Comparison of digital elevation models of riparian wetland generated from airborne laser scanning of different accuracy

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Abstract— **In the last decade, the development of laser scanning allowed the widespread use of this technology in Poland. Currently, Airborne Laser Scanning (ALS) become the most reliable source of elevation data for large areas. It was selected as a main source of data in the project IT System of the Country's Protection against extreme hazards (ISOK), which provides LiDAR data for almost whole country. Despite progress in availability of accurate elevation data, there are specific areas were quality of the data collected in ISOK is not sufficient, e.g. Kampinoski National Park (KPN). The lower data quality can be expected in marsh ecosystems covered by dense vegetation in the floodplain and former river valleys. The aim of this work is to compare ALS Digital Elevation Models (DEM) collected with different scanning parameters, evaluate and determine causes of their quality degradation.**

I. INTRODUCTION

A. *IT System of the Country's Protection against extreme hazards (ISOK)*

The project "IT System of the Country's Protection against extreme hazards (ISOK)" is realized nowadays in Poland. Its aim is to create complex system for water management, especially flood protection [1] including accurate digital elevation model (DEM). As a main source of elevation data Airborne Laser Scanning (ALS) was selected. ALS mapping of Poland area was started in 2011 year. In the first stage of project realization (2011-2013) around 65% of the country area was scanned. In 2013 the second stage began and that aim was to collect additional LiDAR data for above 90% of the total country area. Data was collected in 2 standards. Standard I rural areas, points density 4 pts/sq. m (in special cases the density was higher – 6 pts/sq. m), standard II urban areas, points density 12 pts/sq. m [2].

B. *Nationwide LiDAR data in context of local scale (natural river valley case)*

Despite that the ISOK project provided dense, high quality data, it's nationwide character, in some particular areas like e.g. area with dense natural vegetation coverage or relatively wet area (natural river valleys, floodplains, wetlands) it's quality (especially DEM) could be not enough and generate significant errors in hydrodynamic modeling and estimating of the water storage capacity [3]. The problem concerns Kampinos National Park (KNP) located in central-eastern Poland. A numerous marshland habitats pose a problem for laser beam, as a result limits the possibility of beam reflection from the ground. An additional issue are communities of sedges', especially *Caricetum cespitosae* or *Caricetum appropinquatae* which form tussocks as a mixture of root system, organic and mineral muddy materials [4]. Sedge's tussocks influence a floodplain micro-topography, which in our opinion can be difficult for ALS technique to acquire and then process for extracting this structure from the vegetation.

C. *ISOK LiDAR data problems within the Kampinos National Park*

If we are interested on large natural area bigger than one ALS block the continuum of the natural objects and phenomena could be not kept on, what can strongly influence results. In the possible worst situation a part of the object is scanned in autumn and another part in spring two years later, by different instrument. The full area of the KNP was covered by ISOK system ALS mission. Its premises is divided by the border of four blocks, which indicates that, the data was acquired in different time ('Fig. 1'), and it's processing was done separately.

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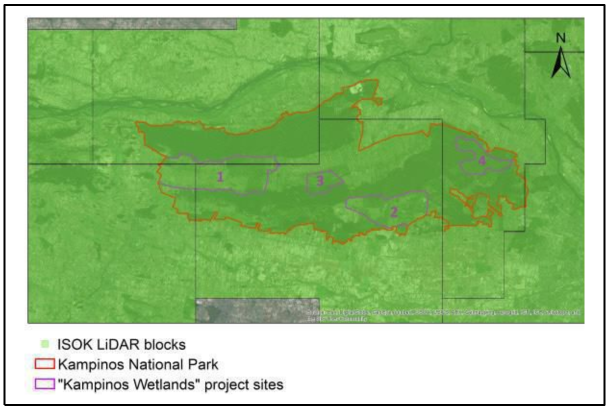


Figure 1. ISOK block borders in the Kampinos National Park. Four regions of "Kampinos wetlands" project realization: 1- Lower Łasica, 2- Zaborowski Canal, 3 – Żurawiowe, 4 – Wilcza Struga.

In extreme cases, like in the part of the KNP – Lower Łasica region (Region no. 1 on Fig.1)), the date of the ALS scanning missions differs in time by 1.5 year 'Fig. 2'. These gap for riparian ecosystems, with the high rate of vegetation variability between missions periods and the fact that the part of the data was acquired late spring and other in the autumn (different water regimes) in our opinion it's causing significant quality degradation.

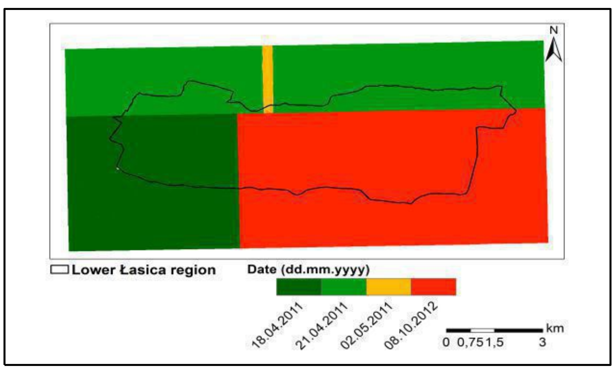


Figure 2. ISOK LiDAR data acquiring date based on the points "GPS Time" parameter.

II. Study Area

Kampinos National Park (KNP) was established in 16 January 1959, for protection of the unique mosaic of landscape consisting of dunes, wetlands and forests. It covers a total area of 385.44 ha. It is located close to Warsaw agglomeration, a capitol of Poland. Intensive urbanization pressure from the Warsaw agglomeration has been considered to be an important cause for increasing groundwater degradation [5]. Groundwater table lowering and changes in the water balance are recognized as the main causes behind changes in the ecosystems in KNP [6,7] conducting to decrease of wetlands by 54% during the last 200 years [8]. KNP with its buffer zone is recognized by UNESCO as Kampinos Forest Biosphere Reserve and is an area of NATURA 2000. The purpose of the ALS data acquiring, was to generate accurate DEM, which will be later used for the hydrodynamic modeling of the reanaturisation works planned to realize within the LIFE+ project *"Kampinos Wetlands"*. We performed analysis for whole KNP area and selected the lower Łasica region for more detailed study.

III. Methods

A. Acquisition of the new LiDAR data

The existing ISOK data has been collected.. In the 21 October of 2014, the new LiDAR data was acquired and analyzed. Aim of the measurements was to acquire whole area within short period of time (one day), while the water level is very low, outside the of vegetation season and with increased accuracy compared to ISOK data. The parameters of new mission (TABLE 1) were discussed according to the aim of scanning, budget, and selected based on the knowledge and experience of the company – responsible for the data acquisition (MGGP Aero sp. z o.o.) and they significantly differ from the ISOK standard. They were two standards of point density – 6 points per sq. m for whole KNP area and 12 points per sq. m for Lower Łasica (Fig 1).

TABLE I. ALS PARAMETERS

Parameters	ALS collection	
	ISOK	***"Kampinos Wetlands"***
Field Of View (FOV)	≤ +25° (in forest areas≤ +30°)	30°
Points density	4 pts/sq. m	6 and 12 pts/sq. m
Altitude above ground	900 m	700 m
Flight line overlap	20 – 30 %	50 %
Flight term	October to April (outside the vegetative period) years 2010 – 2012	21 October 2014 (low water states)

*Acquired only for lower Łasica region

B. Terrestrial Laser Scanning of the tussocks

First verification issue was to compare point clouds with of the real ground surface. The most difficult places were selected for that – area covered by sedge tussocks. In order to capture tussocks geometry we have chosen five testing fields with area around 25 sq. m (5 x 5m). The areas were chosen based on the tussocks shape, height and how densely they were arranged in the area. Before the measurements it was necessary to clear those areas from vegetation, leaving only tussocks. Collected data was later registered and filtered within Leica Cyclone software using methodology described in [3].

C. GNSS measurements

Second verification issue was comparison of DEM products. In order to compare quality of final DEMs derived from, the GNSS reference point network consists of 6250 points was measured (with 2475 on Lower Łasica region), predominantly in the autumn and winter in years 2014-2015. Two GRS-1 and two GR-3 TOPCON GNSS receivers were used for measurements performing. The geodetic service NAWGEO [9] was used for GNSS data correction in RTN (real time network) VRS (*Virtual Reference Station)* method with use of GPRS modules. In remote area, out of GPRS range we used a single base station (RTK) method with correction via radio. The measurements focused mostly on the areas of wet meadows (sedge, reed) but also forest managed and wild meadows. Locally total station and leveling instrument were used.

D. DEM and point cloud analysis

To estimate the DEM accuracy, the elevation error was calculate as mean error and absolute mean error using the GNSS RTN/RTK reference data. Mean error (ME) is a mean difference between DEM and GNSS reference points. It shows direction of the error (whether elevation values are overestimated - positive value or understated - negative value). Absolute mean error (AME) is an absolute mean difference between DEM and GNSS reference points. It indicates the general accuracy of the models.
In order to verify differences between DEMs, differential analysis was performed, using "Kampinos Wetlands" DEM as reference. Aim of this is to capture regions with the greatest difference between both DEMs. Both ALS clouds were compared with TLS cloud as reference using Global Mapper profiling tool.

IV. Results

A. Digital Elevation Model accuracy

Figure 3 Shows error values for the whole KPN area, while Figure 4 shows errors on the Lower Łasica region (where the data were acquired in two densities (6 and 12 pts/sq. m).

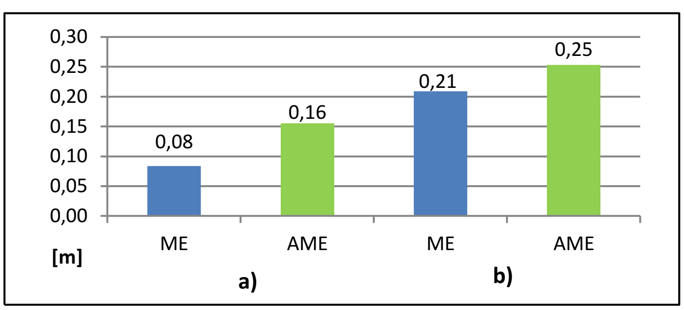


Figure 3. Elevations error of both DEMs, on whole Kampinos National Park. a) Kampinos Wetlands DEM – 6 pts/ sq. m; b) ISOK DEM – 4 pts/ sg.m

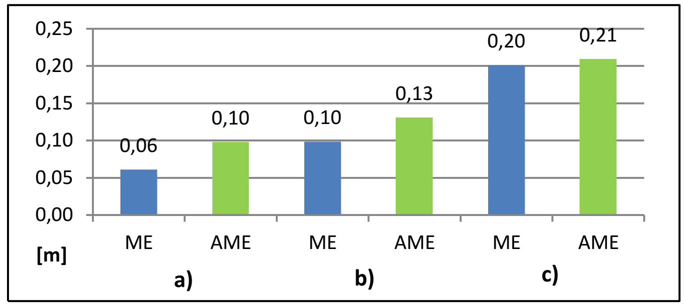


Figure 4. Elevations error of both DEMs, on Lower Łasica Region. a) Kampinos Wetlands DEM – 6 pts/ sq. m;. b) Kampinos Wetlands DEM – 6 pts/ sq. m; c) ISOK DEM – 4 pts/ sq. m.

Results are showing that DEM from "Kampinos Wetlands" data has higher accuracy. It also was observed that the higher point density, generates smaller errors. In order to observe which areas influenced the ISOK DEM accuracy the most, difference between two DEMS was calculated, using "Kampinos Wetlands" DEM as reference. It was observed that areas located near the river are much higher on the ISOK DEM, additionally the ISOK block boundary can be observed, showing that the data due not align with each other (Fig. 5).

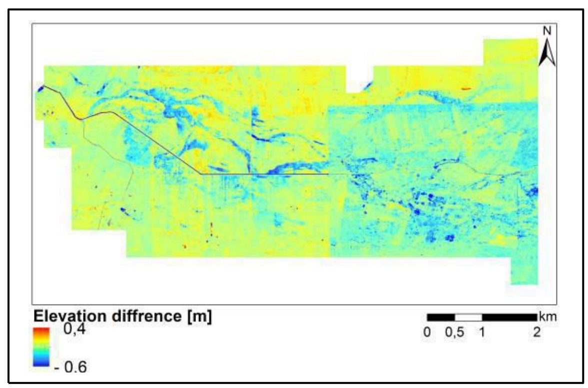
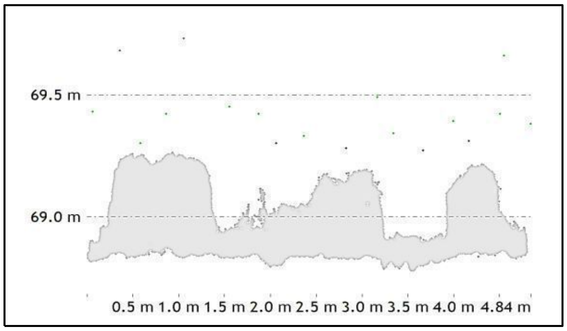


Figure 5. Elevation difference between both DEMs.

B. Tussocks detection and impact on DEM accuracy

The diameter of the tussocks is around 30 - 40 cm and their height from 20 up to 40 cm (depending on the stage of the sedges development). Their size causes difficulties while detecting them by the ALS. We used two types of fields to verify possibilities of detecting them, using ALS, mowed from vegetation and scanned just before ALS measurements (this only applies to "Kampinos Wetlands" data) and mowed after. While ISOK data are well above the ground and tussocks level (Fig. 6). The "Kampinos Wetlands" data points classified as Ground are on the level of tussocks' tips (Fig. 7).



ISOK profile through LiDAR and TLS point clouds, on the measurements field. Points legend: Gray – TLS, Brown – ALS ground, Green – ALS vegetation.

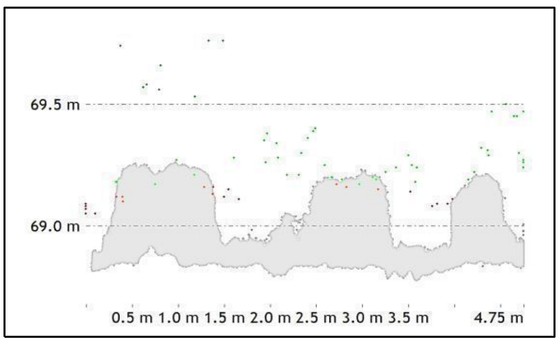


Figure 6. "Kampinos Wetlands" profile through LiDAR and TLS point clouds, on the measurements field. Points legend: Gray – TLS, Brown – ALS ground, Green – ALS vegetation.

Analyzing situation on field mowed before the ALS, the Ground points are on the center level of the tussocks (Fig. 8).

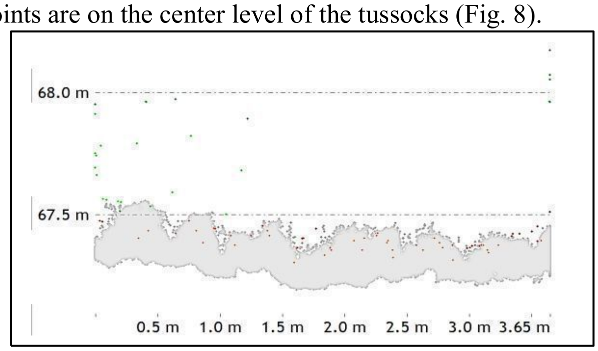


Figure 7. "Kampinos Wetlands" profile through LiDAR and TLS point clouds, on the mowed before flight field. Points legend: Gray – TLS, Brown – ALS ground, Green – ALS vegetation..

V. CONCLUSIONS

In this work we analyzed how accurate DEM derived from ALS is on the natural river valleys. It was observed that higher points density gave better results, this is due to that in dense vegetation it's harder to capture the ground points. Major problems with ISOK data is the date of the ALS mission. The high time gap between blocks affects the quality of data. Another problem is that the data was collected during wet period, which also affects its quality. Correctly selected parameters and appropriate term of the ALS measurements, are key to ensure the highest quality of data. Despite all the benefits that ISOK generated, there will always be the problems like the KNP. That's why it's important to make the necessary preparations of the data because if the errors will be located at this stage, there will be adequate time to eliminate them. This is important when we analyze water management and flood protection.

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