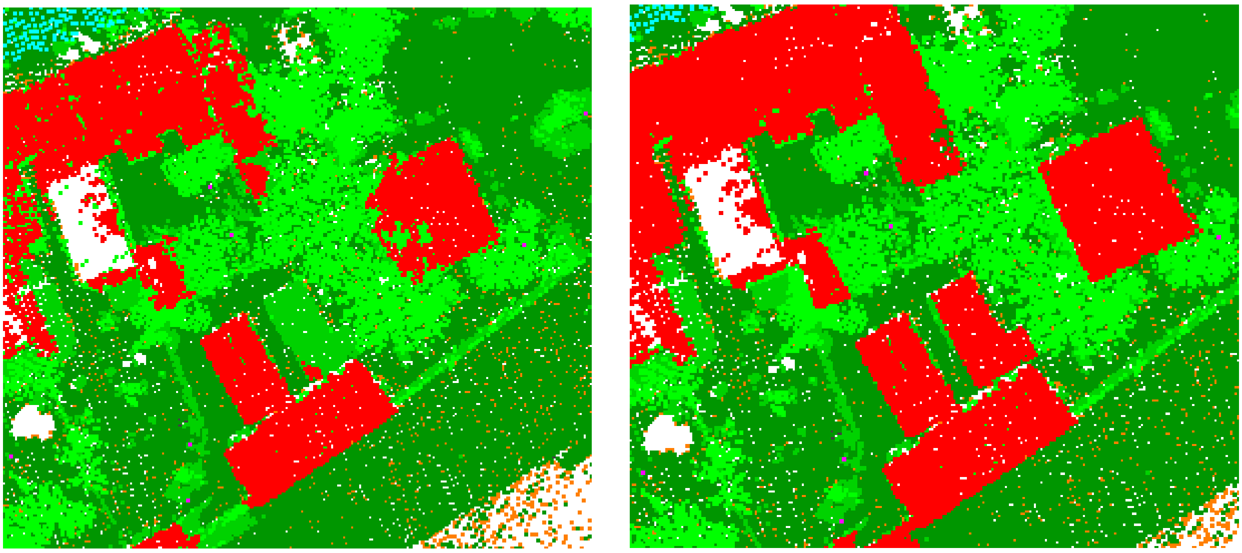
Source: own elaboration.

Fig. 7. Interpretation problems associated with covering areas with tree crowns and black roofs



Source: own elaboration.

Fig. 8. The DTM fragment before manual classification of points (left) and after the classification (right)



Source: own elaboration.

Fig. 9. Fragments of images depicting buildings detected automatically (left) and after manual adjustment (right)

5. SUMMARY AND CONCLUSIONS

The experiment connected with assessing the sealing degree of the catchment area, made on the basis of the ortophotomap and point cloud, originating in airborne laser scanning, illustrated the benefits of the accepted methods and their reliability. It was limited only to a small extent due to a number of problems that arose during classification. The methods applied in the research differ in the degree of their complexity, this also involves the difference in the amount of time required for their use. Despite errors, all analysed methods can be used in engineering - in the conceptualising and designing of work.

It is worth noting that the undertaken experiment was the first attempt to use lidar data to calculate the sealing degree of a catchment area. In order to draw broader conclusions a similar comparative analysis should also be carried out for another area. According to the authors, the reliability of the obtained results should be confirmed using cloud point data with the intensity and echo saved, then by comparing the obtained data with the results obtained using other classification methods, for example object-based image analysis (OBIA).

On the basis of the carried out and described experiment it should be stated that:

- the results of the assessment of the sealing degree of the catchment area on the basis of both orthophotomap and point cloud only slightly differ from each other
- the fastest way to obtain a reliable result is the supervised classification of an ortophotomap, unsupervised classification requires customising a number of adopted classes to achieve a satisfactory result
- sealing degree assessment of a catchment area on the basis of a point cloud with unsaved intensity and a rebound echo for flat surfaces (bituminous roads, unhardened surfaces) requires the use of additional data
- shadows cast by buildings and high trees constitute the biggest problem while classifying the orthophotomap
- an additional difficulty related to the orthophotomap classification is to identify buildings with black roofs, often confused with road surfaces as well as covering parts of area with tree crowns - particularlyalong roads
- all three methods are suitable for use in engineering practices.

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