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# ACQUISITION OF PHOTOGRAMMETRIC DATA USING UAV – CASE STUDY: BISTRIȚA LIMESTONE QUARRY, VÂLCEA

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**Abstract:** *Through this paper the project team aimed to demonstrate the utility and feasibility of using flights and photogrammetric methods in surface mining in mountainous areas. Thus, in the first part of the paper, the working principles, the applied methodology, the criteria for selecting the methodology, and the necessary resources are presented, and later the results obtained from the case study from the limestone quarry in Bistrița, Vâlcea are presented. At the same time, the environmental, relief and accessibility conditions in the mining perimeters were identified and practical recommendations were issued regarding the execution of a photogrammetric data acquisition flight in the surface mining operations in the mountain area. This paper indicates risk factors identified in quarries in the mountain area and offers practical solutions to avoid them.*
**Keywords:** *drone, UAV, limestone, mining, photogrammetry, surface mining*

## 1. Introduction

Mining activities are found all over the world to meet the needs of mineral resources required in various industrial or economic sectors [1, 2]. Among these, surface mining stands out for the complexity of the activities, the relatively large areas and the environmental footprint [3]. Surface mining involves dislodging, blasting, excavating, loading, transporting, and processing significant amounts of soil, which causes changes to the topography of the land and the environment throughout the life of the mine [4]. These changes materialize in radical changes to the topography and land cover, the establishment of dams, embankments, tailings deposits, etc.

From a legal and managerial point of view, all these environmental changes and influences must be properly monitored and managed throughout the exploitation life (from exploration to environmental restoration) [5], which requires the acquisition and use of accurate topographical data. Surface mining presents a high degree of danger generated by deep excavations, steep and unstable slopes, dust concentrations in the atmosphere, etc. At the same time, the level of risk is directly proportional to the time spent by surveyors in exploitation and to the frequency of data collection through traditional methods. So, modern methods of data acquisition (use of drones, photogrammetric and remote sensing methods) make the field activities of topographers more efficient and reduce the risks to which they are exposed [6, 7]. Also, compared to traditional methods, modern methods show high efficiency and accuracy generated by the multitude of sensors that can be integrated and used [7].

Considering the wide range of mining operations that can be carried out with UAV flights, their efficiency and effectiveness, as well as the fact that most of these operations involve the acquisition of primary data and subsequent processing using photogrammetric methodologies and products [4, 7, 8], this paper carries out an analysis of the currently used photogrammetric methods (with general applicability) and the possibility of using these methods in the mining field. In this sense, a case study was carried out in a surface mining operation, namely the limestone quarry from Bistrița, Vâlcea county. At the same time, taking into account the mountainous area where the case study was carried out, the particularities (positive and negative) generated by the environmental conditions and the terrain profile were investigated in the process.

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## 2. Materials and methods

### *2.1. Study area*

The flight for the acquisition of photogrammetric data was carried out in the NW part of Vâlcea county, at the limestone mining operation at Bistrița, Costești commune, a location that can be seen in figure no. 1. The quarry was established in 1960, and currently the mining perimeter has reached an area of approximately 1,161 km2 and an extension in depth of 200 m. Mining in the quarry was carried out on 8 steps of 30 m height each and a working slope of 75°, located between elevations +732 and +977 m [9].

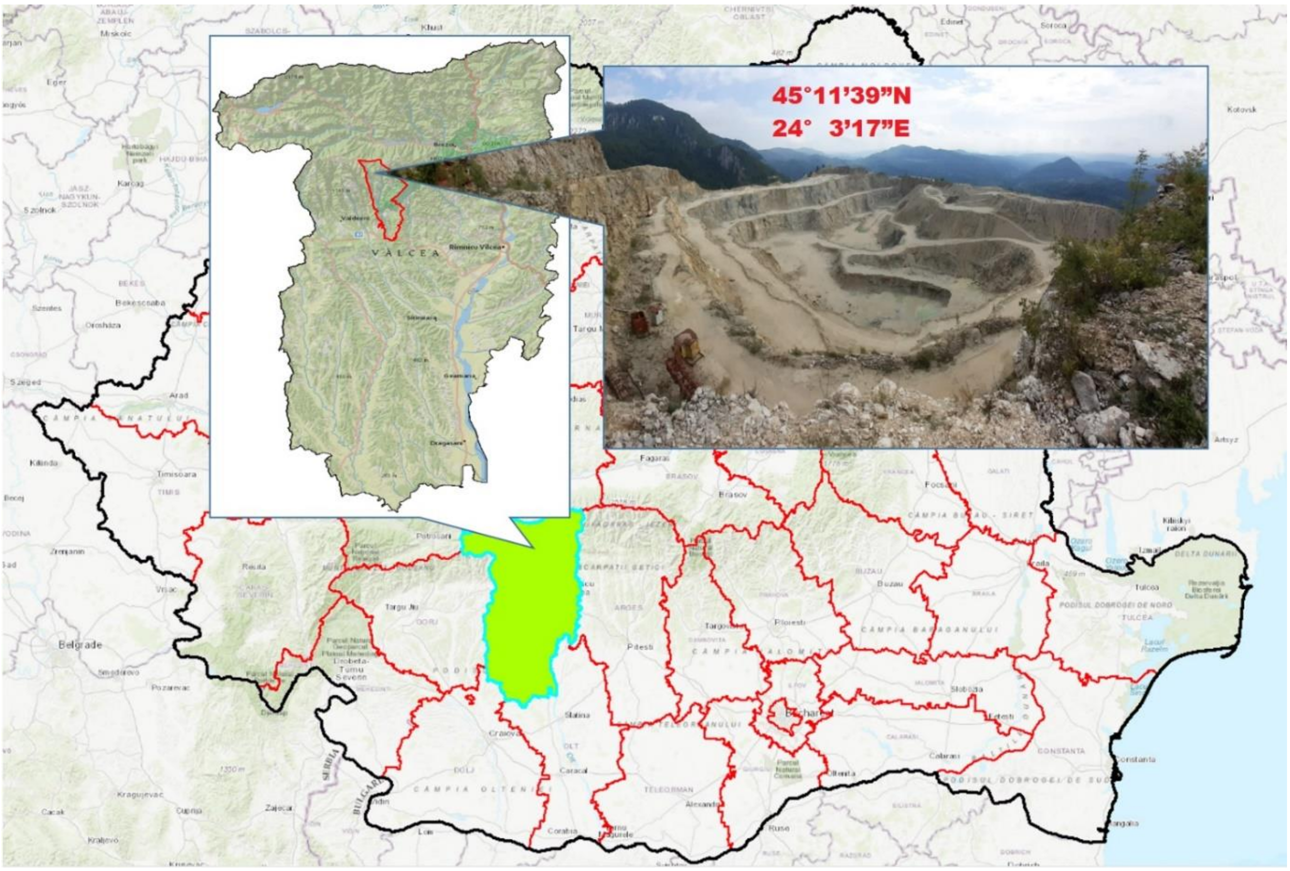


Figure 1. Limestone mining Bistrița, Vâlcea, Romania

The case study covered an area of approximately 130 ha and flight missions were conducted at three quarry locations as follows:

- in the area of effective exploitation (quarry), 4 flights were made to acquire photograms, with a one-way flight route, on an area of approximately 106 ha;
- a flight was carried out on the ore transport route for real-time visualization and video data recording, on an area of approximately 4.5 ha;
- in the ore processing and storage location, a photogram acquisition flight was carried out, with a flight route with perpendicular routes, over an area of approximately 20 ha

### *2.2. Methods, systems, and sensors*

A permanent concern of topographical engineers is the collection of precise data, their accuracy being essential in topographical works [4, 7]. In order to meet the accuracy requirements, surveying engineers have to allocate a significant amount of time to data collection, processing and correction operations, at the expense of their actual analysis and use. Advances in technology have facilitated the emergence of modern field data acquisition tools, allowing surveyors to spend more time analyzing data and preparing it for the operational environment [4].

Among the booming technologies we can mention the methods of acquisition and processing of photogrammetric data. By using UAV-type equipment, surveyors have the opportunity to quickly and easily collect data from the field, but they must show a permanent concern for ensuring the correctness and accuracy of the data [6, 7].

Among the methods and technologies used to collect photogrammetric data in compliance with geolocation accuracy requirements, we can mention: the Ground Control Points (GCP) method, the Real Time Kinematic (RTK) method or the Post Processing Kinematic (PPK) method [8]. Even if the mentioned methods involve different ways of working and the use of different equipment, the obtained results will be similar (they will present insignificant differences). The topographic engineer has the responsibility to analyze the environment in which the activities will be carried out, to inventory the available material resources and to establish the method that best suits the analyzed context.

Table 1 summarizes the principles of operation, as well as some advantages and disadvantages for each presented method.

Table 1. Applicable methods for the acquisition of photogrammetric data

| Method | Principle | Advantages | Disadvantages |
|---|---|---|---|
| *GCP (Ground Control Points)* | o It is a method usually used in topographic or photogrammetric projects;<br>o It is based on points marked on the ground for which the coordinates are known or can be determined;<br>o The quality of the final results depends on the number of points used, their arrangement and density. | o Used relatively often;<br>o It is a known method;<br>o Quality results are obtained;<br>o precision and accuracy<br>o validated working method. | o a high consumption of time;<br>o it requires more staff;<br>o a difficult access in some areas for ground marking. |
| *RTK (Real Time Kinematic)* | o It is an increasingly used method;<br>o Associates coordinates to the frames at the time of flight, coordinates corrected in real time;<br>o Each coordinate corresponds to the center of each frame. | o Provides high safety for operators in the field;<br>o Fast and efficient;<br>o Coordinates associated with frames in real time, without requiring further processing. | o It is not yet widely used;<br>o High costs of the necessary equipment;<br>o Environmental constraints and weather conditions;<br>o Legislative restrictions;<br>o Low number of qualified personnel for such operations;<br>o Risks of communication interruption between the UAV and the reference station. |
| *PPK (Post Processing Kinematic)* | o It is based on the collection of two sets of data at the time of flight: data from the GNSS receiver of the UAV and data collected by a reference station;<br>o Each frame (frame center) has associated primary coordinates received from the UAV's GNSS receiver;<br>o Through further processing the associated coordinate corrections are made. | o Provides high safety for operators in the field;<br>o Reduced time for field activities;<br>o It can be used in difficult relief conditions, less favorable environmental and weather conditions;<br>o Frames also keep the initial coordinates. | o Method used relatively rarely, so it is not sufficiently validated;<br>o Equipment is required for further processing;<br>o Deviations caused by human error may occur in the final results. |
| *Floating* | It involves flying with equipment that has low positioning accuracy and cannot be considered a valid method or used for topographic and photogrammetric projects. However, it is used for practical projects in an unconstrained environment that does not require precision of the final results. | | |

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Figure 2 schematically shows the operating principles and communication channels between the equipment involved in the photogrammetric data acquisition process.

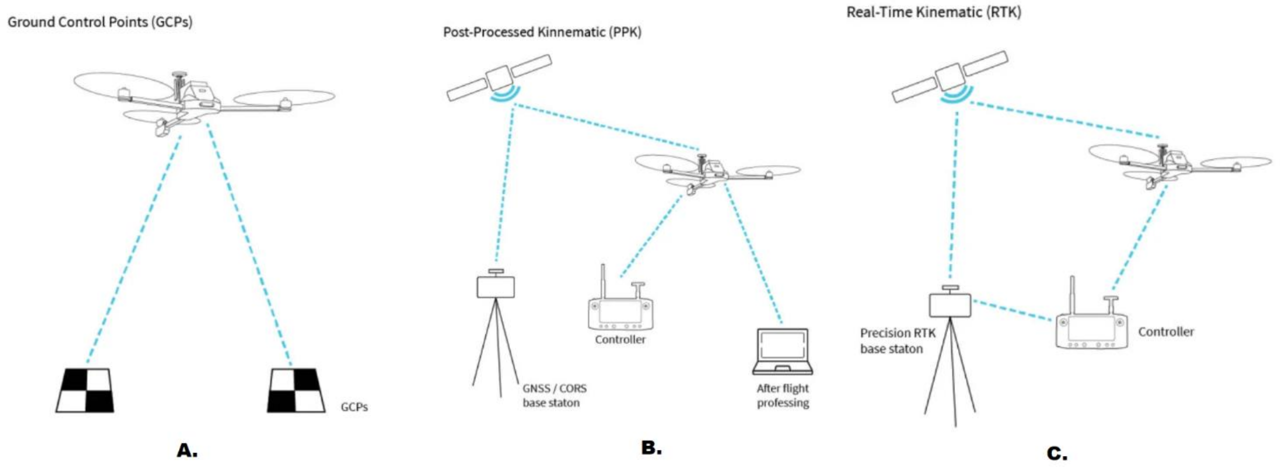


Figure 2. A.GCP Positioning, B.PPK Positioning, C.RTK Positioning [10]

### *2.3 Workflow*

In order to ensure the success of a photogrammetric project, it is imperative to know and manage both the available resources (equipment, qualified personnel, budget) [11] and the environment in which the activities will be carried out (weather conditions, flight restrictions, interferences, etc.) [7, 12, 13]. Starting from this principle, the workflow to be followed was established and the resources needed to achieve the objectives were estimated [11, 14]. To carry out the case study, it was proposed to go through the work stages as shown in figure 3.

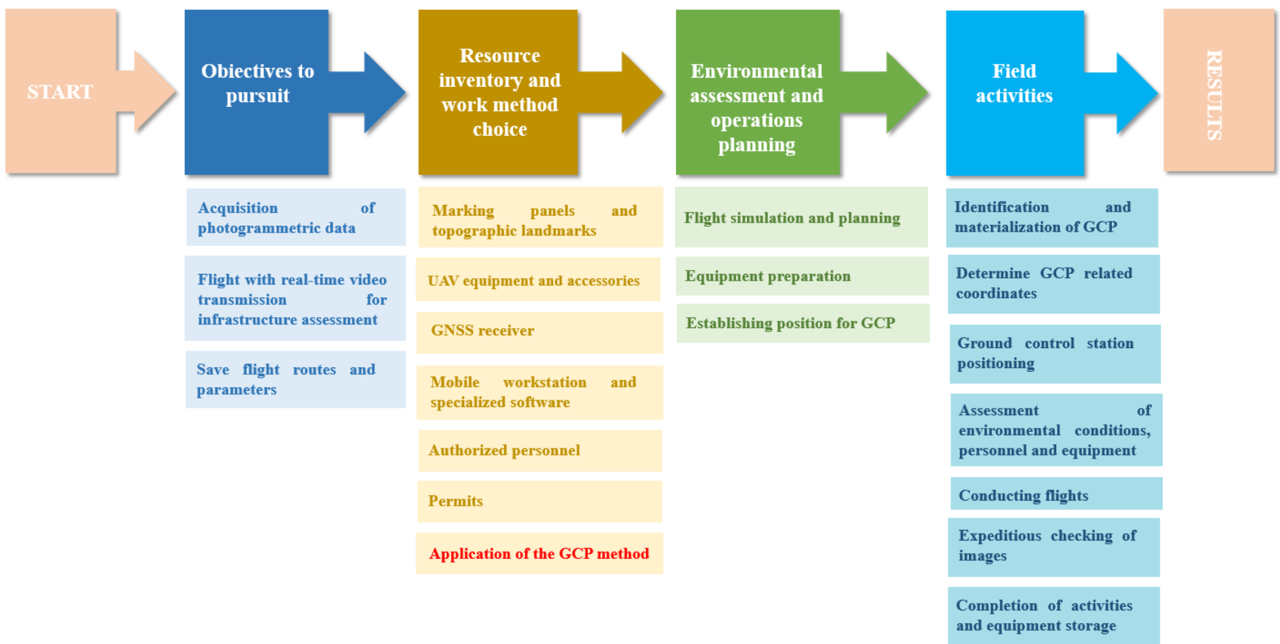


Figure 3. Suggested workflow

**Pursued objectives:** the proposed objective is to carry out a flight with a UAV-type equipment for the acquisition of photogrammetric data from the limestone quarry from Bistrița - Vâlcea. Data thus obtained will be included in photogrammetric processing to obtain specific digital products (orthophotoplan, digital model, point cloud). The following secondary objectives were also established: conducting a flight with real-time video transmission to assess the condition of the automated ore transport infrastructure (conveyor belt) and to memorize the parameters and flight routes for future use.
**Inventory of existing and required resources:** As a result of the preliminary assessment of the work area, it was found that the flights are to be conducted in a mountainous area with slopes and magnetic interference, which may affect the flight capability of the UAV. Thus, it was considered that the most suitable method that

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can be applied is the use of GCP [8, 10]. The use of this method requires: waypoints, terminals for the materialization of certain known coordinate points on the ground, UAV equipment and accessories, GNSS receiver, mobile workstation and specialized software, authorized personnel to conduct the flight, means of transport and permits necessary (from the operator of the operation and from the Romanian Civil Aeronautical Authority).

**Environmental assessment (office and field stage) and operations planning (office stage):** after securing the necessary resources (equipment, personnel) the operations planning was carried out. The main stages completed are:

- *Simulating and planning flights* in accordance with the technical capabilities of the equipment and observing the existing legislative restrictions (permits, prohibited areas, maximum flight ceiling). The main parameters of the planned flights are presented in table 2

Table 2. The main flight parameters

| Parameter | Values related to the flight | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Tracked ground resolution (cm) | 2.00 | | | | | |
| Degree of longitudinal overlap | 70% | | | | | |
| Degree of lateral overlap | 60% | | | | | |
| Camera position (sensor RGB) | 90° | | | | | |
| Area (ha) | ~28 | ~23 | ~31.5 | ~24 | ~4.5 | ~20.5 |
| Frame size (m) | 97 x 73 | | | -- | | |
| Flight path consisting of X points | 106 | 77 | 137 | 96 | 36 | 50 |
| Number of passes | 14 | 8 | 14 | 9 | 13 | 2 |
| Photo shutter | For each 21.89 m | | | -- | | |
| Estimated number of frames | 413 | 324 | 476 | 336 | 146 | -- |
| Estimated flight distance (km) | 7.9 | 6.1 | 8.7 | 6.3 | 2.9 | 4.2 |
| Estimated flight duration (min:sec) | 13:07 | 10:16 | 15:04 | 10:36 | 04:53 | 09:54 |
| Minimum altitude AMSL (m) | 631 | 718 | 807 | 706 | 591 | 598 |
| Maximum altitude AMSL (m) | 790 | 871 | 983 | 900 | 604 | 844 |
| Flight path with tracks | No | | Yes | | No | |

Figure 4 exemplifies the route related to the first planned flight, the flight profile and the main parameters for processing and determining the optimal route.

Figure 4. View of the planned flight route and flight profile

- *equipment preparation* (UAV, GNSS receiver, mobile workstation) in compliance with good practice rules: preparation of accumulators, firmware updates, equipment calibration, going through checklists.

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- *establishing the GCP position* in compliance with ground visibility requirements, their distribution and density.

**Field activities - photogrammetric flights:** have been planned in such a way that all conditions regarding work and personnel safety are observed and to reduce the time spent in the mining perimeter as much as possible.

Among the most important activities carried out, we mention: the identification and materialization of the GCP, the determination of the coordinates related to the GCP, the optimal positioning of the control station on the ground, the assessment of the environmental conditions/personnel/checking of the equipment in accordance with the "MEUH" [13] and "I'M SAFE" [12] good practice recommendations, actual flight performance, expeditious checking of frames, completion of activities and preparation of equipment for storage.

## 3. Results and discussions

### *3.1. Results*

As a result of conducting the case study, the main objective and one of the two secondary objectives were met. Table 3 summarizes the obtained results, in relation to the proposed objectives.

Table 3. Obtained results

| Objective | Details |
|---|---|
| *Main objective*<br><br>Acquisition of photogrammetric data in areas of interest | Objective achieved: 1249 frames related to the 6 flights completed were acquired.<br>(Originally estimated at 1695 frames) |
| | The inventory of coordinates related to ground control points (GCP) and check points (CP - Check Points) was obtained |
| *Secondary objective*<br><br>Conducting a real-time video transmission flight to assess the condition of the automated ore transport infrastructure (conveyor belt) | Objective not met due to existing terrain conditions (dense vegetation, lack of clearing) which could generate the collapse of the flight equipment. |
| *Secondary objective*<br><br>Saving the plan, parameters and flight routes for future use | Objective accomplished by saving flight plans. They were exported in XML format (including flight parameters), so that later flights can be repeated under the same technical conditions.<br>It should be noted that the flight plans which were actually used, and which include corrections and reconfigurations made in the field, have been saved. |

### *3.2. Discussions*

Due to similar projects in the past, the team members have experience in performing photogrammetric flights, but the present case study generated new challenges. The particularities regarding the area of action, the terrain profile and the specifics of the mining activity in a surface quarry generated difficult conditions for carrying out activities in the field. Next, we bring to your attention certain aspects of a technical and practical nature, as follows:

- Staff safety: access to the location was achieved with difficulty because the access roads were affected by precipitation, as can be seen in figure 5. A1 and A2; one of the access roads to the mine was completely blocked by the dislocation of the rocks from the upper slope, as can be seen in figure 5.B. Given the conditions in the field it was necessary to reposition the ground control station and reconfigure the flight plans.
- It is recommended to use personal protective equipment (helmet, reflective vest, boots) during the entire time spent in the mining perimeter;
- Due to the unstable terrain and especially during periods of heavy rainfall, marking points on the ground and determining the related coordinates is difficult. Thus, it is recommended to use smart panels that can be permanently positioned and used for long periods of time.

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Figure 5. A1 and A2 Access roads affected by precipitation; B. Access Road blocked by dislodged rocks from the slope

- In the area of interest, strong electromagnetic interference caused by the existing electrical network and transformers was encountered, with a direct impact on the possibilities of safe use of UAV-type equipment. Figure 6 shows elements generating electromagnetic interference. Thus, the repositioning of the control station, the recalibration of the UAV and the reconfiguration of the flight plans were required.


Figure 6. Factors generating electromagnetic interference

- Even though the UAV type equipment used is equipped with sensors to detect obstacles, a crash occurred during the autonomous flight caused by existing vegetation and certain limitations of the software used. The crash caused damage to two propellers, but after they were replaced, the flight was able to continue. Therefore, the following is recommended:
    - the existence of spare parts and accessories, which can be quickly replaced, which leads to the continuation of planned activities;
    - the use of software products that have proven their effectiveness and that have been practically validated in mining perimeter activities.
- In various good practice guides, it is recommended to optimize flight routes by positioning the flight direction parallel to the long side of the surface of interest, with the aim of reducing energy consumption and increasing flight autonomy. However, in the case study we observed that the terrain profile (flight profile) has a significant influence on the estimation of flight times. The limitations of the vertical movement speed (climbing, descending) of the drone generate delay times, so in the case of rough terrain we recommend optimizing the flight routes according to the terrain profile.
- UAV-type equipment has limitations regarding the maximum number of waypoints that can be loaded into memory. A large number of intermediate points better reflects the terrain profile and reduces the risk of the drone crashing. Thus, for flights made in areas with large differences in altitude, it is recommended to use as many intermediate points as possible on the flight route.

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- The flight routes were planned so that the flight time did not exceed 55% of the capacity declared by the manufacturer. This approach was based on three aspects:
    - the technical data presented by the manufacturer are obtained in laboratory conditions, completely different from field flight conditions;
    - the batteries we used have already had a certain degree of wear, so it is possible to lose the charging capacity;
    - flights are carried out in a mountainous area with vertical slopes, which can generate air currents that affect the drone’s flight range.
- As shown in figure 7, obstacles have been identified in the flight area that cannot be identified by the sensors equipped with the drone (especially at high flight speeds) and that can cause it to crash. It is recommended to plan the flight at an altitude that ensures the avoidance of such obstacles.

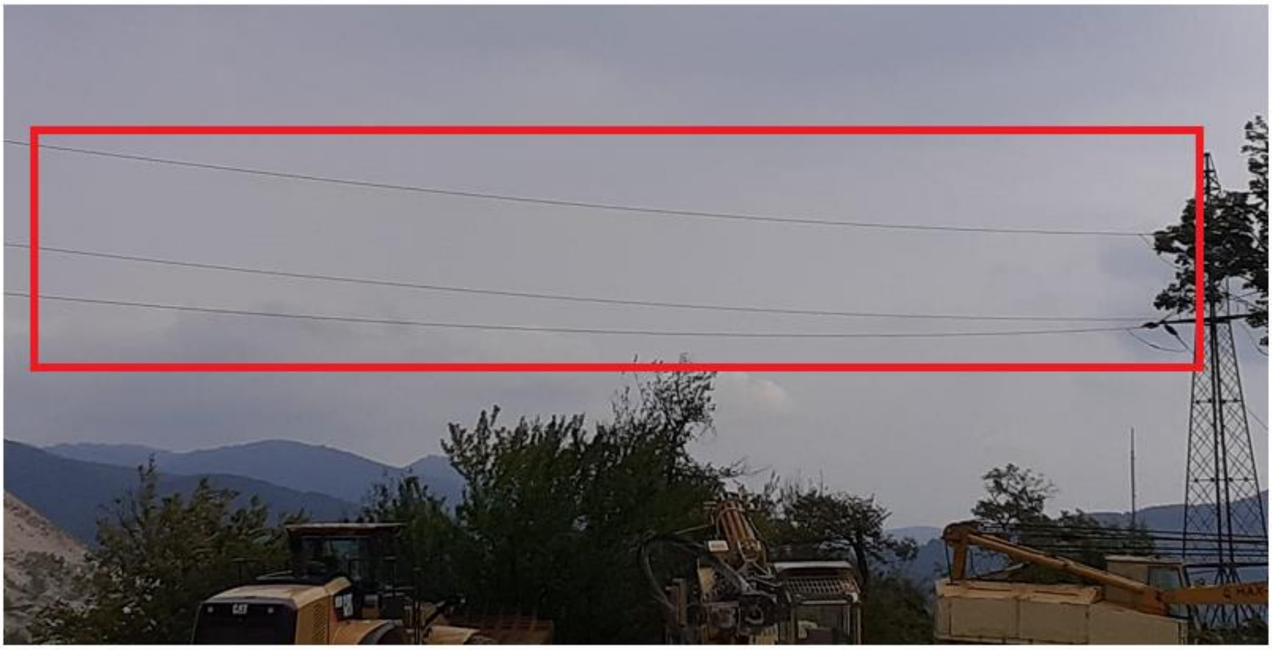

Figure 7. Obstacles difficult to detect - electrical network

- Due to electromagnetic interference and the existing terrain, when performing flights, the drone followed the flight path beyond the existing slope, which caused disconnection from the radio control and automatic return to the take-off point, according to the initial settings. It is recommended that special attention be paid to both flight planning and emergency or incident settings.
- Considering the level of development of the existing vegetation and the reduced level of visibility on the ground, the flight could not be carried out to inspect the ore transport infrastructure. Figure 8 shows the existing conditions in the field. It is recommended that in the planning stage of the activities, the level of vegetation development should also be evaluated, and the data acquisition flights should be planned accordingly. There are also possibilities of deforestation in the areas of interest, but these operations require significant costs and efforts.
- In mountain mining operations, the terrain profile and the surfaces to be covered during a photogrammetric flight make VLOS (Visual Line of Sight) flight impossible, so it is necessary to involve observers with whom the pilot will be in permanent contact during the flight. In this way, EVLOS (Extended Visual Line of Sight) or BVLOS (Beyond Visual Line of Sight) flights can be carried out in compliance with legislative limitations. For BVLOS flights, the pilot can use VR glasses or ground stations to track and direct the flight, but only if there are observers who are in permanent visual contact with the drone and in radio contact with the pilot.
- During the expeditious check, the project team only checked the number of purchased frames and the resolution obtained. In the post-processing stage, it was found that there is an area not covered by the photogrammetric flights, so a new trip to the field was necessary to perform an additional photogrammetric flight. It is recommended that during the expeditious verification of the data, the layout of the frames should also be checked, so that possible inconsistencies can be identified and corrected immediately.

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Figure 8. Vegetation obstructing ground visibility

## 4. Conclusions

Through the conducted case study, the utility and opportunity of applying photogrammetric methods using drones in surface mining operations is demonstrated. So, it can be concluded that the use of drones for the acquisition of photogrammetric data in mining can bring both economic and technical benefits, meeting the expected quality and accuracy requirements.

Even if flights and photogrammetric methods are successfully applied in other fields of activity, the present case study highlights the peculiarities, advantages and disadvantages specific to the mining field, especially in mining operations in the mountain area.

By carrying out the case study, the project team validated the applied methodology, detailed the office and field activities and established the minimum resources required to carry out a photogrammetric flight. At the same time, as a result of the practical activities, the project team identified and highlighted specific aspects of surface mining operations in the mountain area and issued concrete recommendations that have the role of facilitating the success of projects carried out in similar conditions.

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