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THE USE OF LIDAR REMOTE-SENSING DATA TO OPTIMISE ROUTES IN INFRASTRUCTURE PROJECTS

C.A. POPESCU*, A. ŞMULEAC*, M. HERBEI*

Banat University of Agricultural Science and Veterinary Medicine Timisoara, Faculty of Agriculture
adrian_smuleac@yahoo.com

Abstract: *This paper deals with LIDAR (Light Detection and Ranging), a laser-scanning technology with a definite characteristic: it can acquire, process and deliver data in digital format. LIDAR is an optical remote-sensing method of extracting information about remote objects by measuring the properties of light scattered on the objects. LIDAR provides unlimited potential in infrastructure projects and is applied in an increasing range of fields. LIDAR uses the same principle as RADAR, the difference between the two methods lying in the electromagnetic radiation wavelength. LIDAR is based on three systems: laser scanning for precise distance measuring, the positioning system (GPS) and the Inertial Measurement Unit (IMU) for orientation measuring. To obtain data on field topology, the LIDAR system receives laser impulses in the 1040–1060 nm wavelength range (near infrared band).The advantage of this technology is that the laser beam penetrates the vegetation, no matter how dense it may be. The present paper uses 3D satellite images and their applications. It also speaks about the main aspects of altimetry data quality assessment of the Digital Terrain Model (DTM) obtained through laser scanning. The altimetry data were collected in the Vârful Căpăţînii area, in the south, and Zănoaga, up to the limit of Gorj and Hunedoara Counties in the north. The route covers about 4 km and the ground level is between 1474 m at Zănoaga and 1565 m above the Black Sea level at Vârful Căpăţînii. LIDAR technology helps creating numerous data sets that are useful for a wide range of applications. The quantitative and qualitative data obtained with LIDAR technology provide additional information about the condition of the vegetation, the quality of the environment (pollution), drainage basins (flood impact estimation), special constructions (pipes, bridges, high voltages transmission lines), studies about forest fire risk, infrastructure management (road, railway and telephone networks) and land inventory. The LIDAR-type satellite images were used with Global Mapper versions 15.2 and 16.1. For the 15.2 version we used the data set "ASTER GDEM (Global Digital Elevation Model) Worldwide Elevation Data (1.5 arc-second resolution). For the 16.1 version we used the data set "ASTER GDEM (Global Digital Elevation Model) version 2 – Worldwide Elevation Data (1 arc-second resolution), which was released on October 17th 2011. The first version was released in June 2009 and was generated with stereo pair images collected with ASTER instruments. The ASTER GDEM cover is from latitude 83º north to 83º south and includes 99% of the Earth surface.*

Key words: *LIDAR, 3DModel, GPS, ASTER GDEM2, DTM, Global Mapper, IMU*

INTRODUCTION

The concept of LiDAR (an acronym of *Light Detection and Ranging*), came into people's attention in the 1950s, but the topic was researched for years until it proved an extremely viable mapping technology. In short, LiDAR is a sensor fixed with precision in the cockpit of a plane specially adapted for such operations, that sends laser impulses to the Earth and then e-receives with a receiver. The integrated processor determines the time interval when the pulse leaves the aircraft, reaches the soil and goes back, correlating the accurate position of the aircraft, altitude, and speed, for the final calculus of 3D positions of the points on the soil (X, Y, Z), thus producing a "cloud of points" made up of hundreds of thousands or even millions of points.

The LiDAR technology is involved in such projects as "Plan for the prevention, protection and diminution of the effects of floods in hydrographic basins" whose final beneficiary is the Ministry of Environment and Water Management. LiDAR is, practically, the "key" to the project. Though very new comparatively with other "classical" methods of data collecting, it has not been used in Romania yet but in such countries as Poland, the Czech Republic, Spain, Germany (in Europe) or China (in Asia), it has proved a real success in land modelling.

In the first stage of the project, we have flown over major riverbeds that have flooded in the last years. Finally, we got "point clouds" with coordinates x, y, z linked in the reference system Stereo70 through GPS stations on the ground; these points helped generating the digital terrain model. Data were introduced into the hydrodynamic model then we generated risk maps or plan that advance solutions for flood risk reduction.

LiDAR laser scanning produces interactive topographic maps with a height accuracy of up to 20 cm. Current data have an accuracy of up to 1.5 m. as a supplement to land surveys, the technology can be sued in road building, construction sites, etc. it can also be used to evaluate different alternatives in constructions, in education and research, in engineering.

Based on LiDAR data and with photogrammes, one can analyse and classify LiDAR points depending on the requirements of the project. Once drafted, the topographic plan is send for checking, completions, and it is finally turned into a topographic plan for the designer. Data thus collected can be sued to produce a terrain digital model.

MATERIAL AND METHODS

To produce the digital model of the terrain, we used the points produced by measuring with GPS ***Leica 1200*** equipment. Raw data were processed with a ***Leica Geo Office Combined*** programme (to download raw data), a ***TransDatRO 4.01*** (to turn coordinates WGS1984 into Stereographic 1970 coordinates), a TopoLT (to make the 3D models of the terrain and to import 3D points). To fill in the gaps, we used the programme ***Global Mapper v16.1.2*** where we activated the ***LiDAR module***, and for the situation plans, we used an ***AutoCad Civil 3D***.

In the making up of the ***3D*** model, we can apply different colour levels for each face of the model. Colours are applied from the minimum to the maximum heights from datum lines (Z coordinates) that allow ***3D*** models. Colours for colour level application can be edited. The colour palettes thus obtained saved in files and be re-loaded from the saved files.

One can develop a terrain ***3D*** model using points with the coordinates X, Y, Z or space lines and polylines. The interpolation method in this version of the programme is only the triangulation with linear interpolation.

Generating a land digital model concerns the ***data acquisition way***, developing the model proper through different ***interpolation methods*** as well as the ***choice of data representation structure (raster or TIN)***. Interpolation methods of the **triangulation** type that produces a **TIN (Triangular Irregular Network) structure. For each angle,** we memorise *the coordinations and attributes of the three peaks, the topology and the slope and inclination direction of the triangle area*.

To make up the LiDAR point clouds, we used the programme ***Global Mapper v.16.1.2***, a GIS application that provides access to a wide range of space data sets. For advanced processing, we used the LiDAR Module, an optional accessory of the programme Global Mapper that provides numerous advances opportunities of LiDAR processing. The LiDAR Module was launched together with Global Mapper V15 (version 15), to which they added a set of new LiDAR instruments when Global Mapper V16 was launched. To carry out this paper, we used the version 16.1.2 of the programme with numerous improvements compared to the previous variant such as automated re-classification and point extraction for buildings and trees, improving dramatically the automated classification of soil points as well as the ability of filtering LiDAR points depending on class, altitude, colour, filtering support

LiDAR LAS/LAZ, etc. Data obtained with the programme ***Global Mapper v.16.1.2, active LiDAR Module*** was possible with this LICENSED programme.

RESULTS AND DISCUSSIONS

Shuttle Radar Topography Mission (SRTM) is a NASA mission from 2000 that aimed at producing elevation data for most of the world. This is the current data set for digital elevation models (DEM) because it has a rather high resolution (1 arc seconds, or about 30 m, for the U.S.A., and 3 arc-the second, or about 90 m from the Equator, for the rest of the world), an almost world coverage (from 56°S to 60°N), and is in the public domain.

SRTM consisted in a modified special radar system that flew on board the Endeavour and lasted for 11 days, from February 11 to February 22, 2000; it allowed elevation data at almost global level to generate high-resolution digital topographic data on the Earth on 119,560,000.00 km^2. SRTM is an international project lead by *National Geospatial Intelligence Agency (NGA)* and *National Aeronautics and Space Administration (NASA).*

SRTM data for areas outside the U.S.A. were collected at 3 arc-seconds, i.e. 90 m. The new data generated with SRTM at 1 arc-seconds or about 30 m produce high resolution.

Figure 1 presents a road section that is the subject of this paper, a section located between Vârful Căpăţînii in the south and Zănoaga, up to the limit of the counties Gorj and Hunedoara in the north. The route is about 4 km, and the height from the datum line of the terrain was between 1,474 m at Zănoaga and 1,565 m Black Sea level at Vârful Căpăţînii.

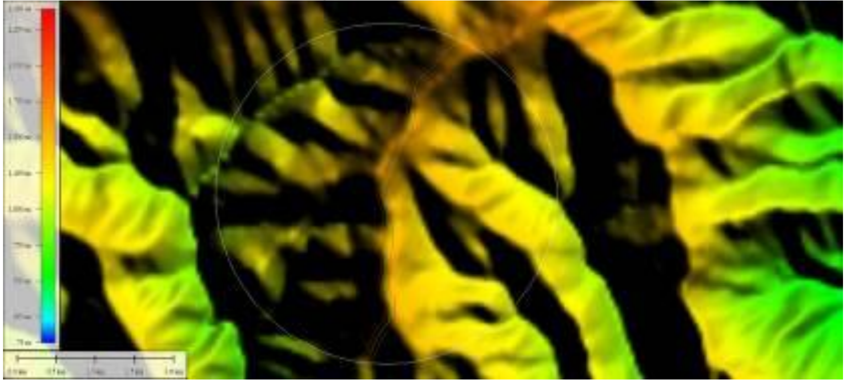

Fig. 1 - SRTM World Elevation Data (3 arc-second Resolution)

ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is a Japanese sensor, one of the five distance sensor devices on board Terra, the satellite launched around the Earth by the NASA in 1999. On June 29, 2009, they launched the Version 1 ASTER GDEM1 (Global Digital Elevation Model) model digital (GDEM) for the public, a common operation of NASA and Japan (Ministry of Economy, Trade and Industry) for the development of the most complete mapping of the Earth ever made and covering 99% of the Earth's surface. GDEM covers the planet from 83°N to 83°S (more than SRTM that covers from 56°S to 60°N), becoming the first system of Earth mapping that provides proper coverage of the Polar areas. It was by the compilation of 1.3 million images taken by ASTER using a single passage and comparing global topographic elevation measurements at 30 m (98 ft).

Despite the high digital resolution, true resolution is considerably lower and not as good as the SRTM data (it has errors).

One of these limitations were confirmed by the MECI and NASA, which points out that the current version of the GDEM product is the "research class".

In October 2011, they launched publicly the Version 2 of ASTER GDEM1 (Global Digital Elevation Model). It is considered an improvement of the Version 1. These improvements include horizontal and vertical increase of precision, a more horizontal resolution, a poorer presence of artefacts, and more realistic values over water bodies. Though it shows "a considerable improvement of the actual detail level", it is still considered a "experimental or research degree" due to the presence of artefacts. A recent study showed that, on uneven mountain terrains, ASTER Version 2 of the data set could be a more accurate representation of the soil than the SRTM elevation model.

Below we present comparisons between the two sets of data – SRTM World Elevation Data (3 arc-second Resolution) and ASTER GDEM2 World Elevation Data (1 arc-second Elevation Resolution).

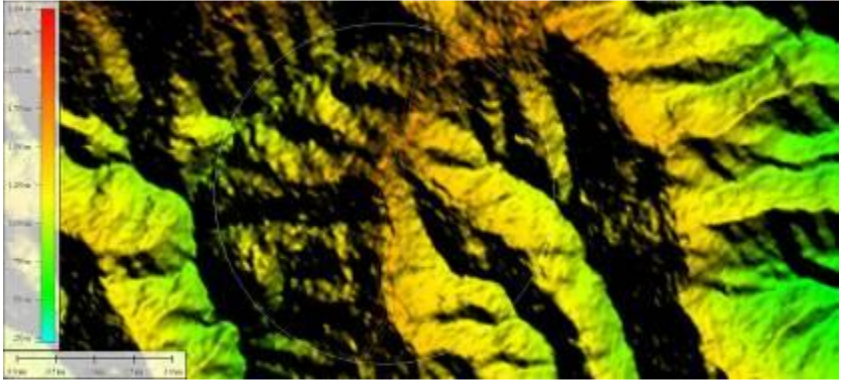

Fig. 2 - ASTER GDEM2 World Elevation Data (1 arc-second Elevation Resolution)

Though the ASTER image (Figure 2) provides a higher resolution compared to the SRMT image, the latter provides higher precision with coverage of the entire world. In this paper, we developed a digital model of the terrain with both ASTER GDEM 2 and SRTM. Of the two Digital Models (Figures 3, 4) of the terrain after data processing, we see that ASTER GDEM2 (in the drawing, red represents the Main curve, green represents the Secondary curve and blue represents Intermediary curves) is more rough, while SRTM3 (grey) presents level curves that are more rounded.

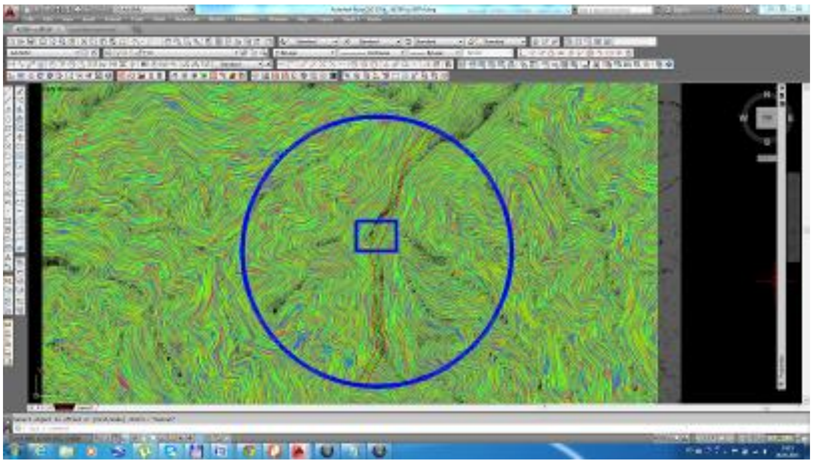

Fig. 3 - 3D model for SRTM and ASTER GDEM2 in AutoCAd

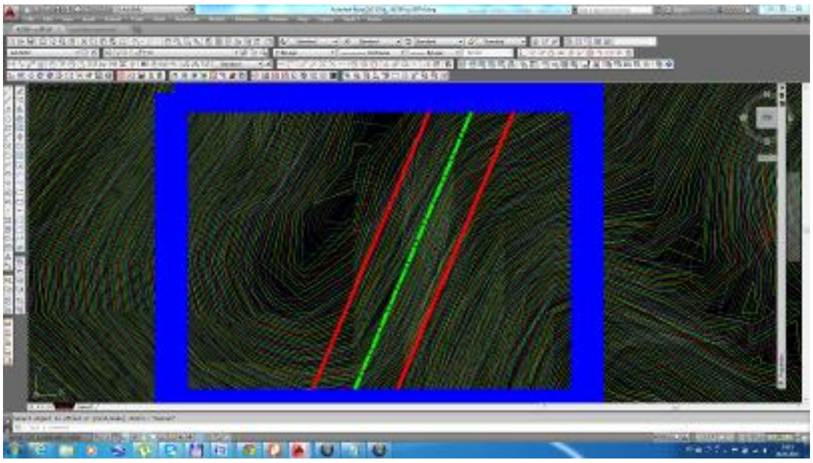

Fig. 4 – Presentation of the two 3D models

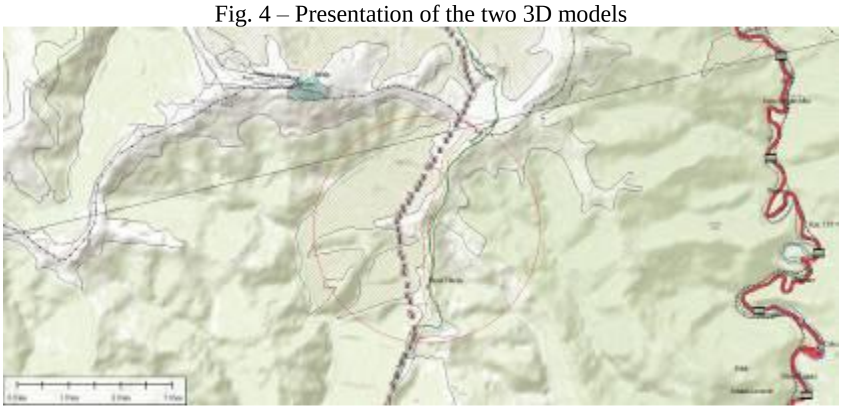

Fig. 5 – Presentation of the studied area

Fig. 6 – Presentation of the area with World Imagery

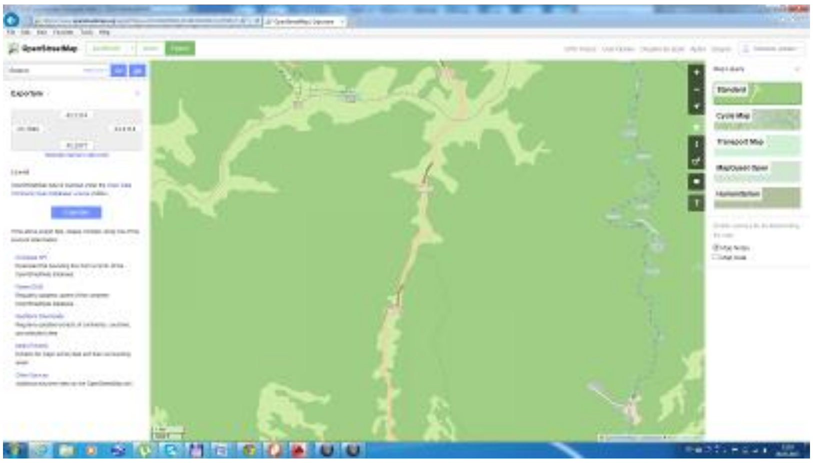

Fig. 7 – Presentation of the area with OpenStrreMap

Presentation of the studied area with the programme Global Mapper v16.1.2. (Figure 5).

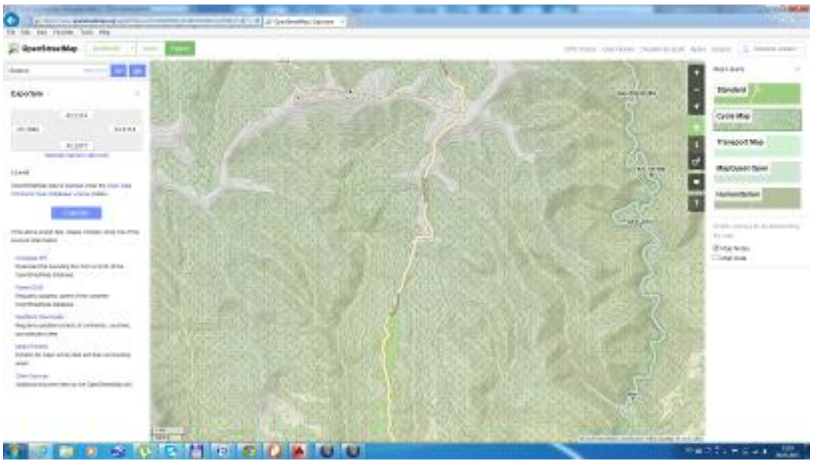

Fig. 8 – Presentation of level curves with OpenStrreMap

Later in the paper we present LiDAR data production with the programme Global Mapper Version 16.1.2., more percisely image processing and personalised data. With the programme Global Mapper and Open Topography, we managed to produce personalised data for the studied area, and theaccuracy of the data in this case is much higher than when produced with LiDAR.

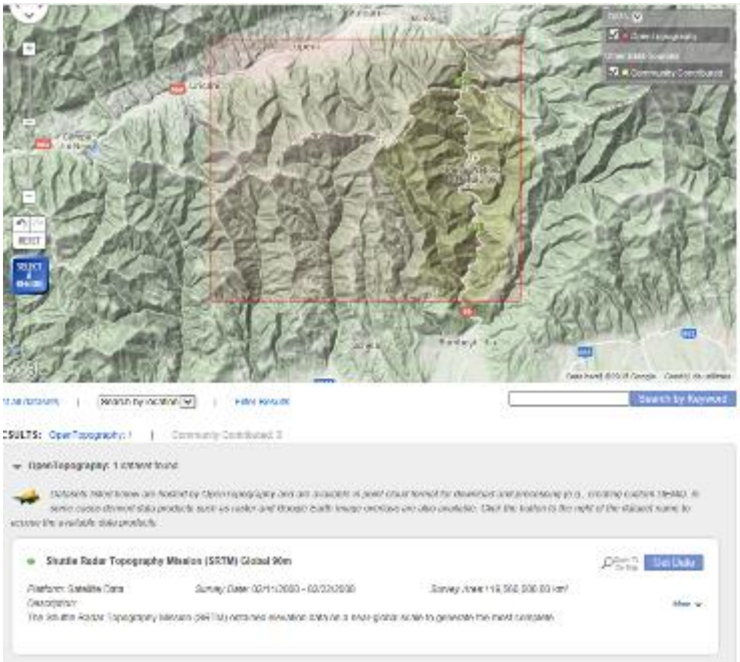

Fig. 9 – Establishing the area for the personalised SRTM image

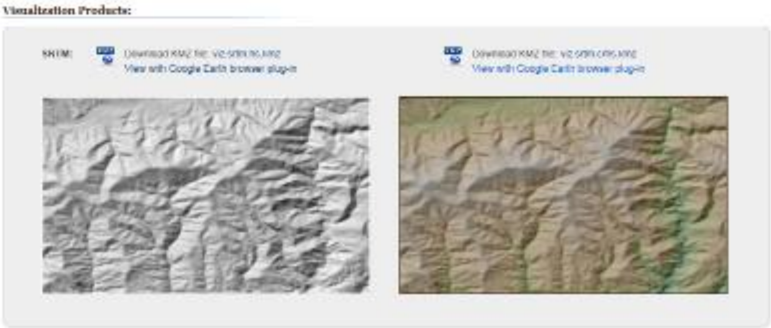

Fig. 10 – Results produced with the programme Open Topography

Figure 10 presents an image produced through processing and data personalising. With these images, one can produce data with higher accuracy of height from datum lines, an accuracy that is close to height from datum lines in the field with GPS equipment, with a difference of up to 1.5 m. With this technique, we could produce values and areas difficult to access or even not accessible at all.

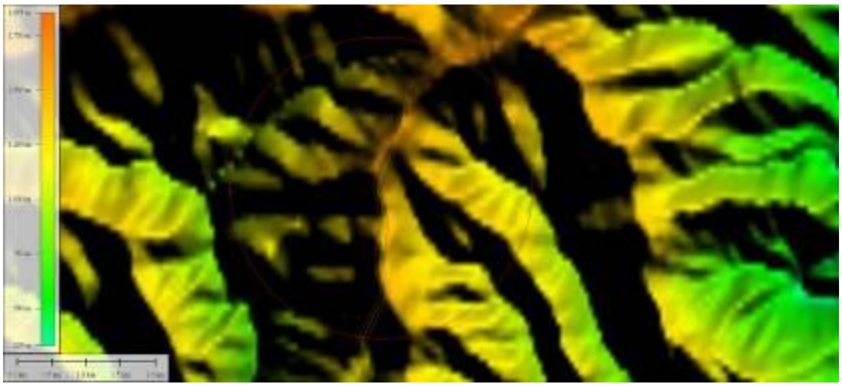

Fig. 11 – File produced after personalisation with LiDAR Topography Data

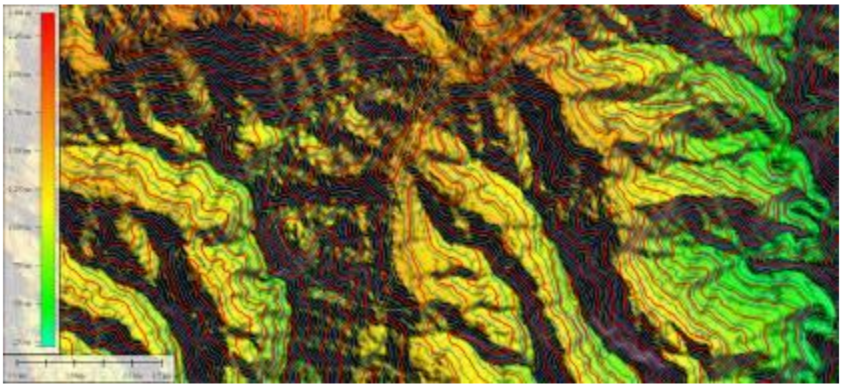

Fig. 12 – Generation of level curves based on ASTER GDEM2 image, E=25 m

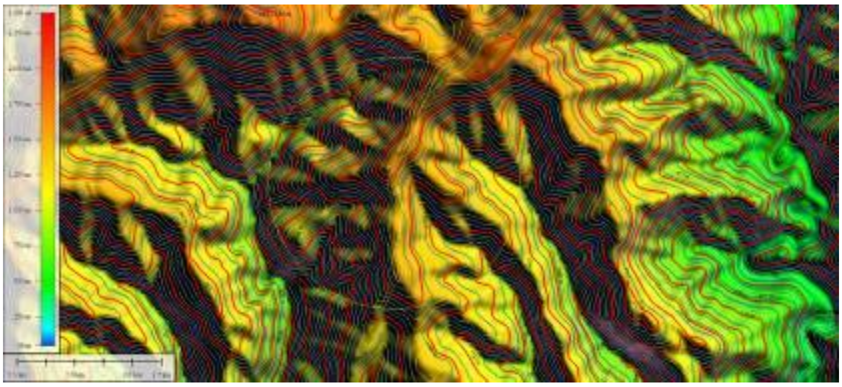

Fig. 13 – Generation of level curves based on a SRTM image, E=25 m

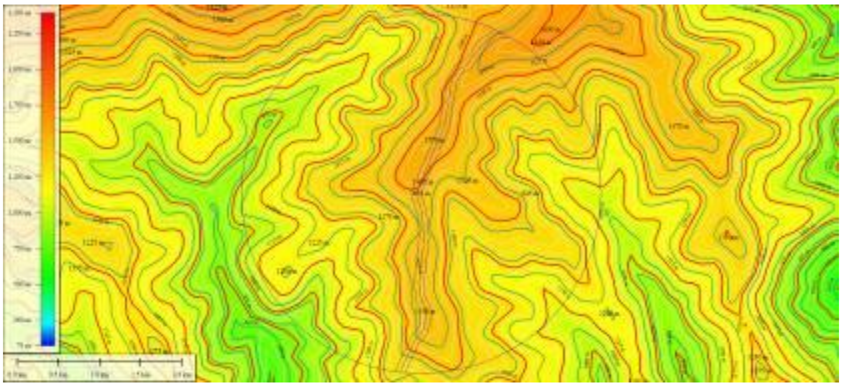

Fig. 14 - Generate Area Features Colored Based on the Curent Elevation Shader in Addition to Contours, E=25 m

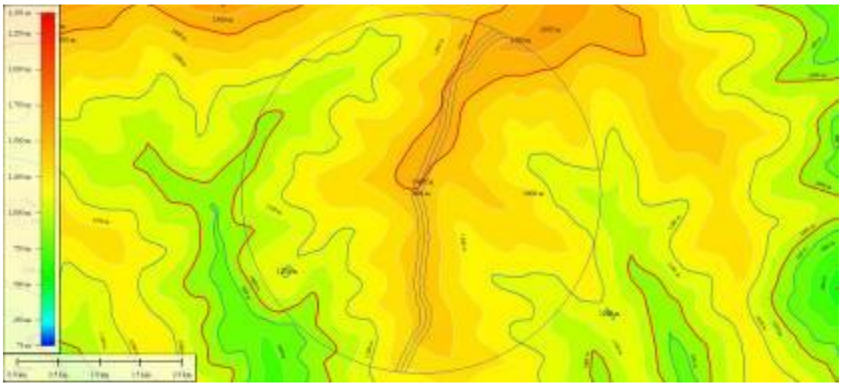

Fig. 15 - Generate Area Features Colored Based on the Curent Elevation Shader in Addition to Contours, E=100 m

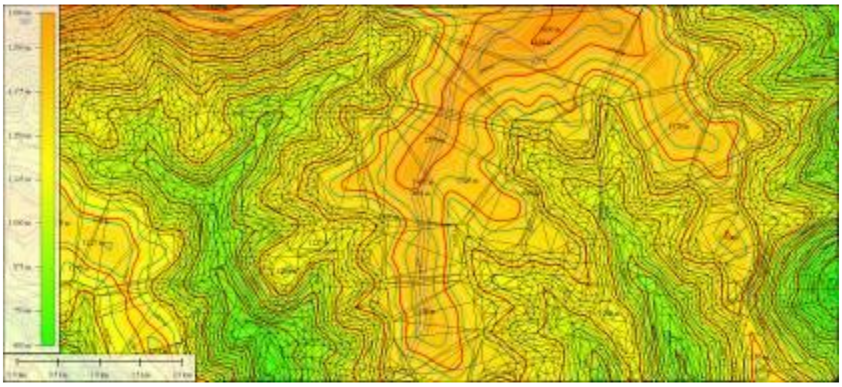

Fig. 16 - Create elevation Grid from 3D Vector Data - Triangulation Network (TIN)

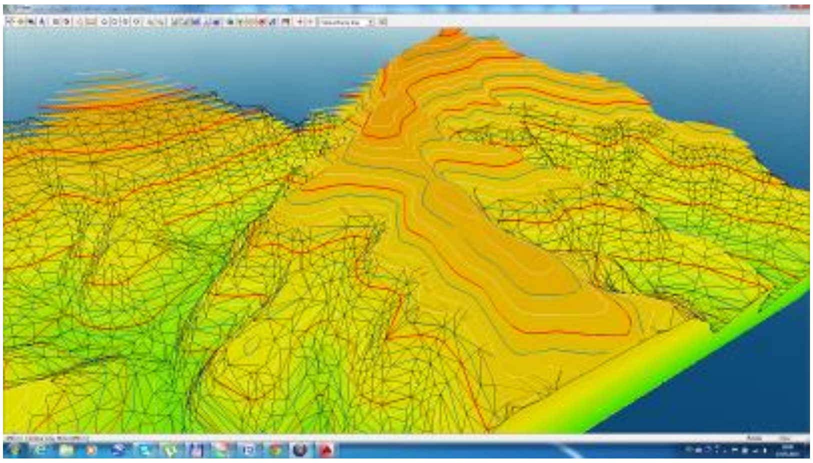

Fig. 17 - 3D presentation of the studied area

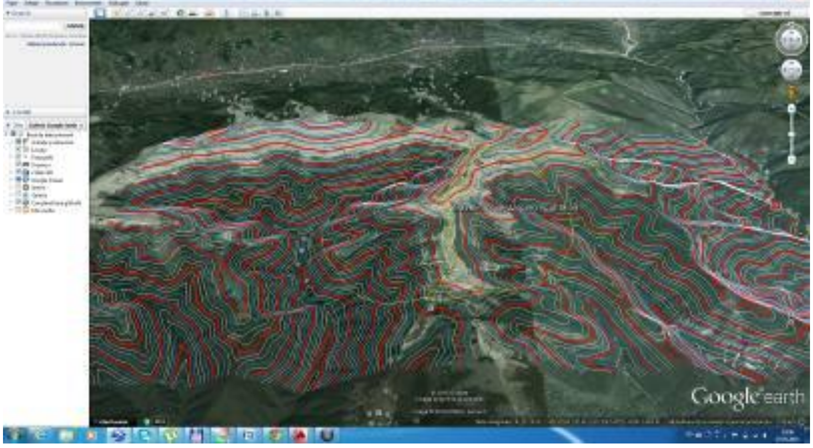

Fig. 18 – Importing level curves on Google Earth

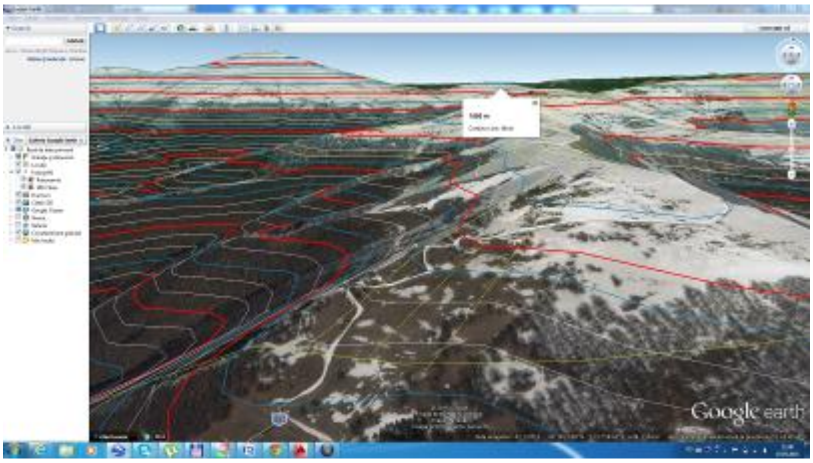

Fig. 19 – Presentation of level curves that take the shape of the relief

Generating level curves based on SRTM Worldwide Elevation Data images (3 arc-second Resolution) is shown in Figure 11 where there is superposition of level curves over SRMT image. Curves were developed at 25 m equidistance where, based on SRTM processing, they obtained 184 characteristics. Red represents the main curve, white represents the secondary curve, and blue represents the intermediary curve. We then generated level curves and colours depending on altitude where, as in Figure 10, we keep colours for level curves. Processing produced 282 characteristics at 25 m equidistance. Figure 13 presents level curves also based on altitude colours at 100 m equidistance where we produced 66 characteristics. Figure 14 presents the generation of the TIN model of the terrain based on the GRID model that contains 12,662 characteristics. The 3D presentation of the area is presented in Figure 15. The values obtained were imported in the AutoCad and compared with data in the field, developing a new set of curves based on LiDAR point clouds presented in Figure 16. Level curves once produced can be presented even by importing them in Google Earth, which is shown in Figure 17.

Fig. 20 – Presentation of the relief of the studied area

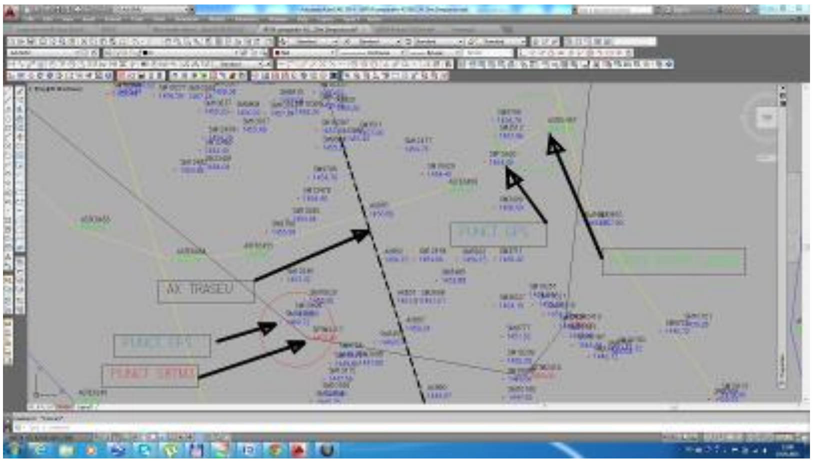

Fig. 21 – Compared presentation of SRTM3, ASTER GDEM2, GPS data

CONCLUSIONS

Collecting SRTM data with ASTER GDEM was possible with the programme Global Mapper version 16.1.2., a licensed programme, in which, for better results, they activated the LiDAR Module (also licensed), a module that can be purchased apart from the programme Global Mapper. Comparing SRTM with ASTER GDEM shows only the differences between the two sets of altitude. To establish which is closer to reality, we need a set of reference coordinates x, y, z in relation with which are evaluated SRTM and ASTER, i.e. the GPS points. Such an evaluation was done for this paper. Our set of data was made up of terrain points with the equipment GPS Leica series 1200.

As for data processing, it required a long time and, finally, after comparing the data produced with both ASTER GDEM2 and SRTM and also the GPS points from the field we concluded that the precision of SRTM World Elevation Data (3 arc_second Resolution) is very close to the GPS data from the field, with little differences of up to 1.5 m (e.g., image 28 cm) a difference of height from datum lines produced with ASTER GDEM2 World Elevation Data (1 arc_second Resolution) where there were differences between height from datum lines and height from datum lines of 7.96 m. along the route of 4 km, SRTM represented the closest terrain relief with differences to the points in the field with GPS equipment of up to 1.5 m.

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