# THE DIGITAL ELEVATION MODEL OF SĂRATA MONTEORU AND OTHER PHOTOGRAMMETRIC PRODUCTS OBTAINED THROUGH PROCESSING DATA ACQUIRED BY UAV SYSTEMS

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**Abstract.** Along with the alarming technological advance in recent decades, the accuracy of topographic data acquisition has become an increasingly accessible task, benefiting from innovations like LIDAR (Light Detection and Ranging) and UAV (Unmanned Aerial Vehicle). The cost reduction of these technologies was significant, because airplanes and helicopter flights were no longer necessary and drones currently have a very high potential for accurate and high resolution photogrammetry. The aim of this paper is to present the steps of generating numerous photogrammetric products (including the Digital Elevation Model) of a surface of 460 hectares, located in the village of Sărata Monteoru, along with the significance and applications of these models.

**Key words:** UAV, photogrammetry, orthophotomap; Romanian Subcarpathian bend region

## 1. INTRODUCTION

Photogrammetry is one of the branches of Geomatics that deals with obtaining the geometrical properties of physical objects and the environment in which they are located by processing and interpreting photographic images. This process requires capturing photographic information about an object from multiple perspectives to generate the elevation values of the terrain with the best accuracy (Hackney & Clayton, 2015; Nache *et al.,* 2017). Currently, most topographic maps are made by interpreting data obtained from air and space photogrammetric missions, representing one of the conventional applications of this science (Păunescu *et al.,* 2010). Besides, the photogrammetry measurement principles are used in architecture, geology, archeology, meteorology and, more recently, in the reconstruction of road accident scenes, *i.e*., photogrammetry at short range (Vorovencii, 2010).

In terms of classification, photogrammetry is of two types: analytical photogrammetry, by which the imaging geometry is reconstructed through optical or mechanical devices) and digital photogrammetry, that is a method which allows generating three-dimensional models by using sets of digital photographs (Konecny, 1985). The method that has been used for the Digital Elevation Model generation of Sărata Monteoru is the Digital Photogrammetric method.

## 2. LOCATION OF THE STUDIED AREA

The Sărata Monteoru village is located in Buzău county (Merei commune), at an altitude of 86 m in a depression drained by the Sarata River, situated on a flank of Istrița Hill at the south-eastern extremity of the Romanian Subcarpathians bend, in an area covered by a rich vegetation and shelter of winds. The area of the village of Sărata Monteoru belongs to Istrița hilltop, which is an elongated anticline in the general east-west direction. From a geological point of view, the sediments are composed of Miocene to Pliocene and Pleistocene pelites and arenites. Due to this type of deposition, the groundwater has a high degree of mineralization, being linked to the fault system located in the vicinity of Tinosu, Mizil and Niscov localities; the water is, therefore, undrinkable, due to its features (Ungureanu, 2004).

## 3. METHODOLOGY

The surface area of 460 ha (Fig. 1) was covered in 24 hours of flight with an average flight time of 40 minutes and the UAV system used, was a multi rotor (or multi copter) drone of FAE 750 Hexa type, equipped with a Sony A6000 photographic camera, which was maintained in a horizontal position by a gimbal stabilizer. The UAV was controlled by a 9XR model radio controller and the ground control station is represented by the Lenovo L560 laptop computer.

Generally, ground control stations display real-time data on the performance and position of the drones, and is also used for controlling the UAV in flight and for charging. Digital data transfer (such as roll, pitch, yaw, GPS position, speed, battery level, etc.) between the UAV controller and the ground control station was performed through a 433 MHz band antenna (Hackney & Clayton, 2015).

Last but not least, the OSD (on screen display) connects the drone camera to the ground video monitor. It works on the 5.8 GHz band and displays the following information by default: alerts and system messages, distance (m) from the drone to the ground control center, video resolution of the camera mounted on the drone, selected frequency option, selected bandwidth, drone battery level and additional telemetry information.

The actual aero photogrammetric mission was planned by using the ground control station and specialized software (Mission Planner). The camera configuration settings and flight parameters were as follows:

- Flight height: 200 m
- Flight speed: 7 m/s
- The orientation of flight paths: 179 degrees
- Camera focal length: 20 mm
- Number of pixels of the sensor: 6000 pixels / 4000 pixels;
- Physical size of the sensor used: 23.5 mm / 15.6 mm

Although the aero photogrammetric mission was loaded, the actual flight could only be performed after marking (and measuring) the landmarks and control points (Table 1), arranged as evenly within the work area. In this case, 60 landmarks have been marked.

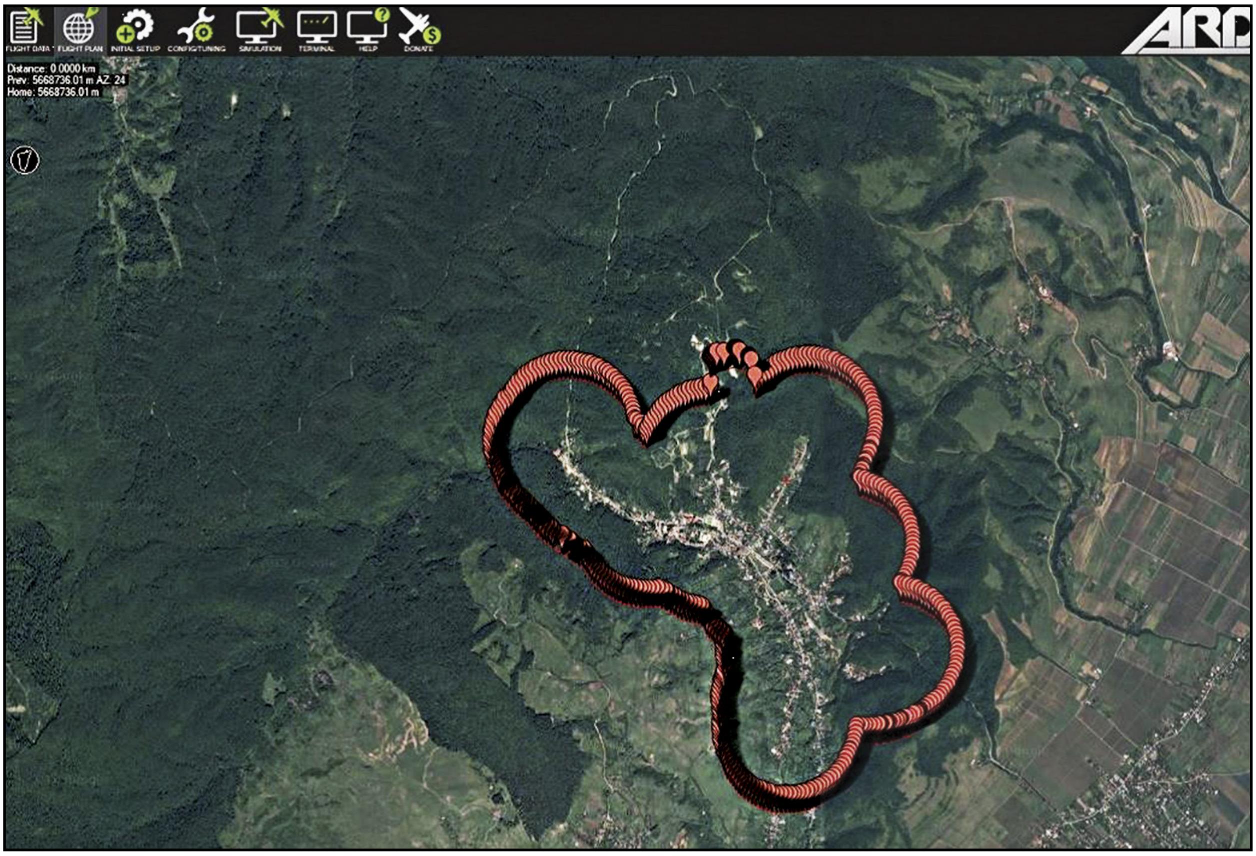


**Fig. 1.** Perimeter of the flight area, as displayed in Mission Planner (a software which serves as a ground control station).

Following the aero photogrammetric mission, 1879 photographic images were acquired, which will eventually be processed in dedicated software.

**Table 1.** Example of landmarks used as control points for assigning real-world coordinates to each pixel of the raster.

| No. | N | E | H |
|---|---|---|---|
| 14 | 406127.1 | 629827.2 | 171.057 |
| 19 | 406500.3 | 629706.3 | 185.0376 |
| 15 | 406278.2 | 629556.3 | 185.0376 |
| 20 | 406278.2 | 629556.3 | 167.6508 |
| 21 | 406378.5 | 629379.3 | 167.088 |
| 28 | 406704.4 | 629157.7 | 167.0768 |
| 26 | 407375.8 | 629421.2 | 239.6742 |
| 24 | 406866.7 | 629165.9 | 178.169 |

## 4. DATA PROCESSING

The acquired data sets (photograms) were later uploaded into Agisoft Photoscan, which is a professional tool for photogrammetric processes. One of the key features of this specific software, is the ability to generate several types of photogrammetric products, like:

- Orthophotomap (or orthoimage)
- DTM (digital terrain model)
- DEM (digital elevation model)
- Point cloud
- Dense point cloud

After the coordinate system (Dealul Piscului 1970/Stereo 70 for Romania) was established, an assesment of image quality was required to remove the skewed, overexposed or underexposed images. Following the removal of erroneous images, the sparse cloud points (image tie points) were generated, representing a collection of data points defined by a given coordinate system, *i.e.*, in this case, a 3D coordinate system) (Vîlceanu, 2013).

By using the landmarks coordinates, control points and cloud points (that were previously measured/generated), the dense cloud points (Fig. 2) were created, from 262,640,991 points. The difference between the sparse cloud points and the dense cloud points is that the second one is calculated by rectifying image pairs so that epipolar lines become parallel.

The Digital Elevation Model (DEM) (Fig.4) represents the bare-earth surface (raster grid) referenced to a vertical datum and it does not include anthropic elements (such as power lines, bridges, buildings) and natural ones (trees and other vegetation types). To obtain DEMs from the drone images, the dense point cloud needs to be filtered in order to remove all the points which are situated above the earth surface. The classified point cloud (Fig. 3) is generated in two steps:

1. The dense point cloud is divided into cells of a certain size, from which the points with the lowest altitude are determined and through triangulation of these points, an approximation of the Digital Elevation Model is created.
2. New points are added to the ground class, only if they lie within a certain distance from the digital model and if the angle between the digital model and the line to connect these new points is less than a certain angle.

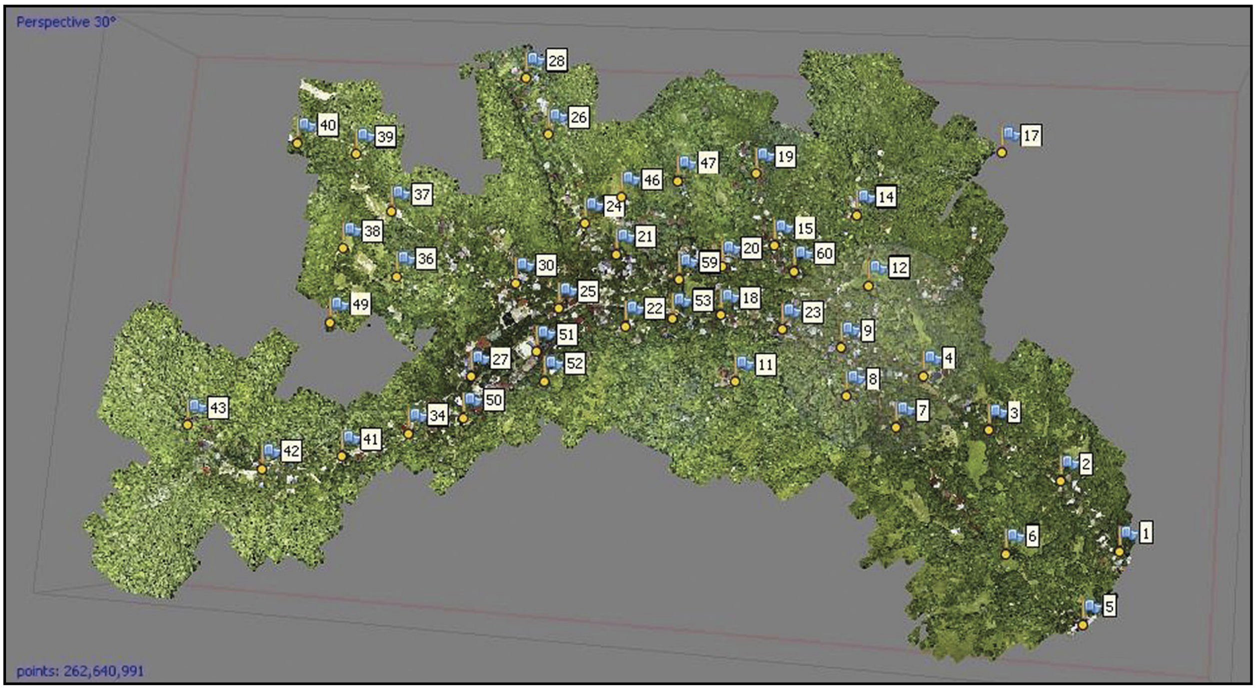


**Fig. 2.** The dense could points and the entire set of landmarks (with numbers) used as control points.

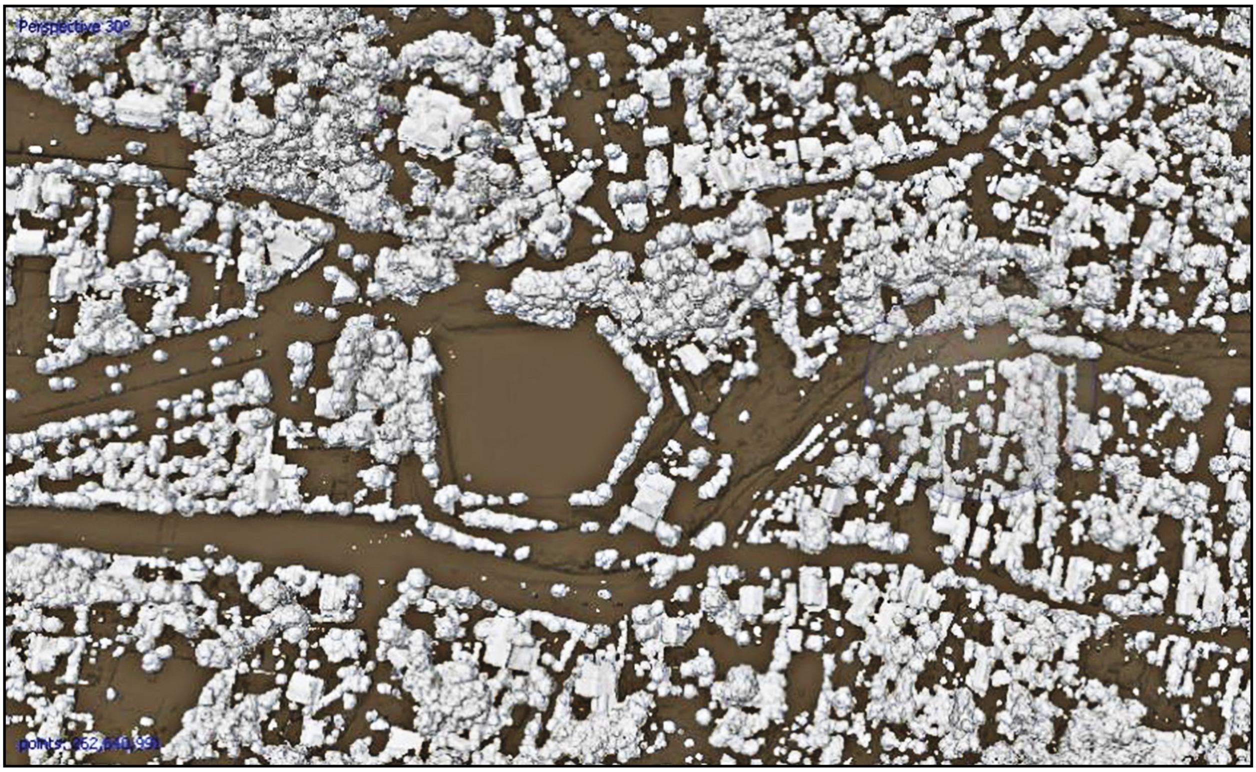


**Fig. 3.** The classified point cloud, in which the white areas represent the remaining unclassified points (vegetation and buildings).

The DEM (Digital Elevation Model) and the DTM (Digital Terrain Model) are usually synonymous, but, in some cases, the DTM represents a vector data set composed of regularly spaced points and natural features, such as ridges and breaklines which augments a DEM by including linear features of the bare-earth terrain. In the case of Sărata Monteoru, the generated Digital Elevation Model (Fig. 4) is identical to the DTM and was overlapped on a satellite image of the village (Nache *et al.,* 2017).

The digital terrain model can be used for a variety of calculations and simulations, according to Păunescu *et al.,* (2010), and this includes:

- Determining the variation of the relief
- Obtaining topographic profiles of the terrain
- Generation of contour maps
- Carrying out volume calculations
- Carrying out studies to prevent flood risk
- Generating 3D Models

The DEM was exported into a GIS software (Global Mapper) and was further used for the calculation of a more appropriate and easy to visualize classified point cloud (Fig. 5) (without any white areas, like in Agisoft PhotoScan) and the topographic profiling of an outcrop (Fig. 6) and a fracture located in the outcrop (Fig.7).

Global Mapper includes several powerful terrain analysis commands that allow you to model elevation data like the Path Profile Tool through which topographic profiles can be generated along a specified path using loaded elevation datasets.

For a more complex view of the landscape variation, a 3D model (Fig. 8) was generated, and, unlike standard vector data, this 3D model contains a 3D mesh structure where various 3D points are connected through edges and faces. The 3D mesh contains internal vertices that allow for more complex 3D geometry, in contrast to 3D vectors, where the elevation is displayed only at the edges of an area. It also includes light and shadow features and a picture (from an orthophotomap) mapped to the vertices, creating a more realistic surface; it is worth mentioning that some parts of the vegetation contain aberrations in elevation data, as usually.

In Global Mapper, flood simulations are possible by raising the water level of selected areas or a fixed elevation by some height. This type of process, according to Nache *et al.,* (2017), is useful for:

- Flood risk assessment;
- Flood management;
- Flood control;
- Flood maps, which help to locate places at higher levels to escape or engage in rescue operations;
- Providing floodplain maps adjacent to rivers and streams;
- Visualization the sea level rise and fluctuations in coastal areas.

In this study, a flood simulation and 4 floodplain maps were created by increasing the water level of Sărata Monteoru River (a tributary river that flows into the Sărata River) with 40

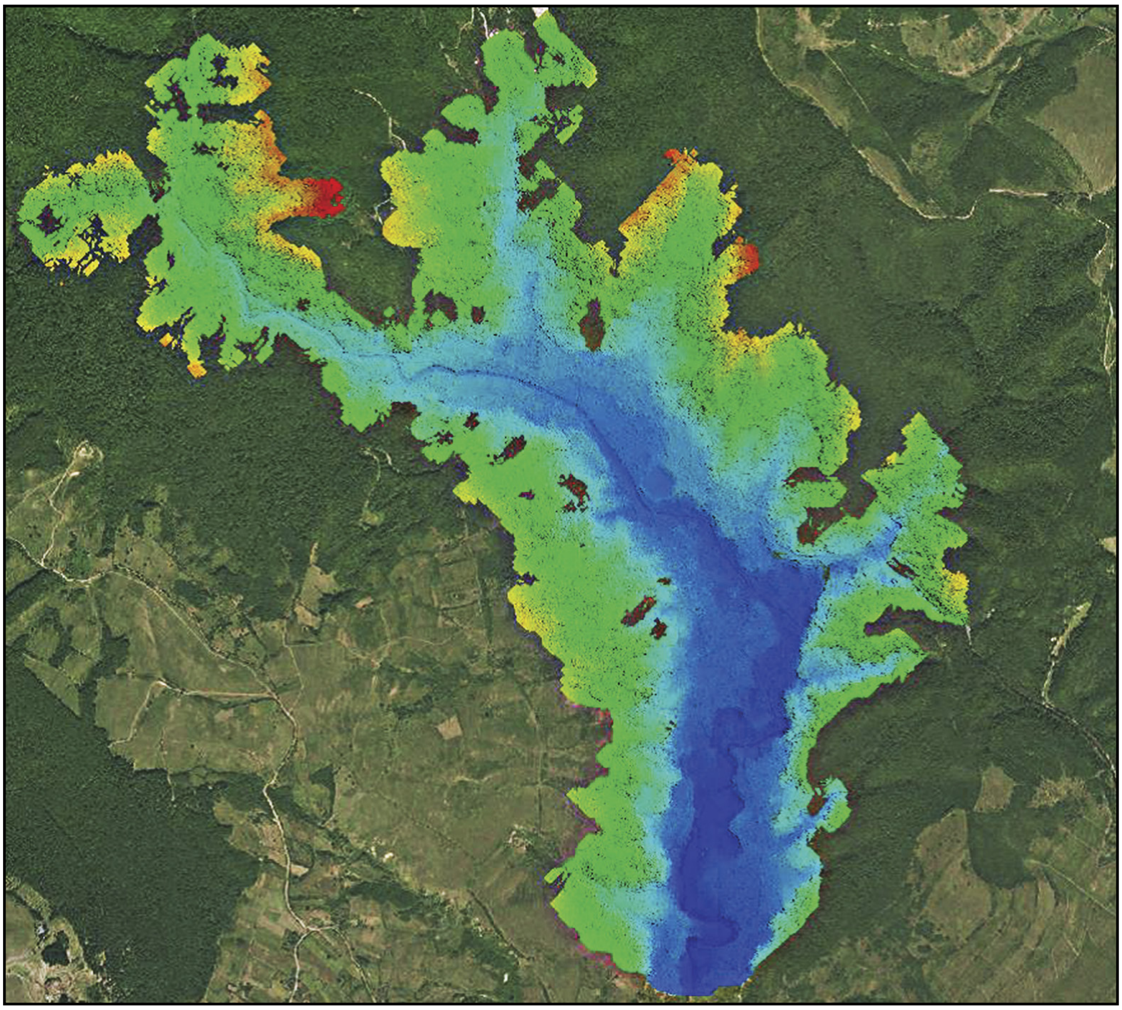

**Fig. 4.** DEM (Digital Elevation Model) overlapped on a satellite image of the area (downloaded from the World Imagery server affiliated to Global Mapper), the representation and visualization being in the form of pseudo-colors (using blue for the lowest elevations and red for the highest elevations).

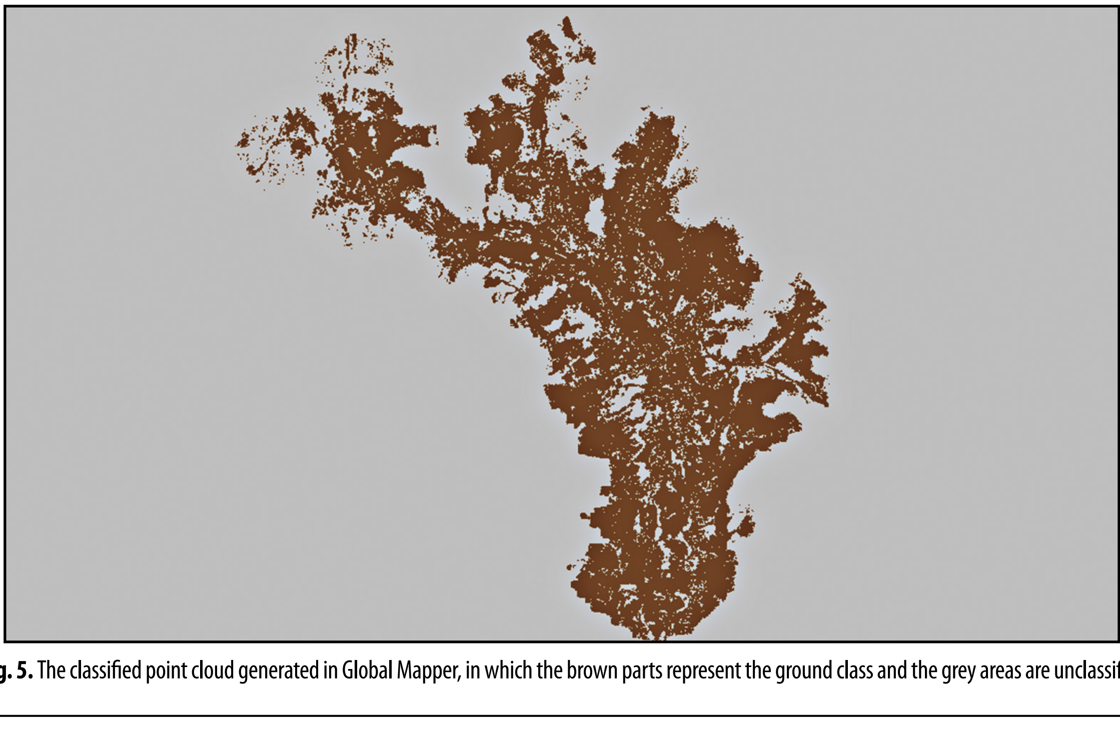

**Fig. 5.** The classified point cloud generated in Global Mapper, in which the brown parts represent the ground class and the grey areas are unclassified.

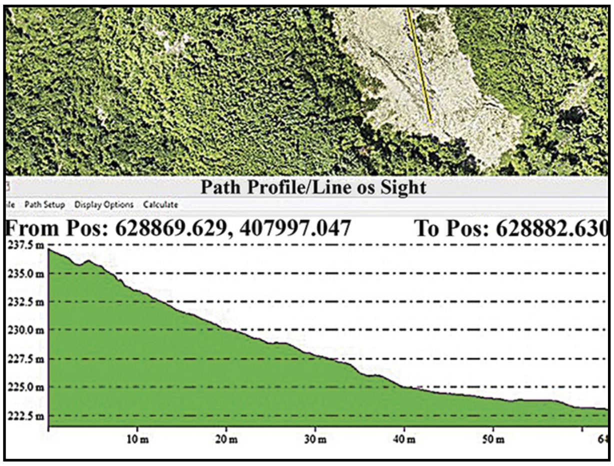


**Fig. 6.** Topographic profile of an outcrop (situated in the north-eastern part of Sărata Monteoru) generated in Global Mapper.

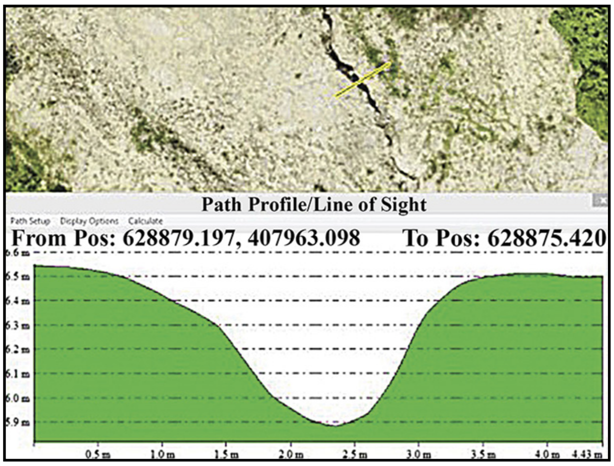


**Fig. 7.** Topographic profile of a fracture located in the outcrop, mentioned in the previous figure, generated in Global Mapper.

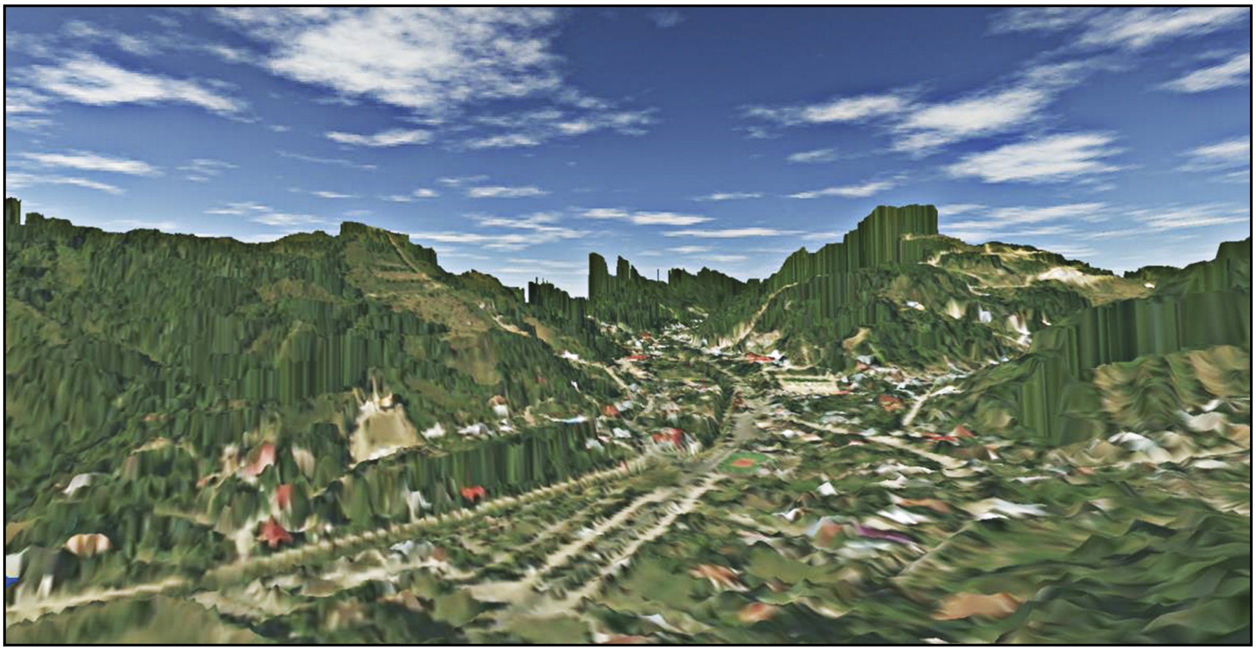

**Fig. 8.** A 3D perspective of the Digital Elevation Model (with an orthoimage mapped to the vertices) showing the variation in elevation.

m (Fig. 9). The hydrostatic level of these 4 floodplain maps, shown in Fig. 9, was increased by 10 m for each map and it shows the areas that might be covered by water.

Further calculations were possible, due to the versatility of Global Mapper. Therefore, we have generated a contour map (Fig. 10) and an orthophotomap (Fig. 11) of the Sărata Monteoru village.

The last photogrammetric product, which was fairly easy to obtain by georeferencing and applying geometrical corrections (ortho-rectifications) to the photograms data sets, was the orthophotomap (Fig. 11). The orthophotomap was generated in Agisoft PhotoScan.

## 5. CONCLUSIONS

With the UAV technology, accurate information is obtained on a large scale even in areas that, due to flooding, landslides, volcanic activity, etc. are considered dangerous to access or inaccessible. The dedicated software needed for data processing (Agisoft PhotoScan and Global Mapper) has a high level of functionality and versatility. Finally, the use of UAV systems, for the generation of Digital Elevation/ Terrain Models, leads to very good results and may be highly effective for areas with small variations of the relief, involving low cost and a relatively short time of data acquisition for studies with a stretch of several tens of hectares.

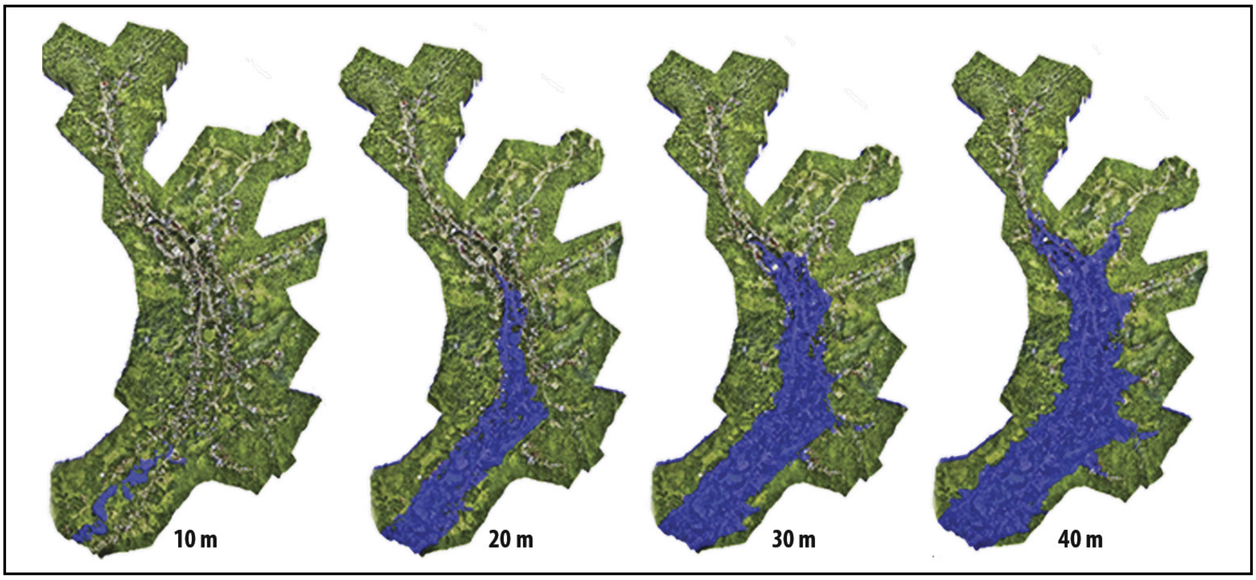


**Fig. 9.** Flood simulations and floodplain maps, from left to right; the level of water rises 10 m each.

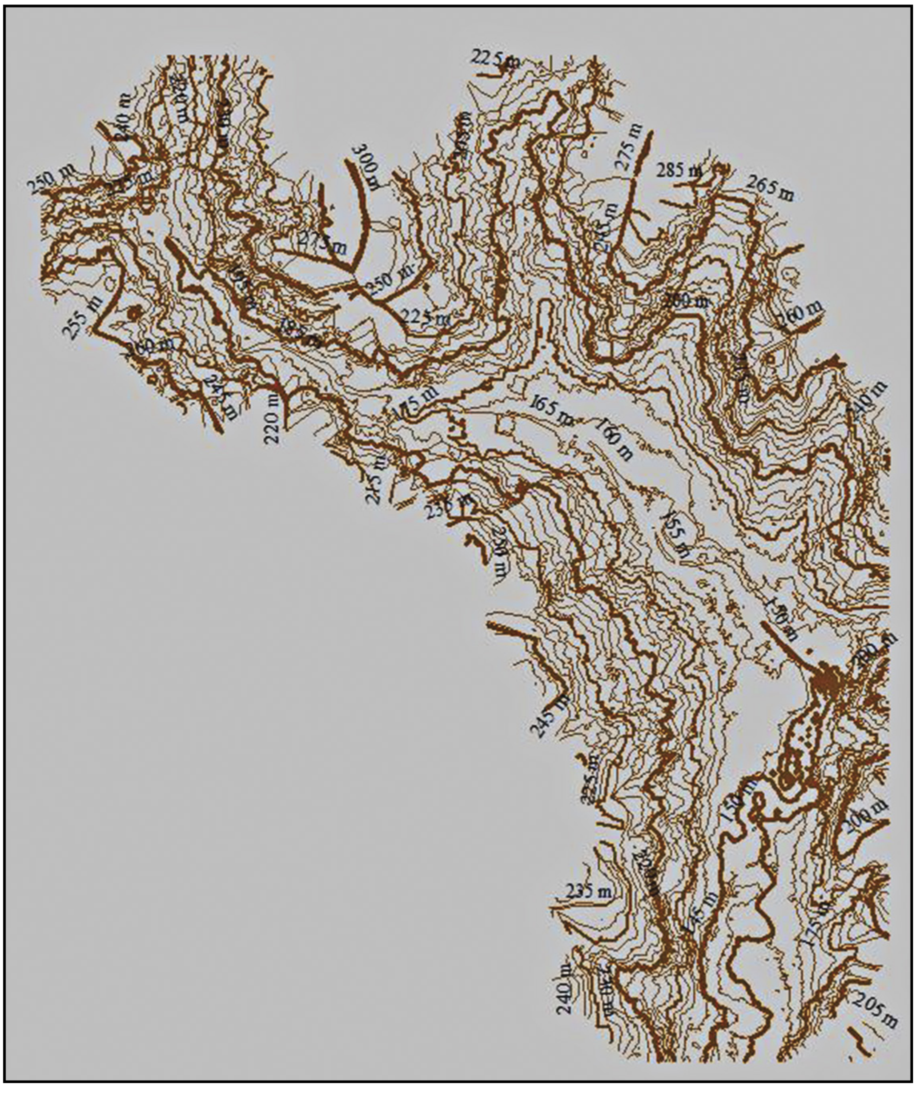


**Fig. 10.** The contour map of Sărata Monteoru locality.

**Fig. 11.** The orthophotomap representing the geometrically corrected image referenced in the Stereo70 projection system.

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