COMPARING LIDAR DTM WITH DEM−5 OF HUNGARY

József Szatmári1, Nándor Szíjj2, László Mucsi1, Zalán Tobák1, Boudewijn van Leeuwen1, Csaba Lévai1, János Dolleschall1

1University of Szeged, Department of Physical Geography and Geoinformatics, Szeged, Hungary
2Carto-Hansa Ltd., Budapest, Hungary

e-mail: dolleschall@gmail.com

ABSTRACT

Requirements for precise digital elevation data of varying levels of detail are being formulated for different fields of application, such as inland excess water research in the Maros-Körös Interfluve. In this study two different digital terrain models were compared: the DEM−5m of Hungary and DTM−1m (Digital Terrain Model) generated from Airborne Laser Scanned (ALS) data. ALS data as well as stereo aerial photographs were acquired for three different areas in November 2009. The ALS data set was used to create a 70 km² DTM−1m. The data set of DEM−5m used for comparison consisted of high resolution DEM derived from Hungarian topographic maps at scale 1:10000 and points of IV order triangulation network. The results were compared to both DEM generation techniques to the data received from in situ measurements. Visual and statistical assessments were made, including profile and contour comparisons, allowing the spatial variation in accuracy to be explored. A mean vertical difference of 0.3 m and a standard deviation of about 0.7 m were calculated. Maps of differences were created for all sites. The differences are both natural and anthropogenic forms. These forms do not appear at DEM−5. And furthermore there is an error in DEM−5 which cannot be explained with surface forms. The digital terrain model DTM−1 that has been created incorporates natural geomorphological forms that are essential for inland excess water modelling and cannot be identified on the DEM−5 model of Hungary.

Keywords: LIDAR, ALS, DEM, DTM, inland excess water, geomorphology

1. Introduction

Excess water is a serious hazard in several lowland European countries. However, the international scientific community considers it as a true Carpathian Basin placed problem both from a natural and a social point of view. The very compound ‘excess water problem’ raises the need for a complex research effort in order to find solutions. In Hungary the usual annual damage is approximately 100–150 M €, however in years with exceptionally high inundation-rates it can reach up to 500 M €. The May and Nov–Dec 2010 rainfall also caused inland excess water inundations...
over 167,000–300,000 ha and by 7 June 2010, extensive damage was caused not only to agriculture but also to transport and tourism. Low and flat alluvial planes near the river Tisza are a characteristic example of an area endangered by inner excess water. Detection of endangered areas and research into this problem can have great influence upon local organisations and individuals engaged in agriculture as well as on regional governments, considering the fact that Csongrád County is a mainly agriculturally oriented area.

Changes in the mean value of climate variables such as temperature or precipitation may also be associated with a change in their distribution as well. The projected change in climate will significantly impact on the the hydrological cycle. Furthermore, it is expected that the magnitude and frequency of extreme weather events will increase, and that hydrological extremes such as inland excess water and droughts are likely to occur more frequently and be more severe. Based on the well established current trends of the global climate changes and their regional scale in the Carpathian Basin, it is reasonable to assume that the hydrological cycle will be accelerated along the river Tisza basin as well, with greater event variability and extremes. Therefore, in order to mitigate the consequences, the assessment of the impacts of climate change on key elements of the hydrological cycle as well as on the surficial geology is important. The average groundwater level varies between two and four meters below the surface. Remnants of river meanders can also be found in the area. In these former meanders, the groundwater may reach the surface. One of the most important factors in inland excess water analyses is the relief (Pásztor et al., 2006; Rakonczai et al., 2001, 2003). Since there are only very small height differences involved in the occurrences of the inundations it is important to use a very high resolution digital elevation model (DEM). In Hungary, the highest resolution DEM available for the whole country is the DEM-5 model with a horizontal resolution of 5 m and a vertical accuracy of 0.7 m (Király, 2004; Winkler, 2006; Winkler et al., 2006). The geomorphological forms, which are important in inland excess analyses, are not visible at this accuracy. Also digital elevation models derived from the contours of the 1:10000 topographic maps do not have sufficient accuracy which would be needed in this study. To overcome this problem, on November 19, 2009, an airborne laser scanning flight was executed to collect LIDAR data over three areas in south-east Hungary. From a flying height of 1500 m, 70 km² of terrain was surveyed with an average point density of 1.4 points/m². In total 106 million points were measured. The accuracy of the LIDAR points was evaluated on two test areas for a total number of points of 15,000. The RMSE error for the total amount of points was 4.6 cm, while 99.76% of all points were within the specified vertical system accuracy of 15 cm. The maximum vertical error was found to be 22 cm (Table 1).

At the same time as the height recordings, stereo colour and near infrared aerial digital photographs were collected with a digital mapping frame camera (DMC). The resolution of the aerial photographs was 15 cm. The images were collected with a 30% overlap in the flight direction and 60% overlap between consecutive flight lines. The images were geometrically corrected using geodetic base points with a known location, which were highlighted on the ground, and selected points that were measured with geodetic instruments after the flight and the accuracy of the LIDAR points was evaluated based on these points too (Table 2).

Table 1. – Accuracy of LIDAR data on pre-measured control points

<table>
<thead>
<tr>
<th>Study area</th>
<th>Number of ALS Points</th>
<th>Max. [cm]</th>
<th>Min. [cm]</th>
<th>Arithmetic-Mean DTM [cm]</th>
<th>Root-Mean-square DTM [cm]</th>
<th>Standard Deviation DTM [cm]</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Székkutas</td>
<td>6820</td>
<td>22.0</td>
<td>-18.0</td>
<td>0.1</td>
<td>5.1</td>
<td>5.7</td>
<td>99.76</td>
</tr>
<tr>
<td>Batida- Tápairét</td>
<td>8479</td>
<td>15.0</td>
<td>-18.0</td>
<td>-0.3</td>
<td>4.1</td>
<td>4.1</td>
<td>99.96</td>
</tr>
</tbody>
</table>

Where: ΔH = H_lidar - H_higm - DTM
H_higm DTM = interpolated geodetic measurements

Table 2. – Accuracy of LIDAR data on vertical ground control points

<table>
<thead>
<tr>
<th>Study area</th>
<th>Number of ALS points</th>
<th>Max. [cm]</th>
<th>Min. [cm]</th>
<th>Root-Mean-square [cm]</th>
<th>Standard Deviation [cm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batida- Tápairét Székkutas</td>
<td>11</td>
<td>26.0</td>
<td>-20.0</td>
<td>10.7</td>
<td>11.1</td>
</tr>
</tbody>
</table>

Where: ΔH = H_lidar - H_ver
H_ver = vertical GCPs measured by RTK GNSS
Based on the aerial photographs, linear features were digitized in three dimensions with stereo-photogrammetric methods (Fig. 1). Based on this data, a 1 m resolution digital elevation model (DTM-1) was created (Fig. 2).

### 3. Comparison of two different height model

We have compared the Hungarian DEM-5 model (with a horizontal resolution of 5 m and a vertical accuracy of 0.7 m) and DTM-1 generated from ALS data. Table 3 contains the differences of the same points in the two models (relative errors) in the different areas. During the comparison DEM-5 was subtracted from DTM-1 (DIFF = DTM1 – DEM-5). If the difference is below 0, then the surface of DTM-1 is under the surface of DEM-5 and if the difference is above 0, then the surface of DTM-1 is above the surface of DEM-5.

Difference maps were also created for the three areas. The differences are both natural and anthropogenic forms. The negative differences are old river channels, artificial channels, and small local holes. The positive differences are dikes of dirt roads, accumulations by old river channels, and small local hills.

Nevertheless there is a huge positive difference (almost 15 m) to the NE of Tápairét (Fig. 3). This area was examined in an ortophoto. On the basis of this ortophoto (Fig. 4) it is clear that this difference is caused by the construction of a highway, more precisely, the construction of a bridge. So this difference is not an error of DEM-5, because the elevation in this area shows the height of a bridge, not the surface.

There is also a negative difference in Batida which cannot be explained with the forms mentioned above. In the South of the area there are two rectangle-like shapes (Fig. 5) with a 2–4 m negative difference (the DTM-1 is under the DEM-5).

It is important to know that Batida is an archeological area, so it is very likely that these differences are caused by archeological work. On the basis of Fig. 6 it is unquestionable that the upper layer of the soil has been removed and field examinations also confirmed that this difference was caused by archeological excavation. So it is important to note that this difference is not an error of DEM-5 either, because it is an anthropogenic form.

Finally, the differences between the two models were examined in Székkutas as well. The positive differences are dikes of dirt roads and small local hills just as in the other two cases. The negative differences are mostly small local holes. However, there is a large area with more than 1 m negative difference in the SW part of the study area (Fig. 7).

The shape of this area is more than 1000 meters wide in the SW–NE direction. The area was examined first in an ortophoto (Fig. 8) then on the field, but there was no geomorphological or anthropogenic form which could explain this difference. According to the accuracy check mentioned above, the elevation of the DTM-1 is very close to the real elevation of the surface. So the question is: what is wrong with the DEM-5 model? DEM-5 was derived from Hungarian topographic maps at a scale of 1:10000 and points of the IV order triangulation network, so the area was also

### Table 3. Differences between DTM-1 and DEM-5

<table>
<thead>
<tr>
<th></th>
<th>Székkutas</th>
<th>Batida</th>
<th>Tápairét</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of compared points</td>
<td>1,167,790</td>
<td>767,255</td>
<td>829,336</td>
</tr>
<tr>
<td>Maximum positive difference (m)</td>
<td>+4.4</td>
<td>+3.0</td>
<td>+5.0</td>
</tr>
<tr>
<td>Maximum negative difference (m)</td>
<td>-2.8</td>
<td>-6.2</td>
<td>-7.3</td>
</tr>
<tr>
<td>Mean (m)</td>
<td>-0.05</td>
<td>+0.05</td>
<td>-0.29</td>
</tr>
<tr>
<td>Standard Deviation (m)</td>
<td>0.37</td>
<td>0.49</td>
<td>0.65</td>
</tr>
</tbody>
</table>
This area can be easily found in the DEM-5 model (Fig. 10). According to the model in this area there has to be a higher elevation than in the surrounding areas. So — on the basis of these investigations — it is very likely that this difference is caused by an interpolation error.

On the basis of the comparison in these three areas, DTM-1 incorporates natural geomorphological forms and anthropogenic objects that are essential for inland excess water modelling and these cannot be identified on the DEM-5 model of Hungary, e.g. old river channels, local holes, artificial channels, etc.

But on the basis of the 70 km² area examined (with 70 million points), the mean accuracy of DEM-5 is better than 70 cm, but DEM-5 also contains pixels with an error larger than one meter, e.g. the interpolation error mentioned above.

4. Summary

Inland excess water is a serious hazard and is currently a problem in Hungary, particularly in Csongrád County. This research aims at the solution of several interrelated questions with the means of both fundamental and applied research in the areas of Marosszög. First, we intended to examine the formation of the different types of excess waters. We would like to find and test a novel methodology for the field mapping of inundations, which will include the verification of remotely sensed data on test sites, in order to evaluate their use in excess water protection works.

We have proved by visual and statistical assessments, including profile and contour comparisons, that the ALS survey with an average point density of 1.4 points/m² is a proper base for terrain modelling in excess water investigations. The missing forms of DEM-5 are mainly linear natural and anthropogenic forms. The digital terrain model DTM-1 that has been created incorporates geomorphological forms that are essential for inland excess water modelling and cannot be identified on the DEM-5 model of Hungary.

These results will be a significant help to the water management authorities and affected population in both preventive and operative actions. These and the use of the enormous quantity of data, information, and knowledge previously accumulated by the related fields according to the newly outlined schemes and aspects may lead to a long term solution for this perennial problem. The integration of modern and traditional tools and approaches is the key for generating a change in the strategy of excess water management.

Acknowledgement

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