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LIDAR data application in the process of developing a hydrodynamic flow model exemplified by the Warta River reach

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ABSTRACT

The aim of the study was an attempt to use the information from airborne laser scanning to develop a reliable, simple method of obtaining data characterizing the resistances caused by the presence of vegetation during high water flows in. The study was carried out in the reach of the middle Warta River course, between Nowe Miasto nad Wartą and Solec, i.e. covering the Warta River from km 322+700 km to km 314+200.

The study used geospatial data obtained with the use of various techniques. As part of the analyses, airborne LiDAR data (ALS) were used in the form of a classified cloud of points derived from the resources of Central Office of Geodesy and Cartography [in polish. *Główny Urząd Geodezji i Kartografii*]. An additional source of land cover information was the Data Base of Topographic Objects [in polish. *Baza Danych Obiektów Topograficznych* - BDOT10k] with accuracy and detail corresponding to a 1:10 000 topographic map. The information on land cover in the scope of flowing water, stagnant water and crops on agricultural land were used.

For the purpose of the work, a hybrid model was constructed. The model was built on cross-section measurements and digital terrain model (DTM). The data were implemented in a way that allowed for defining 1D model sections and reach with calculations performed using a two-dimensional model. The applied 2D hydraulic mathematical model was constructed on a single cartesian grid. Therefore, the search has been undertaken to find solutions allowing for reducing the original DTM resolution (1m x 1m) to one that would not cause a significant quality loss. This solution would, at the same time cause model calculations to be made within a reasonable time. Taking into account above requirements, it was planned that the conversion process of the DTM with a resolution of 1m would be carried out using the most popular and simplest method, i.e. resampling of a regular square mesh with the use of the nearest neighbor method into DTMs with a resolution of 2 m, 3 m, 4m, 5 m or 10 m. The following indicators were used to assess the quality of converted DTMs: Root Mean Square Error (*RMSE*), correlation coefficient R_d. In addition, took into account data on extreme values, i.e. the minimum (min_h) and maximum (max_h) values of height elevation difference. Based on the conducted analysis, it was possible to determine the optimal converted raster resolution.

In order to determine the values of roughness coefficients in hydrodynamic mathematical model, the information on vegetation on the basis of LiDAR data was used. The data from BDOT10k and the information obtained based on orthophotomap interpretation were used as supplement sources. By using DTM and DSM (digital surface model) data, there were obtained averaged heights of vegetation in the considered research section. The values were assigned to single pixels, creating a new thematic raster (Fig. 1a). This approach allowed for defining data regarding the occurrence of "low vegetation" representing meadow or wasteland, "medium vegetation" representing second-growth forest, as well as "high vegetation" representing high forest (Fig. 1b). Additionally, based on the information included in BDOT10k

and on the basis of orthophotomaps, there were identified the areas corresponding to arable land, ponds/ small water reservoirs and the river channel. This procedure allowed for obtaining a raster layer that defined the spatial location of three floors of vegetation, arable land, ponds or small water reservoirs and the riverbed (Fig. 1c).

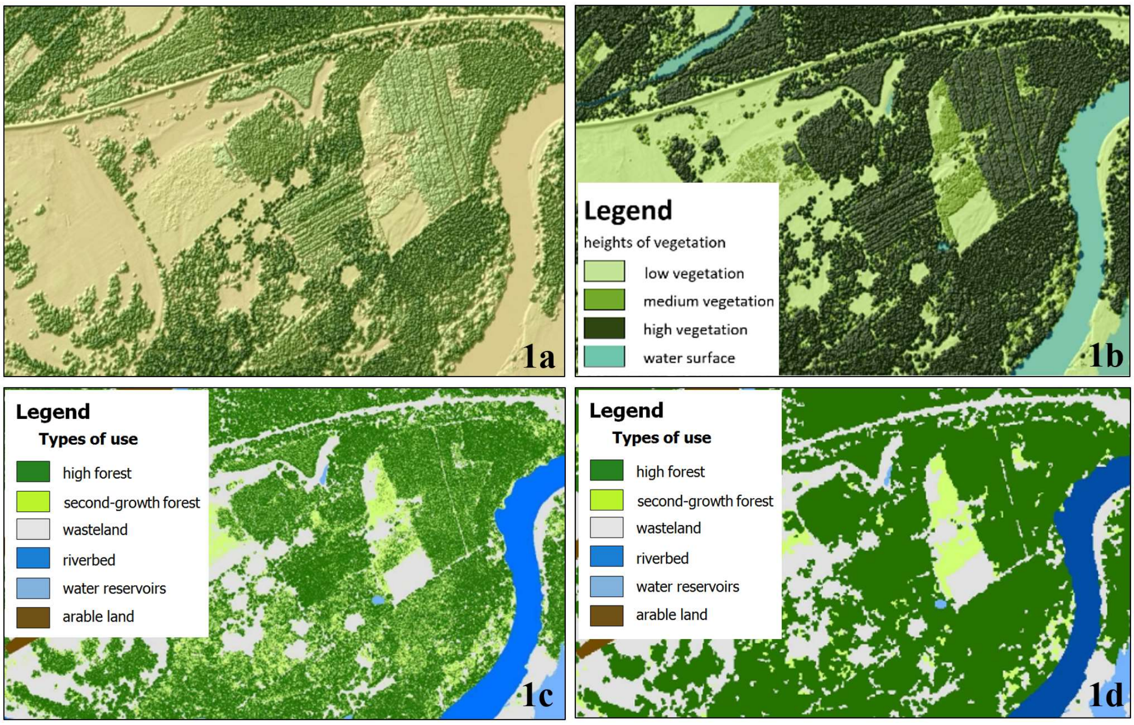

Fig. 1 Fragment showing DSM with an original resolution (1a), DSM with an original resolution including vegetation stratification (1b), DSM with an original resolution including vegetation stratification and BDOT10k data (1c), converted DSM including vegetation stratification and BDOT10k data (1d).

Pre-determined Manning's coefficients were assigned to the separated areas, using tabulated coefficient roughness values published in the literature. As part of the final stage of work, the data were implemented into mathematical models. The procedure consisted in transforming the raster layer (Fig. 5d). This was necessary due to the use of a generalized digital terrain model.

Implementation of the predefined values of roughness coefficients in the hydraulic mathematical model enabled to carry out a series of model simulations. The calculations included the values of low water flows measured in August 2015 (first series) and high water flows from the June 2010 flooding (second series). In the process of model calibration, there were used methods of model quality classification by such parameters as: correlation coefficient R calculated for water table ordinates and flow rates, special correlation coefficient R_s, total square error TSE, culmination level error ΔH_{max}. Finally, taking into account the values of correlation coefficient, special correlation coefficient and total square error, the achieved simulation results was satisfactory.

The results achieved showed that the conversion of the original DTM provided the acceptable parameters of converted DTM. Furthermore, the results achieved on the basis of field studies and mathematical flow model calculations confirmed that DTM and DSM data obtained by means of airborne laser scanning might be used for a simplified land cover analysis that supports the assessment of floodplain capacity. Therefore, the applied method, i.e. vegetation stratification, can be an attractive alternative or complement to previously used BDOT10k.