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

AUTOR: **Albert Malinger, Tomasz Kałuża, Tomasz Dysarz**

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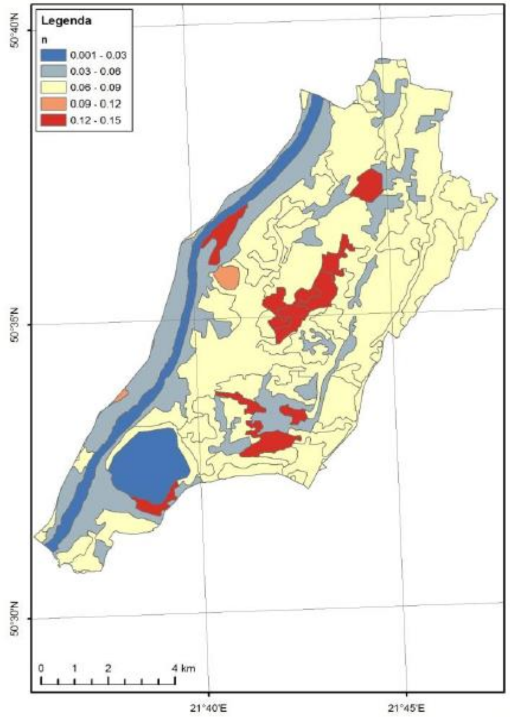
I. INTRODUCTION

Until now, the resistance has been developed based on the **Coor**dination of **In**formation on the **E**nvironment (CORINE) database or data from the Topographic Database (BDOT) or other data like orthophotomaps.

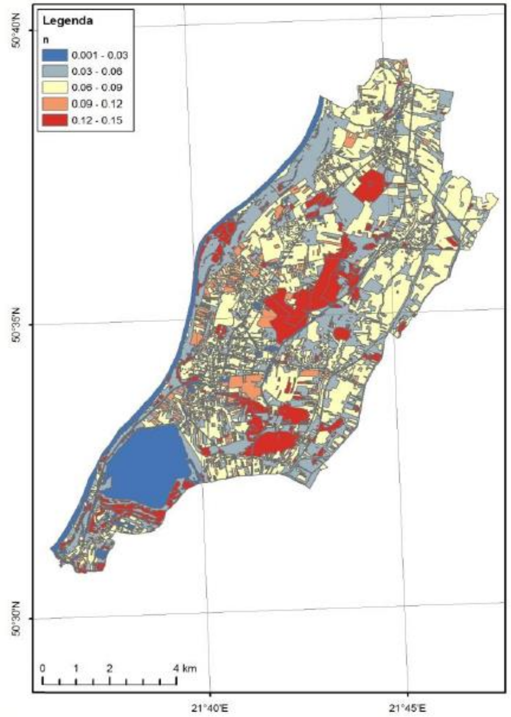
LiDAR data can be new, detailed data on terrain coverage and resistance.

Corine LC – from 1990



(1 : 100 000)

BDOT10k – from 2012



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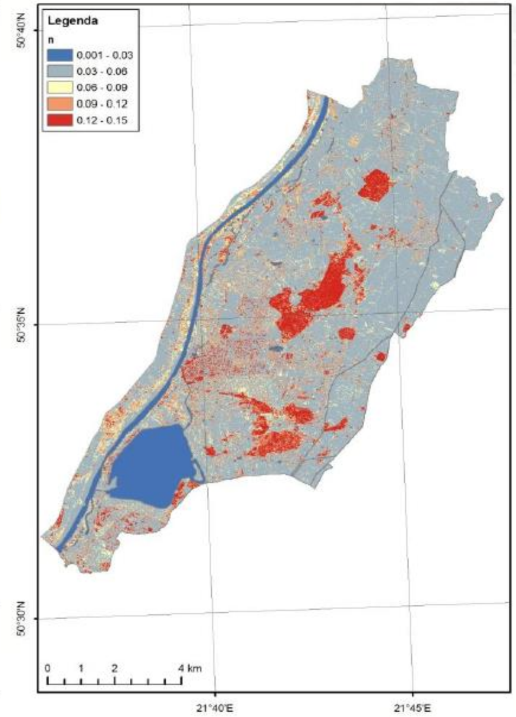
LiDAR – from 2013



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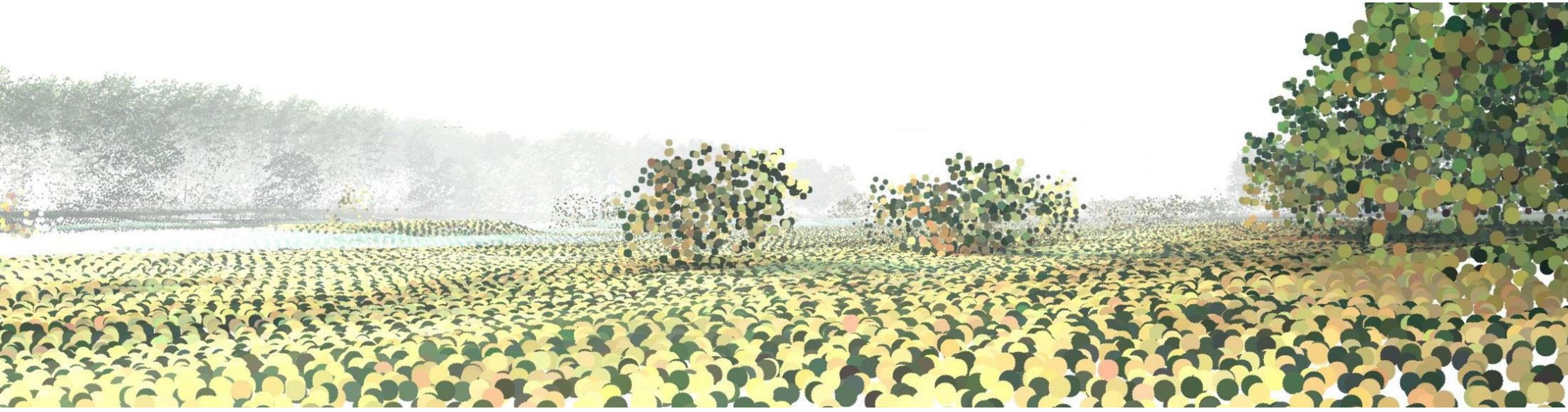
II. PURPOSE OF THE STUDY

<u>What does „*LiDAR*” mean?</u>

Light **D**etection **a**nd **R**anging (***<u>LiDAR</u>***) or **A**irborne **L**aser **S**canning (***<u>ALS</u>***) is a remote sensing method that uses laser beam to measure ranges (variable distances) to the Earth. The process includes three main stages:

1. Emission from the scanner;
2. Hits the target;
3. Returns reflections (echos) to the scanner.

After this process, it is possible to obtain **a point cloud data**. Based on point cloud data, **digital terrain model (DTM)** and **digital surface model (DSM)** were generated. These data are available from the Central Office of Geodesy and Cartography.



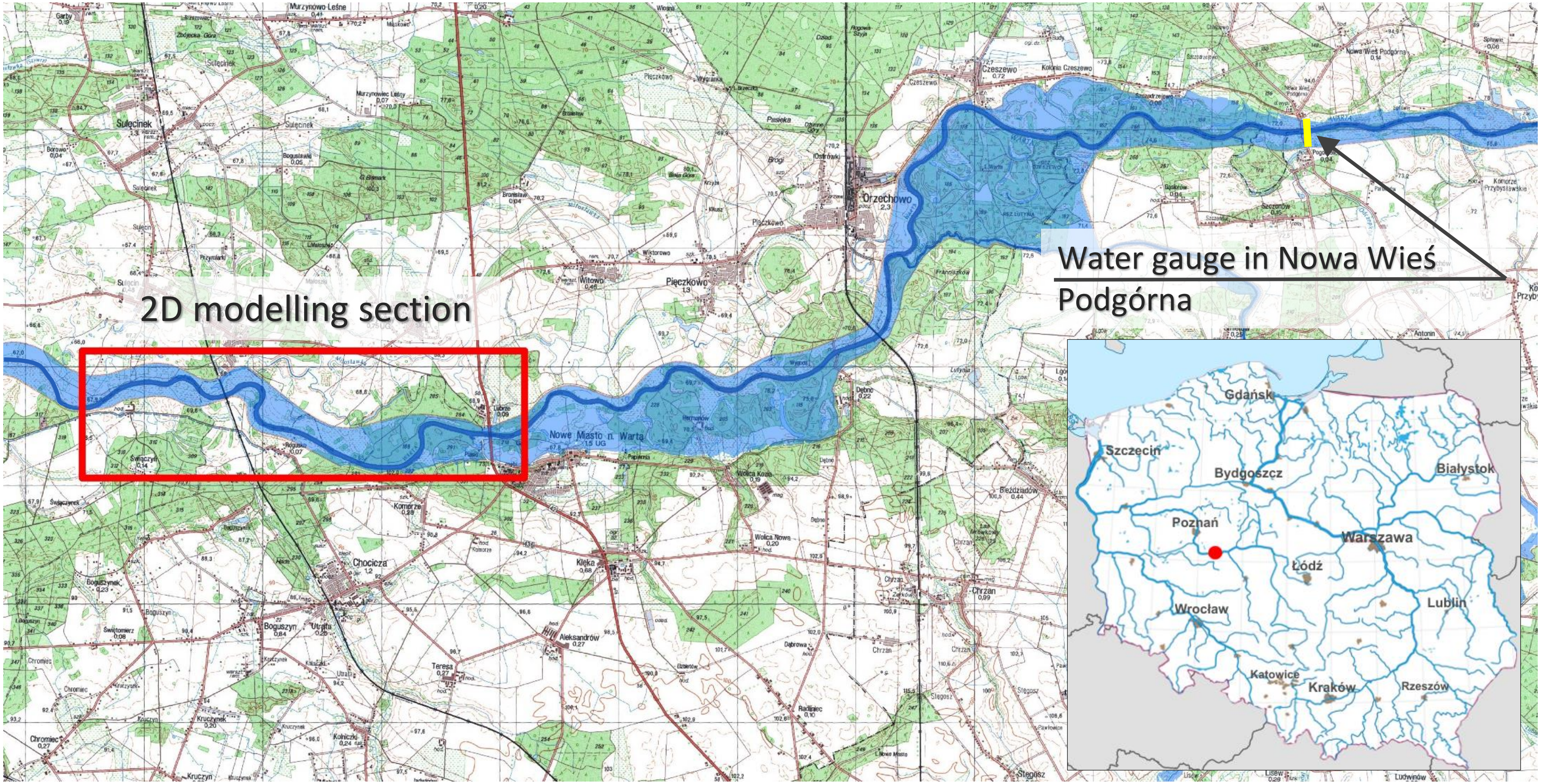
II. PURPOSE OF THE STUDY

The main purposes of the study:

- selection of the size of the computing cell in the 2D hydrodynamic model;
- use the information from LiDAR data to develop a simple method of obtaining data characterizing the resistances caused by the vegetation during high water flows in the reach of the Warta river.

III. MATERIALS

III a. Study site location:



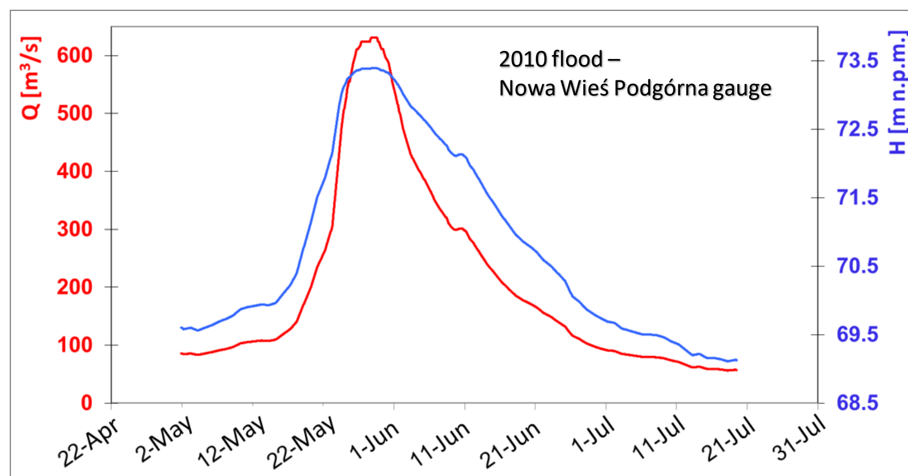
III b. Input data:

Geospatial data

- digital terrain model (DTM) and digital surface model (DSM) with 1 m resolution;
- Data Base of Topographic Objects (BDOT10k);
- the elevation of points specifying the marks of high water during the flood in 2010 and elevation of low water from 2015, measured by GNSS RTN receiver;
- cross-sections of the main channel of Warta river, measured by GNSS RTN receiver.

Hydrological data

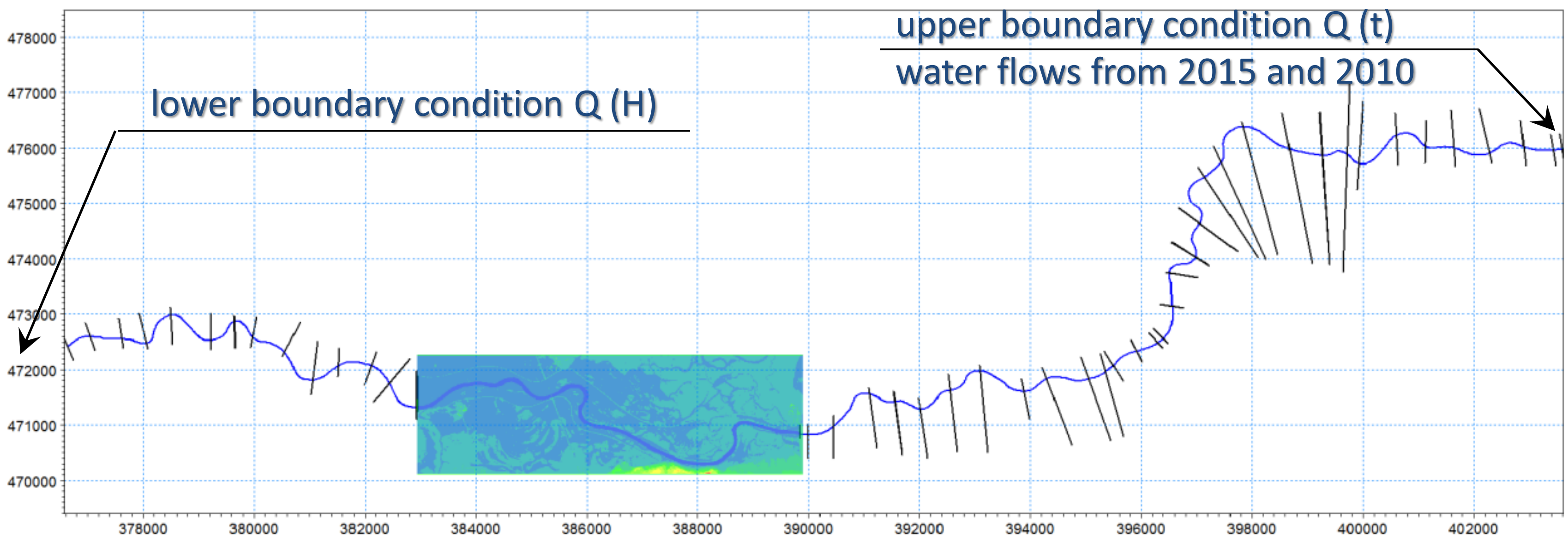
- Based on measurements, from the water gauge in Nowa Wieś Podgórna:
  - → Low water flows data from August 2015;
  - → High water flows data from the 2010 flooding.



IV. METHODOLOGY

IV a. Hydrodynamic model and boundary conditions

For the purpose of the work, a hybrid model was constructed:



2D model section (floodplain)

1D model section (main channel and floodplain)

1D model section (main channel)

1D model section (main channel and floodplain)

2D model section (floodplain)

IV b. Processing of digital terrain model

- To reduce the DTM raster resolution, the nearest neighbor method was used. The original DTM (resolution 1m x 1m) has been transformed to a resolution of 2, 3, 4, 5 and 10 m.
- The following indicators, were used to assess the quality of converted DTMs:

- Root Mean Square Error (RMSE):

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} \Delta h_i^{\,2}}{n_L}}$$

- correlation coefficient (R_d):

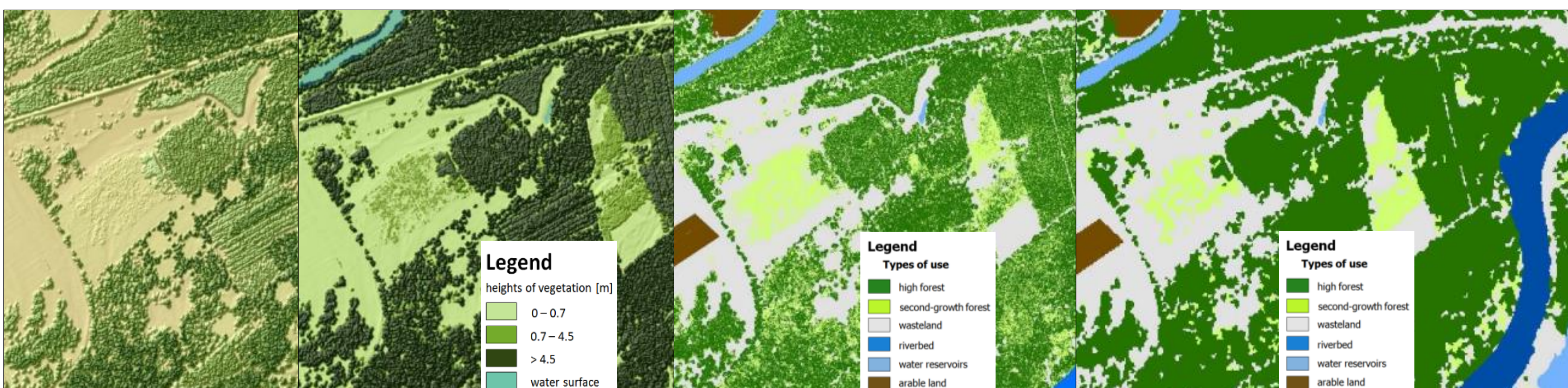
$$R_d(x,y) = \frac{\sum_{i=1}^{n}(hx_i - \overline{h}x_i)(hy_i - \overline{h}y_i)}{\sqrt{\sum_{i=1}^{n}(hx_i - \overline{h}x_i)^2}\sqrt{\sum_{i=1}^{n}(hy_i - \overline{h}y_i)^2}}$$

where:

Δh_i	***– difference in height between the reduced and original model [m];***
n_L	***– number of nodes (points) of the terrain model;***
hx_i	***– node height of the reference DTM [m];***
hy_i	***– node height of the converted DTM [m];***
$\overline{h}x_i, \overline{h}y_i$	***– average values of height [m].***

IV c. Flow resistances

- By using original DTM and DSM data, there were obtained averaged heights of vegetation;
- This procedure allows the definition of "low vegetation" data representing a meadow or wasteland, "average vegetation" representing the second-growth forest and "high vegetation" representing a high forest;
- Based on the information included in BDOT10k, there were identified the areas corresponding to arable land, ponds or small water reservoirs and the river channel;
- Finaly, based on literature, pre-determined Manning's coefficients were assigned to the separated areas. This raster could be introduced into the hydrodynamic mathematical model after generalization.



IV c. Calibration of the hydrodynamic 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);
- There were used methods of model quality classification by parameters: correlation coefficient ***R*** calculated for water table ordinates and flow rates, special correlation coefficient ***Rs***, total square error ***TSE***.

V. Obtained results

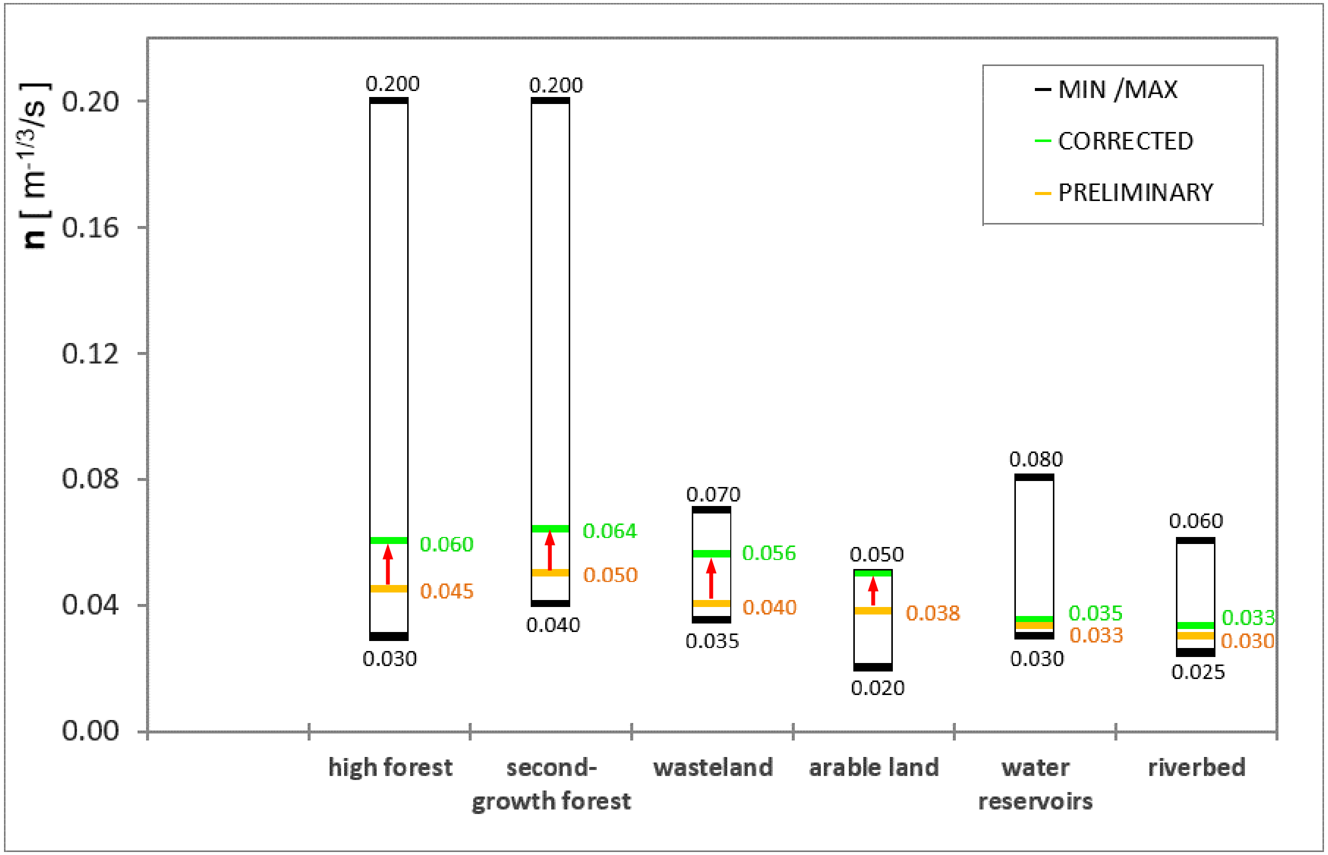
- DTM raster conversion results, including the nearest neighbor method:

Parametr	GRID 2m	GRID 3m	GRID 4m	GRID 5m	GRID 10m
reduction coefficient *r*	ok. 25%	ok. 11%	ok. 6%	ok. 4%	ok. 1%
RMSE [m]	0.0799	0.0949	0.1259	0.1421	0.2356
min [m]	-3.57	-2.49	-3.09	-3.7	-3.85
max [m]	2.34	3.21	2.77	2.83	3.4
correlation coefficient R_d	0.987	0.994	0.978	0.974	0.943

- Based on results, 3m raster resolution was included in the mathematical model.

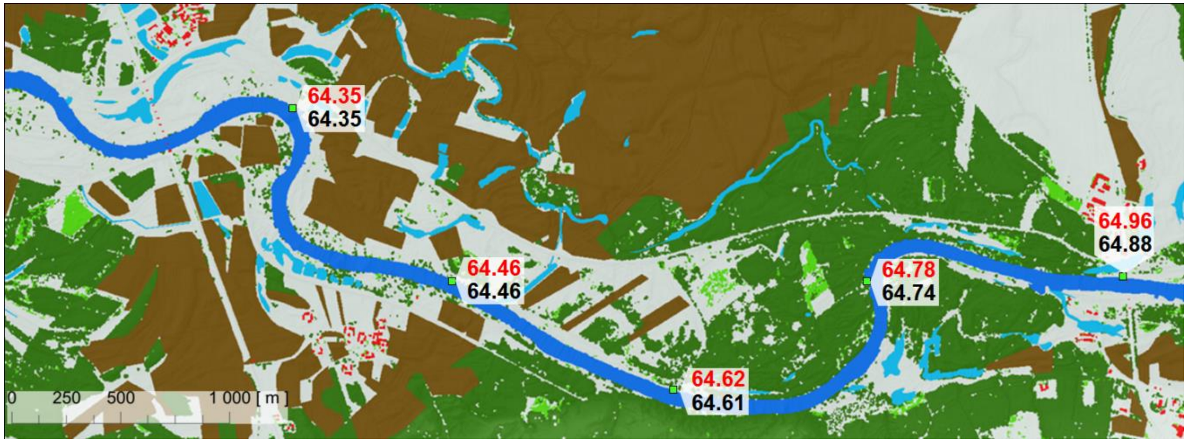
V. Obtained results

- After series of model simulations it was possible to indicate differences between Manning's coefficient values before and after model calibration:



V. Obtained results

- Measured and calculated ordinates of the low water table from August 2015:

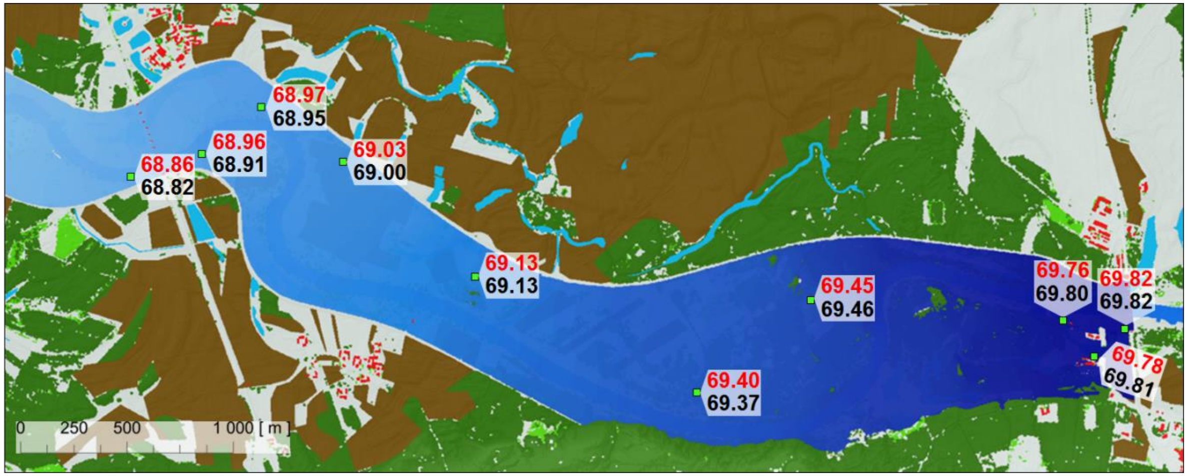


R = 0.998

Rs = 1

TSE = 2.78

- Measured and calculated ordinates of the high water table from 2010 flood:



R = 0.999

Rs = 1

TSE = 1.36

VI. Main conclusions

- The results of the analysis showed, that after reducing the original resolution to 3m, the average Root Mean Square Error (*RMSE*=0.08m) was 1cm more than when the resolution was reduced to 2m. Then, the correlation coefficient R_d represented a highest value and amounted to 0.99;
- The conversion of the DTM into a resolution of 3m provided the acceptable parameters of converted DTM;
- The size of a single computing cell of 3m x 3m was also acceptable due to the calculation time, which was approx. three weeks;
- Using the mathematical model it was found, that DTM and DSM data obtained by LiDAR data, might be used for a simplified land cover analysis;
- The applied method of vegetation stratification, can be an alternative or complement to BDOT10k or CORINE LC data.

Thank you

for your attention!

Poznań University of Life Sciences

Uniwersytet Przyrodniczy w Poznaniu

I. INTRODUCTION

ALS data in Poland:

Currently, ALS data is available for almost the whole country. These data were developed and collected in the non-vegetative phase (**without leaves**).

There are two standards:

- 4 or 6 points/m^2
- 12 points/m^2 - for big cities.