



An Assessment of Topographic and Morphodynamic Features of Borviz Valley, Bodoc Locality, Transylvania Using Photogrammetry

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Abstract

Photogrammetry is a specialized technique essential for acquiring high-resolution 2D and 3D spatial data in a non-invasive manner. Its applications are particularly significant in terrain mapping and topographic analysis, where it serves as a complementary tool for geophysical and geological surveys. Additionally, photogrammetric data play a crucial role in monitoring landslides and erosion, particularly in valley-dominated landscapes, as exemplified in this study. Furthermore, photogrammetry is widely utilized in flood risk assessment and mitigation, as well as in infrastructure planning and land use management, contributing to more informed decision-making in environmental and engineering contexts. In this study, we conducted a survey over an 83,000-square-meter area situated in Borviz Valley (that serves as a tributary to the Olt River), within Bodoc locality, in the historical region of Transylvania, Romania. The aerial photogrammetric data acquisition was carried out using a DJI Phantom 4 Pro V2.0 UAV system, supplemented by a Trimble R2 GNSS system and a network of nine ground control points (GCPs) to enhance geospatial accuracy. The dataset, consisting of 436 images, was processed using specialized photogrammetric software, such as Agisoft Metashape, along with various Topographic and GIS tools, including ESRI ArcGIS and Blue Marble Geographics Global Mapper. This processing workflow resulted in high-resolution 3D models and 2D maps, represented by a range of photogrammetric products, including Digital Elevation Models (DEMs), Digital Terrain Models (DTMs), classified point clouds, and orthophotos (orthomosaics). By generating classified elevation models that include only the terrain class while excluding vegetation, built structures, and other anthropogenic objects, we obtained a more detailed representation of the ground surface, allowing for a more accurate depiction of the valley's morphological characteristics. Furthermore, the orthophoto (orthomosaic), produced by integrating all photographic images acquired during the photogrammetric survey, provides a highly precise geospatial reference. This dataset can serve as a valuable resource for future survey planning across various domains such as topography, civil engineering, general infrastructure, utility construction, etc.

Keywords: Photogrammetry, GCP, DEM, DTM, orthophoto

1. Introduction

Photogrammetry is a relatively modern method for scanning objects, forests, rivers, agricultural fields, and archaeological sites or exploring areas where specific measurements are planned. Thus, this method can be closely linked to various fields—from architecture, archaeology, and topography to geology—where photogrammetric measurements support the creation of horizontal surface maps that capture the subject of interest in 3D or 2D form. According to Sluijs et al, 2024 [1], the images can be terrestrial, taken with digital cameras, DSLRs, or film cameras, satellite or drone-acquired images. Photogrammetric measurements also include determining coordinates, identifying areas of interest, and generating orthomosaics and other digital models. Aerial photogrammetric measurements are carried out using drones, which allow real-time visualization of large areas. In the past, airplanes were used to scan extensive areas on a large scale to generate elevation models of the terrain. More recently, fixed-wing drones have become a more feasible alternative for economic reasons, significantly less costly than manned aircraft. Small-scale drones

are the most commonly used due to their practicality. As Aber et al, 2010 [2] mentioned, drone missions are particularly useful when data collection is required to generate digital models of terrain and vegetation in inaccessible areas, especially in Beyond Visual Line of Sight (BVLOS) operations. The drones can scan smaller objects at closer range, resulting in highly detailed imagery. Over time, these drones have been used to scan terrain, archaeological sites and objects, buildings, and more. Thanks to modern technology, these drones can now connect to GPS systems, allowing for the collection of detailed coordinates of areas of interest. For even greater precision, a ground-based GNSS system can be used to enhance coordinate accuracy, thereby enabling the generation of detailed terrain models. This level of detail allows for accurately calculating elevation differences across the landscape. With such models, photogrammetric measurements can also calculate volumes across large areas. For example, this method can determine the volume of flood-prone zones and the sand volumes that affect beach structures. It can be used to monitor changes and issues caused by climatic, geological, or human factors. The larger the area of interest, the more photographs the drone will need to take—images that must be stitched together using common reference points. As noted by Singh et al, 2025 [3], from a multidimensional perspective, the point cloud can be used to create a final Digital Elevation Model (DEM) and to extract additional deformation monitoring values or structural data. These models provide detailed elevation data over vast areas. The area where the photogrammetry measurements were conducted was selected to develop geological methods to investigate underground structures that facilitate the natural release of CO₂ emissions to the surface.

2. Case study

Between June 8 and 12, in the Bodoc area, Covasna County, Romania, aerial photogrammetric measurements were carried out to support the monitoring and detailed visualization of geophysical investigations, including electrometry, seismic, and GPR (Ground Penetrating Radar) surveys, as well as gas sampling aimed at determining the CO₂ flux released to the surface by the mofettas in the area. The geomorphology of the Bodoc area is highly diverse, with several altitude levels characteristic of its geographical setting. This area is part of the Eastern Carpathians, the Baraolt–Olt River region, and the Braşov Depression, as noted by Aparaschivei et al, 2012 [4]. Altitudes range from approximately 550 meters at the Olt River level to around 1000 meters at the crest of the Bodoc Mountains. Regarding the hydrology of the area, the secondary hydrographic network is entirely drained by the Olt River, which crosses the study area in a north–south direction, along with its left-hand tributaries. Geophysical investigations were conducted along well-defined profiles positioned according to the area of interest, considering obstacles such as vegetation, rugged terrain, rocks, ponds, and other impediments. The coordinates of the profiles and the specific points where measurements were conducted were accurately recorded using a high-precision GPS device, the Trimble R2 GNSS system. Figures 1 and 2 illustrate one of the site plans, showing the layout of the electrical resistivity profiles and the locations where gas samples were collected.

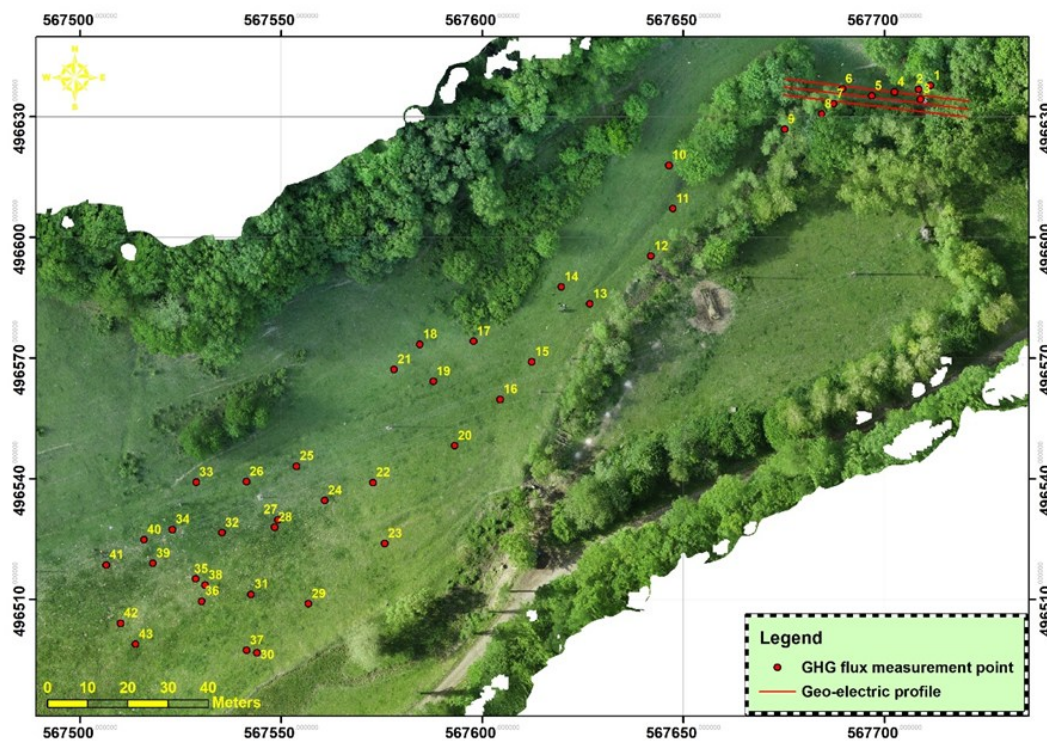


Fig. 1. Site plan of the measurements conducted within the Bodoc perimeter.



Fig. 2. Site plan of the three geoelectric profiles and the location of the VES points along them.

Depending on the designated area and local terrain, 43 gas measurements and three electrical resistivity profiles were collected (shown in the upper right section of Fig. 1). The measurement points were strategically positioned to allow for repetition in future years, enabling comparative analysis of CO₂ fluxes over different periods. The use of the drone aimed to provide an overview of the perimeter where measurements were conducted. This approach allowed for detailed visualization with precise coordinates (extending throughout the entire perimeter), accessed via the orthophoto plan generated using specialized photogrammetry software. The aerial photogrammetry operations within the gaseous mofette perimeter in the Bodoc area covered a surface of 8.96 hectares. According to Dragos et al, 2024 [5], these photogrammetric measurements are of the Structure-from-Motion (SfM) type. This method generates high-resolution 3D digital terrain models by processing overlapping 2D images. A quadcopter drone was used to cover an area of this size, specifically the DJI Phantom 4 Pro V2.0, designed for photogrammetric surveying. This drone had a high-resolution gimbal-mounted camera featuring a 1-inch, 20MP CMOS sensor and a mechanical shutter. To improve the quality of the data generated by the drone, a Trimble R2 GNSS system was used alongside a set of nine ground control targets, placed strategically to mark GPS-sampled points. These ground points facilitated accurate recognition by the photogrammetric processing software for more precise elevation data. The fact that this DJI drone is specifically designed for aerial photogrammetric measurements makes it possible to create a pre-planned flight mission, including the drone's exact route before takeoff. Therefore, the photo-taking path is predefined, allowing the operation to be controlled with the highest precision and attention to detail. The drone's flight path was programmed to ensure maximum accuracy and consistency in the data collection process. The flight plan was created on a Dell field laptop using the DJI Terra application, where key flight parameters could be configured. Thus, the drone operated at a flight altitude of 65 meters, with the camera angle set at 90° (nadir position), meaning the lens was oriented perpendicularly to the ground or object. Regarding image capture specifics: Focal length: $f/5.6$; Shutter speed: 1/2400s; ISO: fixed at 100; Focus mode: manual. To generate the orthophoto plan, the drone carried out a flight mission that captured 436 photographs, which were later aligned using common reference points in Agisoft Metashape, a dedicated photogrammetry software. Further data processing was performed in Blue Marble Geographics Global Mapper. As a result of the photogrammetry work, a dense point cloud consisting of 83,392,000 pixels was generated, of which 28,725 pixels were identified as common tie points (used to align the images for seamless continuity). This dense point cloud is illustrated in Fig. 3 and Fig. 4.

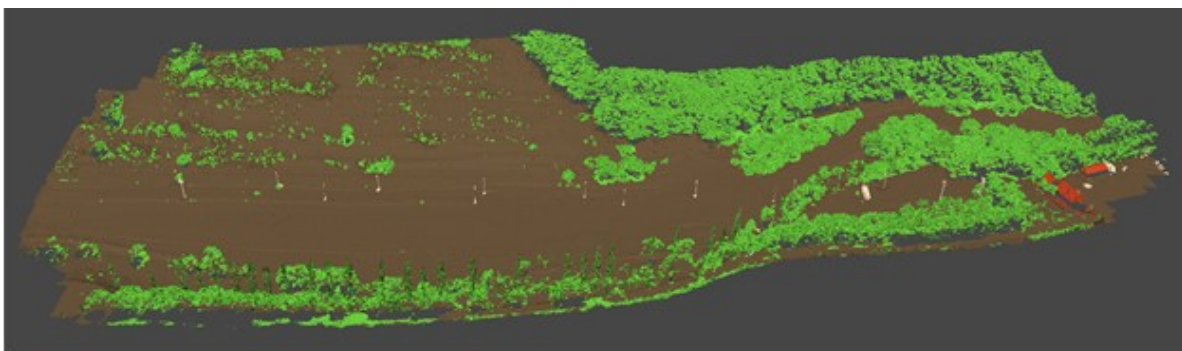


Fig. 3. Dense point cloud classified into the following categories: terrain – brown, vegetation – green, anthropogenic objects – yellow, and buildings – red.

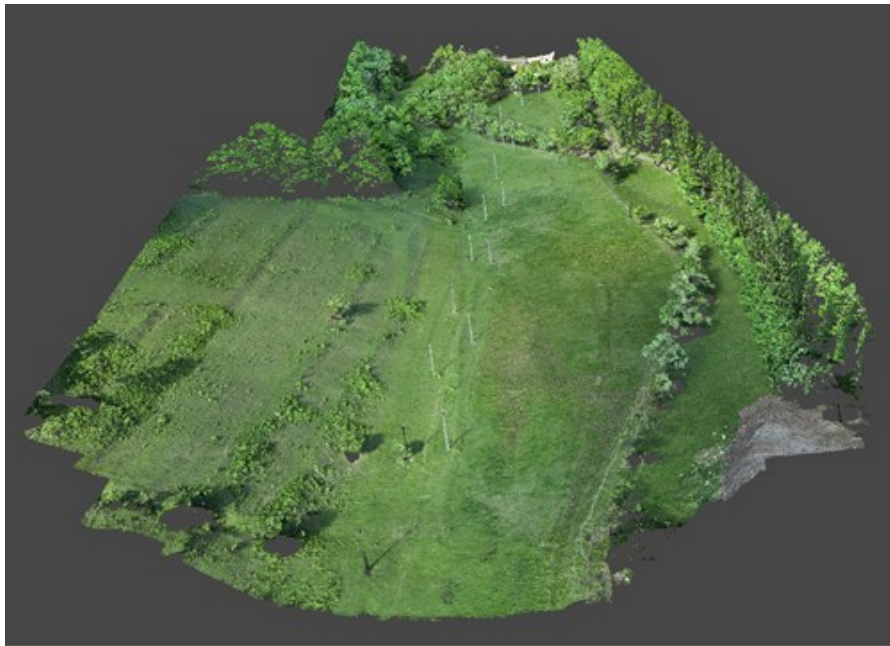


Fig. 4. 3D perspective of the textured dense point cloud.

The raster files representing these models were rendered at a 3.44 cm/pixel resolution. Fig. 5 shows an orthomosaic (orthophotoplan) generated at a resolution of 1.74 cm/pixel, covering a surface area of 0.0896 km². It is important to note that the models were created with a topographic accuracy of 0.04 meters horizontal error and an RMS error of 0.34 pixels, which ensures that these maps can be reliably used for the interactive spatial positioning of objects. Nine ground control targets were used to improve spatial accuracy, where points were recorded with the high-precision GNSS system (as shown in Fig. 5). Thus, by analyzing the generated models, distances between points, topographic profiles, hypsometric maps, and volume calculations can be performed with high precision without requiring labor-intensive direct measurements using ground-based surveying instruments. The targets served to mark the high-precision points (collected using the ground-based GPS) on the map generated from the photogrammetry mission.



Fig. 5. Orthomosaic and the nine ground control points (GCPs).

3. Results

Following the drone flight and the generation of the orthomosaic, 3D maps of the studied area were obtained, featuring high-precision coordinates at any point. This type of aerial photogrammetric measurement is of great importance, as it allows for creating highly accurate terrain models that can be correlated with geophysical profiles. As a result, a much more detailed perspective can be achieved over a broader area surrounding the profiles—not just within the measured perimeters themselves. DTM (Digital Terrain Model) and DEM (Digital Elevation Model) outputs can be generated to develop interactive maps, which can then be processed for volume calculations of various terrain types. Fig. 6, shows the Digital Elevation Model (DEM), representing the terrain surface, vegetation, and building heights. This model is generated before the DTM and, for better visualization, requires the removal of obstructive elements such as trees and structures. In Fig. 7, the Digital Terrain Model (DTM) represents the actual ground elevation, excluding vegetation, buildings, or other

elements that interfere with a clear view of the terrain's horizontal profile. Fig. 6 and Fig. 7 illustrate important details about the valley's shape where CO₂ flux measurements were taken. Based on this, a correlation can be made between the volume of gas emissions and the valley's shape, allowing us to conclude about the influence of topography on CO₂ distribution and movement. Elevation values are represented on the maps using a color gradient: Blue indicates the lowest elevations, followed by green, yellow, red, and finally purple for the highest elevations. This color scheme applies to both the DTM and DEM maps.

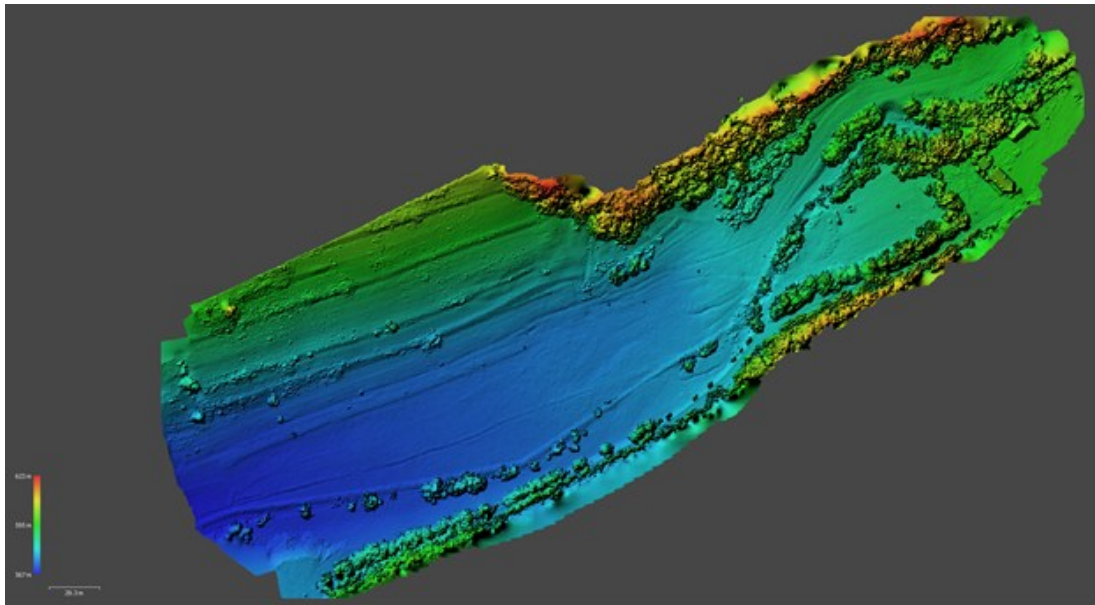


Fig. 6. Digital Elevation Model (DEM).

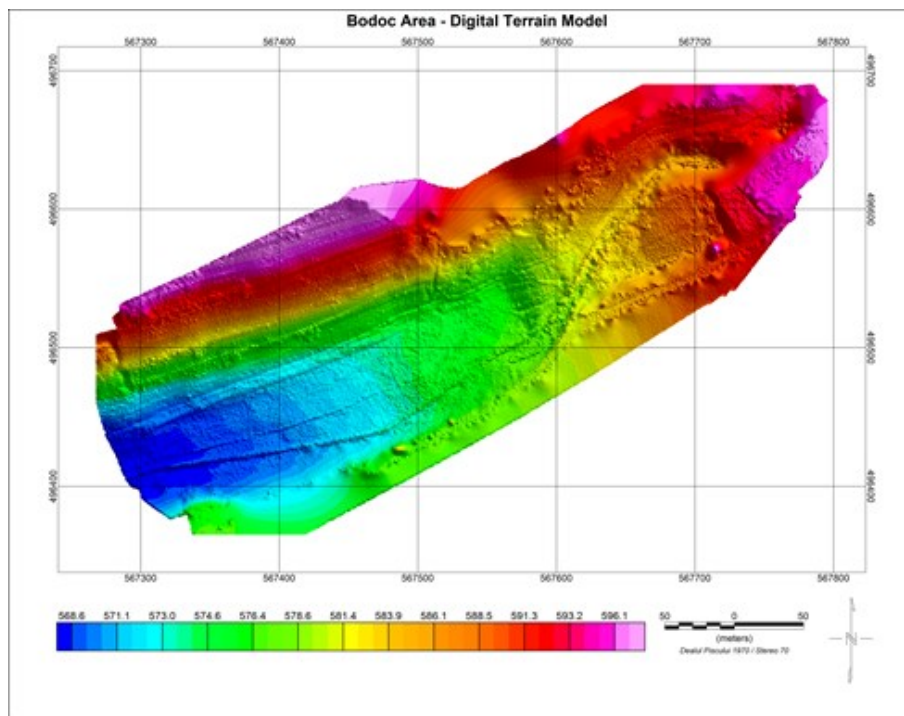


Fig. 7. Digital Terrain Model (DTM).

4. Conclusions

These photogrammetric measurements can be used to correlate with geophysical measurements and calculate volumes in the case of beaches or floodplains to anticipate natural disasters. Another essential application is area monitoring. Monitoring these areas is another important aspect to mention. For example, in the case of geophysical measurements at Bodoc, natural CO₂ emissions vary from season to season. Therefore, photogrammetry is necessary to obtain detailed images and geophysical data to monitor CO₂ fluxes over time — across months or even years — to understand these sites better. Therefore, aerial photogrammetric surveys are extremely valuable, especially when integrated with geophysical measurements, as they provide both a detailed and large-scale overview and the capability to process data into digital terrain and vegetation models. Processing this data in specialized software leads to the final output: interactive orthomosaic maps that can be used for various calculations, including volumes, distances, elevations, and more. Efforts are ongoing to improve this method further to generate even more types of data, simplify fieldwork, and offer new perspectives on areas of interest, depending on the measurements carried out on site.

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