APPLICATION OF REMOTE SENSING TECHNIQUES IN THE COLLECTION OF TERRAIN DATA IN THE MOUNTAIN AREA

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Abstract

Interdisciplinary research in the mountain area is based on the shape of the land surface. This, in order to be taken into account, must be transformed into a quantitative element, thus resulting in the numerical models of the land, with variations over time and in different postures. These numerical models can be realized depending on the nature of the study, through different technical means. Current techniques allow and facilitate the creation of multitemporal databases. These data obtained from the field represent the support for the construction of digital elevation models.

The methodology focuses on creating a database, in a three-dimensional perspective, by means of the UAV (Unmanned Aerial Vehicle), droning, and the available remote sensing means. Thus, through satellite or photogrammetric images, watersheds and sediment accumulation areas can be delimited based on the spatial arrangement of pixels; also can be analyzed the specifics of the vegetation, the way of use and coverage of the land in an area, or the geomorphological evolution of some points of interest by making temporal differences.

The study area given as an example is one with mountain specifics, within the hydrographic basin of the Bistricioara River, in the Eastern Carpathians. Here three control areas were chosen. The results consist in the digitization of real features in the field, in the form of indicators or 3D numerical models on the OXYZ axes. These types of investigations can be repeated at well-established time intervals and can mark the evolutionary differences within the studied areas.

Keywords: UAV, Bistricioara basin, remote sensing, DEM, satellite images, Landsat, Sentinel, supervised classification, mountain area.

INTRODUCTION

Remote sensing represents, science and technology of obtaining information about objects and the environment, through processes of recordings, measuring and interpreting images and numerical records of energy patterns obtained with sensors that are not in direct contact with them (Bergen et al., 2000).

This method of data collection and analysis in order to create a database, denotes a particularly high degree of accessibility of information with a geographical aspect in the mountain area, from different plans and with a vast coverage area.

In the mountain area as a whole, remote sensing can generate the substrate of complex studies. In this way, climate change can be detected; the impact and increase of greenhouse gas concentrations, CO2 emissions, carbon balance, and significant reduction of carbon emissions can also be addressed. In this way, the energy balance in social and environmental systems can also be analyzed.

Also, remote sensing can have an important role in ecological and environmental researches. This may include biodiversity, ecosystem dynamics, land degradation, air and water pollution, residential footprint, ecosystem management and natural hazards (eg earth-quakes, floods, landslides, etc.).

For the mountain area, an important role is given by the possibility of preparing studies regarding natural resources. This may include land use in general, biomass estimation, forests, agricultural land, plantations, soils, and water resources (Wehr, 1999).

Remote sensing favors quantitative and qualitative analyses, when "cloud screening" techniques and atmospheric corrections for mountain regions are correctly applied. In this case, cloudiness plays an important role in the resolution and clarity of satellite images.

In order for the results to be as consistent as possible, Baltsavias (1999) correlated numerous parameters at the base of the detection process and found that optimal information acquisition is achieved when the following conditions are met: the detector must have a wide response on the wavelengths to be detected, a value as low as possible of disturbing factors (generated by the system), and above all obtain the best possible response time, without large fluctuations.

These conditions are difficult to meet at the level of extended surfaces but easy to implement at the level of small surfaces, by means of UAV (Unmanned Aerial Vehicle), for which the response distance is very reduced.

A similar approach was proposed by Lane et al. (2010) who show that new image analysis techniques offer the possibility to generate DEMs from aerial images (especially for geomorphological studies).

At the same time, Kucharczyk and Hugenholtz (2021), provide a critical analysis of remote sensing based on drones and UAVs in studies related to natural risks and disasters, for which the trend of use has increased significantly in recent years.

In the case of landslide and flood forecasting, Sze et al. (2015), created a digital elevation model, needed in hydrological analyses, resource management, and environmental assessment. The model created by Sze et al. (2015) can also be used in InSAR (Interferometry Synthetic Aperture Radar) applications, thus monitoring land deformations through remote sensing (satellite images and photogrammetric DEMs).

In the particular situation of mountainous areas, the presence of areas with extractive activities is a significant problem, since erosion processes are the main problems affecting the restored surfaces due to the frequently steep slopes and the difficulties of re-vegetating the technosols built with mining waste (Carabassa et al., 2021). This type of research proposes to develop a possible determination of soil loss due to water erosion in mine-restored areas, by using G.I.S. and remote sensing instruments (R.S.).

The objectives of the work consist in making demonstrations of three-dimensional models for the mountain area, by means of the images taken with the UAV. These were taken at different time intervals to be able to track the differences between them. In this way, the observation of the evolutionary trends of the relief from the perspective of erosion or accumulation was pursued, by defining some quantifiable values.

Another objective consists in mapping the types of vegetation that cover and constitute the habitats specific to the mountain area.

MATERIALS AND METHODS

Study area. In this work, digital elevation models of the terrain within the Bistricioara Basin, in the Eastern Carpathians, were developed. This is how the downstream side, near the Bistricioara hydrometric station, was modeled.

This area is subject to the most important changes due to the increased input of sediments and implicitly a significantly higher flow discharge, being close to the confluence with the Izvorul Muntelui Lake.

It is drained by the main river Bistricioara, which springs from the southeastern side of the Călimani Mountains, the basin is subordinate to the Bistrița Basin and occupies 11.1% of its total of 7042 km2 (respectively 781 km2).

The DEMs were located at 8 key points with slopes below the average of 16 degrees and no anthropogenic interventions at bed level and in low elevation areas below 600 m elevation. Within the basin, there is an altitudinal interval of 480 and 1745 m maximum altitude (Figure 1).

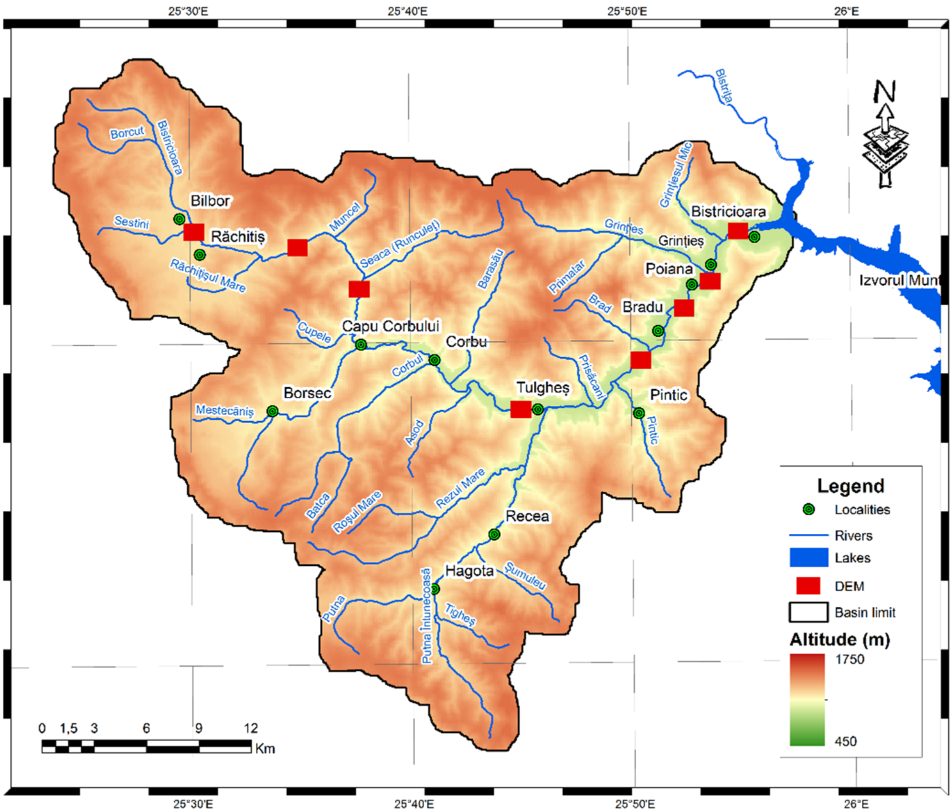

Fig. 1. Study area

The images were taken with the help of drones and processed using the "Structure from Motion (SfM)" method; a modern method of digitizing terrain altitude data and implicitly outlining three-dimensional models of the terrain.

UAVs can be successfully used in geomorphological studies, due to the fact that they present sufficient precision to highlight local phenomena that can generate changes in the relief and indicate the dynamics of the geomorphological process. The methodology involves the use of control points, the acquisition by GPS of elevations, and calibration, to optimize the monitoring process.

It is important that the spatial resolution must be adapted to the size of the study area, for which too low a resolution can affect the quality of the results. In the present case, due to the vegetation, it was necessary to apply some filters to the point cloud, which was sorted and georeferenced according to the control points.

This cloud of points is the basis for the formation of a three-dimensional terrain model (photogrammetric DEM). SfM is a technique of topographic expertise resulting from technological advances in the field of computers but in close complementarity with traditional photogrammetry.

The drone used is the DJI Phantom 4, with the ActiveTrack function, a command that facilitates the flight and implicitly the control of the UAV. Also, the "Camera and Gimbal" system offers an increased degree of stabilization of the captured images, at 30 frames per second and with a 12-megapixel sensor (DJI Phantom 4 User Manual, 2017) and presents the following systems for establishing the level of clarity, which finally materializes in a spatial resolution below 2 cm/pixel (Figure 2).

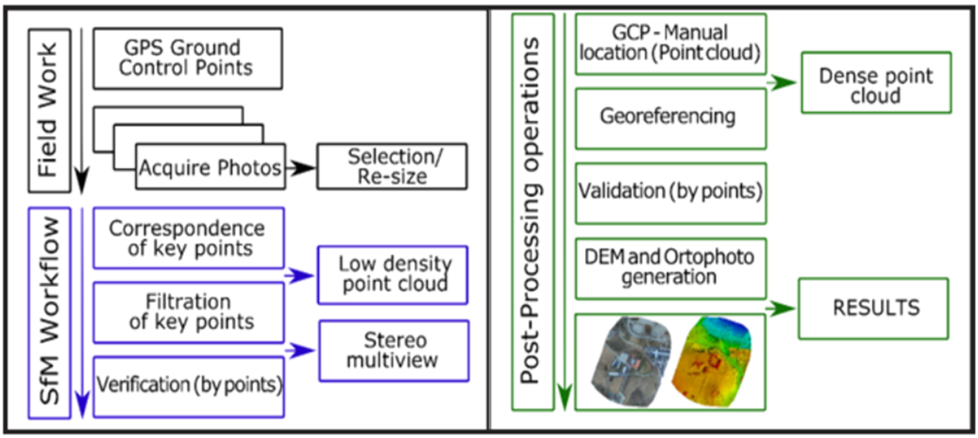

Figure 2. The process of making a Digital Elevation Model

The images taken belong to the Landsat 8 satellite, for which a percentage of cloud cover of less than 10% was established, with filtering operations and automated radiometric corrections applied using the SNAP software, a product of the European Space Agency (ESA, 2022). In this way, an optimal degree of processing was achieved for studies in the mountain area; where high cloud cover often has a significant frequency. Subsequently, the processes of digitization and separation of vegetation classes were carried out in ArcMap 10.6 (Esri ArcGIS).

Supervised classification was used and is based on a priori knowledge of the surface features of a portion of the image and using them as deciding factors in determining the properties of the other portions. Pattern detection is a complex operation and is more important than choosing a specific classification algorithm.

Test areas are derived from measurements and do not exceed 1% of the total image area. In order for the goal to be achieved, complex measurements and the exact knowledge of the features in the field are required in order to establish the classes by this semi-automatic method (Figure 3).

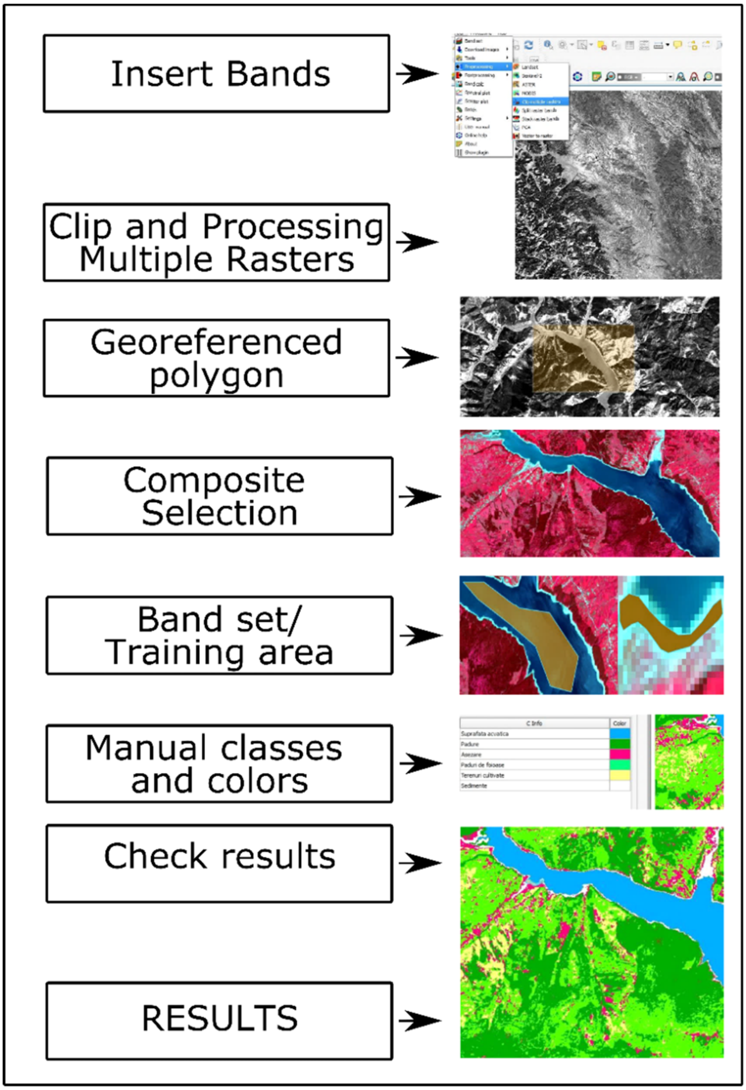

Figure 3. Realization of supervised classification

An important aspect of geomorphological research is the quantitative monitoring of the Earth's surface, in different stations and in diversified environments, at a spatial and temporal scale modified according to the nature of the study.

Current techniques allow and facilitate the creation of multitemporal databases with data acquired from the field and which represent the support for the construction of digital elevation models (DEMs – Digital Elevation Models).

The technique of producing a difference between DEMs (DoD – DEM of Difference) involves a quantification of volumetric changes within the studied area (Wiliams, 2012).

Following observations made with technical means (drone, GPS), the data are transformed into digital and systematic information (Figure 4).

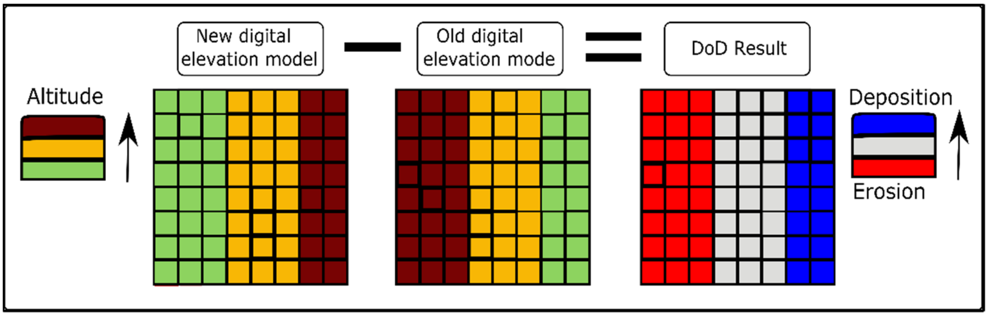

Figure 4. Schematic of the DoD concept

This implies the possibility of extending the analysis period by obtaining new models at well-established time intervals, and at the same time with much better resolution in the areas of interest; with visible changes in addition to the historical information previously held.

The popularity of using digital elevation models (DEMs) to obtain proxy environmental variables has increased over the past decade, especially since DEMs are relatively inexpensively acquired at very high resolutions (VHR; <1 m spatial resolution) (Guillaume et al. , 2021).

RESULTS AND DISCUSSIONS

A key aspect of geomorphological research in the mountain area is given by the quantitative monitoring of the development of the land surface, respectively of the local relief. This process occurs in a diverse natural environment and is observed at constant time intervals.

The current geomatics technology favors the acquisition of data from the ground through multi-temporal surveys with the help of the drone and which materialize in numerical models of the land at a resolution of centimeters (per pixel).

At the time of error elimination, effective methods of calibration of work tools (UAV, GPS) will be used and DEMs will be generated for each previously established time interval.

The results represent a serious alternative for obtaining data from the field, mapping points of interest, and the possibility of comparing them thanks to the mathematical background behind each DEM.

In this case, taken as an example, the topographic surveys and flights with the DJI Phantom 4 drone were carried out over a period of 4 years, during which countless changes occurred at the level of the riverbed.

Most of the changes occur due to the increases in the flow rates of the Bistricioara river, but mostly due to major floods. Thus, the evolution phenomenon of the river bed can be observed. It was accentuated by the anthropogenic activities of bed regularization, deposits of anthropogenic origin, excavations for construction materials (sands and gravels), etc.

Figure 5. Realization of DEMs for the reference (for example) interval 2018–2022 (Bistricioara–Putna Confluence)

Confluences represent areas where major changes occur in short time intervals. Sedimentation and erosion phenomena are recurrent in these dynamic areas from a geomorphological perspective.

In the case of the confluence between Putna and Bistricioara (Figure 5.), a slight change in the level of sediments is observed; a part (of the sediments) is re-included in the hydrographic circuit during floods when the flow is exceeded at bankfull discharge. Also here, the results indicate an incision at the level of the riverbed, with a tendency of up to 25–50 cm. This is a general character valid in the upstream area, where the riverbed deepens.

The amount of deposited sediments decreases and the only areas where there is a positive difference in relief in 2022 compared to 2018, occur in urban areas or through anthropogenic deposits and excavated construction materials.

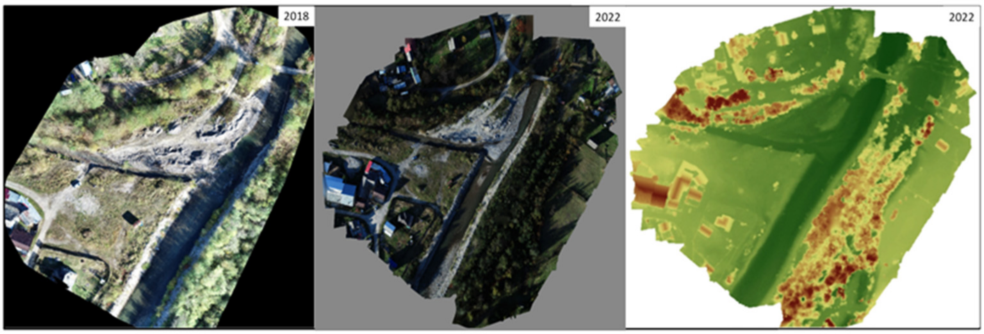

Figure 6. Realization of DEMs for the reference interval 2018–2022 (Bistricioara–Grințieșul Mare confluence)

The confluence between Grintiesul Mare and Bistricioara (Figure 6) takes place downstream, a few kilometers from the discharge area into Lake Izvorul Muntelui. In this area, the bed is in relative balance, between aggradation and incision. Significant sediment deposition occurs close to the output, where we are talking about a aggradation of up to 15–20 cm in the 2018–2022 interval. In this case, can be observed that the erosion phenomenon dominates, the deposits are not only of anthropogenic nature (sands and gravels) but also natural. Sediment deposits, especially lateral ones are significant at the level of the minor riverbed. (Figure 7).

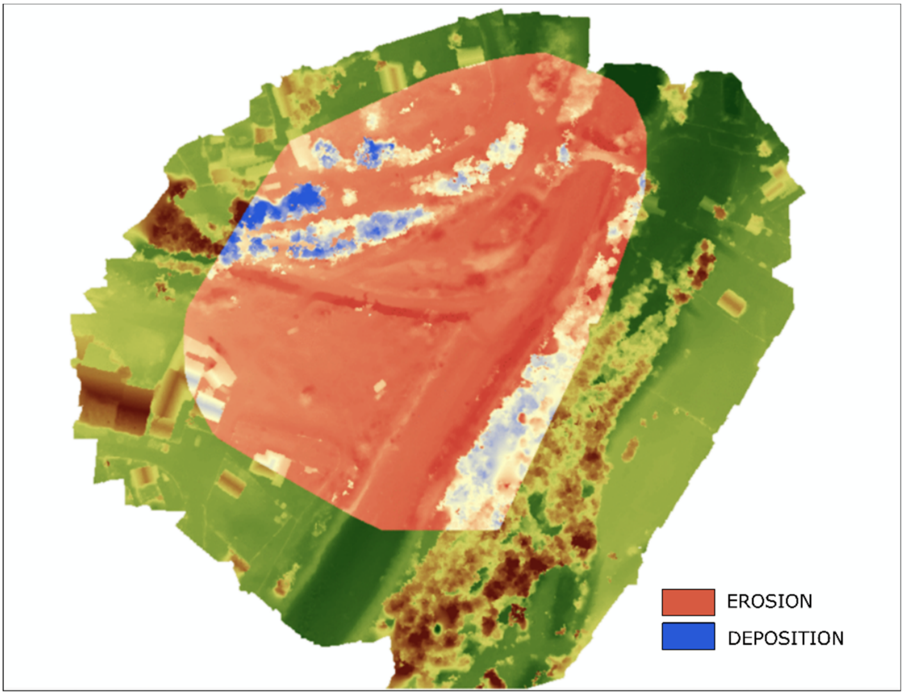

Figure 7. DoD achievement for the reference interval 2018–2022 (Bistricioara–Grințieșul Mare confluence)

The DoD method captures in this way significant differences at the level of a short time interval (4 years). This is a period when geomorphological impact processes can be determined following large-scale natural events.

For the studied period of time, there were no high flow discharge rates, or increases in flood frequencies. The maximum recorded values of the river discharge, do not exceed the threshold of 40–50 m3/s (Stoilov et al, 2020). This fact noted by us implies a reduced dynamics on the local geomorphology.

We can thus say that satellite images have diverse roles in what determines the subject of each study. In this way, supervised classification can be oriented in complex shapes and used both on the basis of a natural color composite; as well as on the background of the processed images (obtained by calculating indicators such as normalized difference vegetation index (NDVI) or other individually calculated indicators) (Negrea et al., 2022). In this case, based on the real color composite, corroborated with field data validation, 7 main classes were determined: built-up area, cultivated land, grassland, broad leaved forest, coniferous forest, sediments, and water body (Figure 8). In the case of these groupings, it was also possible to define some subcategories as well as the absolute total values.

For these, satellite images can be retrieved at different time intervals and analyzes can be developed on land use and land cover themes. It is possible to analyze the expansion of living areas, the dynamics of the hydrographic network, and the level of clogging of Lake Izvorul Muntelui or even the monitoring of certain types of vegetation.

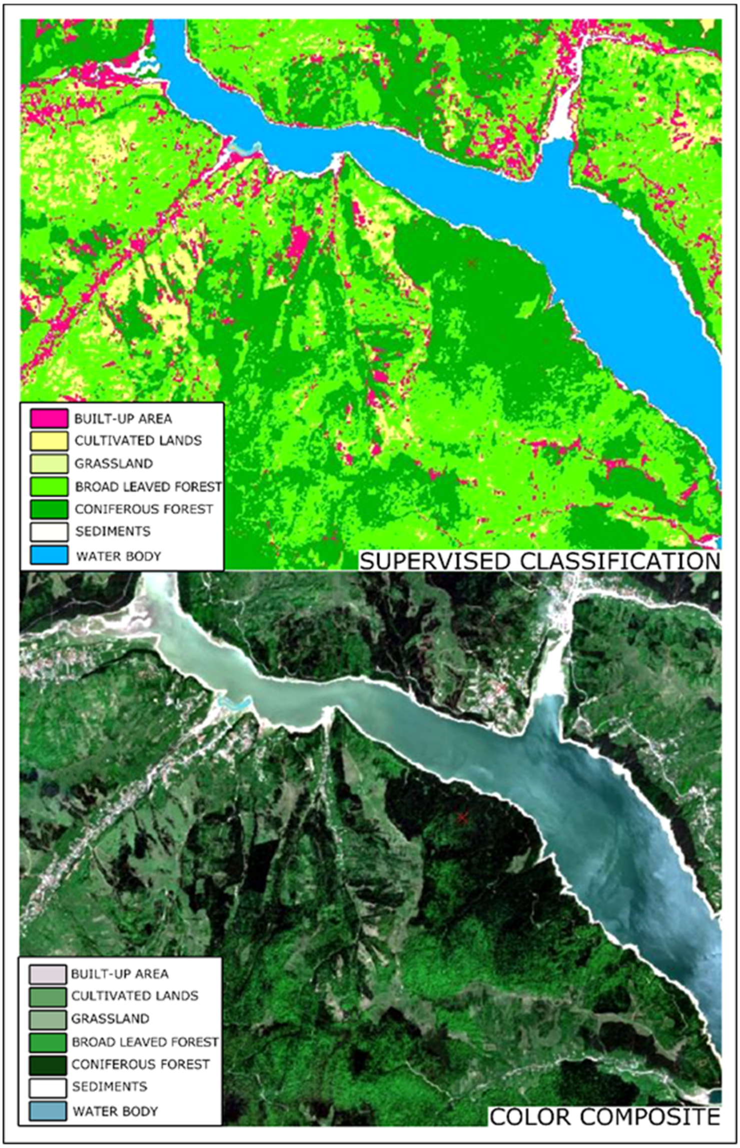

Figure 8. The process of making a Digital Elevation Model

CONCLUSION

This paper captures the ability of UAVs and satellite imagery to be used as alternative mountain data collection technologies by applying simple principles of photogrammetry and remote sensing.

Their application in a geomatic form is realized in a digital elevation model (DEM) or in satellite images (natural color composite or false color composite) with a special resolution.

The results can be used for various studies, their nature also defines the indicators that can be calculated according to the proposed objectives (NDVI, GRVI). An important factor is the selection of the study area from the perspective of the working surface and the degree of coverage with vegetation or anthropogenic elements as in our examples. Compared to other classic ways of obtaining data through remote sensing, these methods significantly reduce the costs of data collection and operation while minimizing risks in hard-to-reach areas.

The three-dimensional data has a centrimetric accuracy, while the quality of the UAV means can result in an increase in accuracy and a reduction in processing time. For areas with wide extensions, satellite data can be used, which, however, sometimes provides a high degree of generalization. The quantifiable character behind these data obtained by photogrammetry can be the basis of comparative analyzes for various points of interest in the mountain area.

The described methodology is based on the technique of using a drone (UAV) to capture images and process them in order to obtain a numerical model. This model has a much better resolution compared to a photogrammetric model, available at a resolution of 5 m, compared to a result of 2 cm by using the drone.

Their preparation implies the chance to extend the analysis over a long period, at well-stable time intervals, for the areas of interest compared to the existing historical data.

The applicability of the method is given by the "Difference of DEMs" technique, which provides a perspective on the interaction between relief forms and dynamic processes in the area. The reliability of the method is provided by the level of accuracy along with the density of the survey points.

The application of remote sensing techniques (as in or examples) in mountain areas is an important step towards the realization of a generous mountain geographic database. This can facilitate various study methods in a vast territory, such as mountainous one, where the accessibility presents major difficulties due to the morphology of the relief.

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This article reflected the work and unjustly broken aspirations in the last months of life of our colleague and friend Stoilov-Linu Valeriu †. May the post mortem publication of this material remind us all of the fragility of life in all its forms. Rest in peace!

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