COMPARATIVE ANALYSIS OF GEODETIC SURVEYS FOR VOLUME DETERMINATION

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Abstract: *The purpose of this article is to present the results of using three geodetic instruments: the Spectra SP8 GNSS receiver, the Leica FlexLine TS06plus total station, and the Leica BLK360 terrestrial laser scanner, applied to the same project, which involves determining the volume of the highest mound in the 'Suta de Movile' landscape reserve in the Republic of Moldova. The time required for data collection, processing, the number of people involved, and the calculation of the resulting volume are just some of the criteria analyzed to determine the most efficient geodetic instrument for such work. Each geodetic instrument offers its own set of advantages and disadvantages, and the decision on which method to use depends on the specific project requirements, processing principles, accuracy and cost.*

Keywords: *mound; GNSS; total station; TLS; digital model; surveying; volume determination*

1. Introduction

The determination of volumes using geodetic methods plays an essential role in a wide range of fields, including construction, mining, urban planning, agriculture, environmental protection, hydrology, and transport infrastructure, due to its ability to provide precise and efficient measurements for the planning, monitoring, and optimization of various projects.

The best method to use depends on the specific project conditions where the volume is to be determined, and on the measurement information available. The engineer must analyze the situation and select the method that will yield the most accurate results in the shortest time. [1]

Currently, there are various geodetic instruments that can be used to collect data on the point cloud for measuring the volume of the object. Recently, the most common instruments used for earthworks are the total station, GNSS receivers, unmanned aerial vehicles (UAV), and terrestrial laser scanners. These are all electronic measurement systems used for monitoring ongoing projects on-site. Each of the methods of survey have their independent limits and setbacks to the accuracy of measurement taken. [2]

This paper will focus on determining the digital terrain model (DTM) using three geodetic instruments (total station, GNSS receiver, and terrestrial laser scanner) and highlighting which of these generates a better 3D modeling. Therefore, after generating the

DTM, the goal is to calculate the volume of the object and perform comparative analyses based on certain criteria, to determine the most efficient geodetic instrument for such works.

2. Materials and methods

2.1. Study Area

This study was conducted at the „Suta de Movile” landscape reserve, located on the slope of the Prut Valley, southeast of the villages of Branişte and Avrămeni in the Râşcani district. (fig. 1). „Suta de Movile” measures 8 km in length and has a width ranging from 2.3 to 1.7 km, with its uniqueness defined by the abundance of microrelief – over 3,500 mounds, mostly elongated and prominent, with steep slopes and heights ranging from 1-3 m to approximately 30 m. [3]. The study was conducted on the highest mound, namely „Movila Ţiganului”, which reaches an approximate height of 16 m and is located one kilometer from the Prut River and 500 meters from the borders of the village of Avrămeni. It is considered the largest mound in the reserve and the most visited. (fig. 1).

Fig.1. The Location of ,,Movila Ţiganului”

2.2. Data collection

In order to conduct a comparative analysis of the most efficient geodetic instrument for determining the volume of „Movila Ţiganului” the Spectra SP85 GNSS receiver, the Leica FlexLine TS06plus total station, and the Leica BLK360 terrestrial laser scanner were used for data collection in the field.

In the study area, a support point from the National Geodetic Network (RGN) [4] was identified, located right at the foot of the mound. This point is connected to the survey network, whose points will serve as starting and verification references for all stages of work (Fig. 2).

The work process began with the setup of the Spectra SP85 GNSS receiver, connected to the MOLDPOS network of permanent stations, ensuring a stable signal and a measurement accuracy of 8 mm + 1 ppm in RTK mode. On the perimeter of the work area „Movila Ţiganului”, the survey network was prepared for the future station points, namely points 1001, 1002, and 1003, arranged to provide a good angle of opening and visibility between them (Fig. 2). When capturing the characteristic points of the mound, emphasis was placed on having the points closer together to achieve higher accuracy, while also considering the relief shape of the mound. In areas with more varied relief, a maximum number of points was recorded. Point capture began from the top of the mound (the highest recorded point) and then rotated around the mound from top to bottom in stages, totaling 994 points, which will later represent the structure of the mound."

Fig.2. Land work - GNSS measurements

Following the GNSS receiver measurements, unprocessed data were obtained, which can be used to represent the point cloud location in the field for visualization and verification. This process was carried out using Google Earth Pro software (Fig. 3).

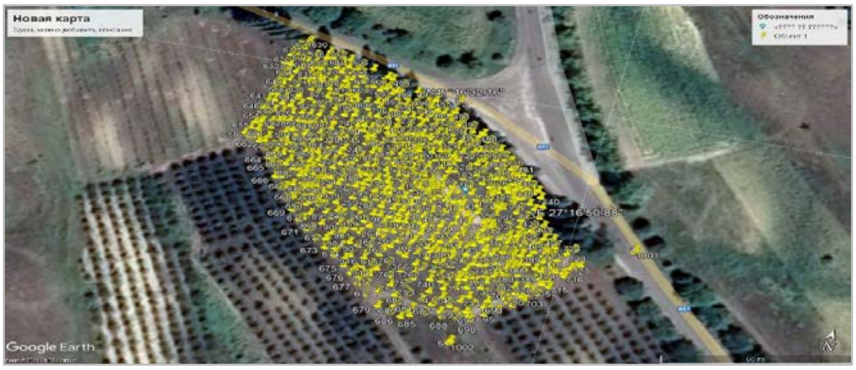

Fig.3. Points imported into Google Earth Pro

After completing the measurements with the GNSS receiver, the data collection phase for the same object (Movila Ţiganului) began using the Leica FlexLine TS06plus total station. The measurement process with the total station started directly with the setup at the first survey point, which was the RGN control point (Fig. 2). This point was verified using the GNSS receiver according to the data from the national thematic geoportal *geodata.gov.md*, where it is listed as point 1001 in this survey.

The total station was set up at each known survey point, determining orientations to these points, starting with point 1001, then 1002, and finally 1003. Just like with the GNSS receiver measurements, the points were collected as close to each other as possible to more accurately represent the structure of the mound, considering every relief variation. This process involved two specialists: the engineer operating the total station from the survey point and the specialist traversing the entire work area with the prism to capture all the necessary points (Fig. 4).

Fig.4. Land work -total station data acquisition

After completing the measurements with the total station, the position of the points in the field can be checked using Google Earth Pro, once the collected data have been exported from the instrument and processed in specialized software.

The third stage of work in the area of interest involves detailed scanning using the Leica BLK360 terrestrial laser scanner. To achieve this objective, it is essential to install orientation markers around the perimeter of „Movila Țiganului” (Fig. 5). These markers must be positioned so that they are visible from each scanning station. During the data processing phase using the specialized software Cyclone REGISTER 360 [5], the orientation markers will serve as reference points for accurate orientation and proper scaling of the resulting point cloud.

It is important that the orientation markers are firmly fixed to the selected surfaces to prevent any accidental displacement caused by external factors, such as wind or vibrations from passing vehicles. The stability of the markers is crucial to ensure the accuracy of the scanned data. After fixing the markers, the next step is to carry out measurements with the total station aimed at the orientation markers to obtain the exact spatial coordinates of each marker (Fig. 5). With the existing survey network around the mound already closed, it will be used as a reference base for the precise measurement of each marker, thus ensuring the accuracy of the spatial data required for the scanning process.

Fig.5. Fixing and measuring the orientation markers

After completing the necessary preparations for the work area, the scanning procedure can be initiated. The Leica BLK360 laser scanner allows for efficient coordination of the scanning process directly from the Cyclone Field 360 application, ensuring easy data management. Scanning can begin by setting the proposed parameters, and depending on the selected settings on the screen, the time required for scanning from a single station will vary Once the project includes two or more scanning points, it is necessary to link them together. Here, there is the possibility to move the stations horizontally and vertically, and to view either a single station or all stations simultaneously.

The collected data obtained from the scanning process require corrections in the Cyclone FIELD 360 application [5], after post-processing in the Cyclone REGISTER 360 software. This work stage is performed on the provided iPad. Once the station points have been adjusted, a precision assessment of the results is conducted, which can be analyzed by creating a coverage report of the scanned object using the point cloud. The data can be viewed in 2D, panoramic, or 3D format (Fig. 6).

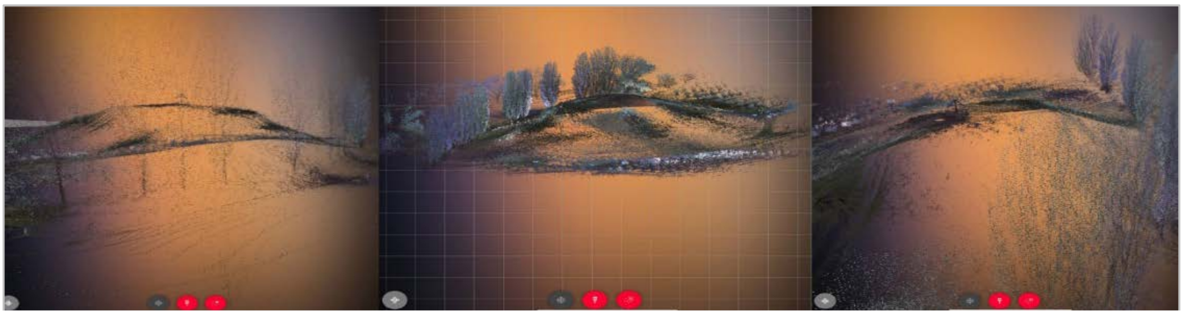

Fig.6. 3D visualization of the mound

2.3. Data processing

In processing the data collected using the GNSS receiver Spectra SP85, the Leica FlexLine TS06plus total station, and the Leica BLK360 terrestrial laser scanner, three software programs will be involved: GeoniCS, Autodesk Revit, and Leica Geosystems. GeoniCS is a specialized geodetic software developed for use in civil engineering, surveying, and geodesy applications. It is usually an add-on for AutoCAD, meaning it functions as a set of additional tools integrated into the AutoCAD platform, providing advanced features for processing and analyzing geodetic data. [6]

Autodesk Revit [7] software allows us to model shapes, structures, and systems in 3D with parametric precision and ease. This software can import topographic data, generate terrain models, add contour lines, and identify areas of interest.

Leica Geosystems software [5] is used in terrestrial laser scanning for capturing and processing 3D data and is essential for projects involving land monitoring, landslides, or structural deformations.

For the case study, all geodetic points collected from the field using the Spectra SP85 GNSS receiver were imported and processed in GeoniCS software. After processing the data, the topographic plan of the „Movila Țiganului” area was obtained, and then by generating contour lines, the digital terrain model (DTM) was developed in an irregular triangular network (TIN) (Fig. 7). The MOLDREF99 national coordinate system [8] was used as the reference system for data processing in GeoniCS software.

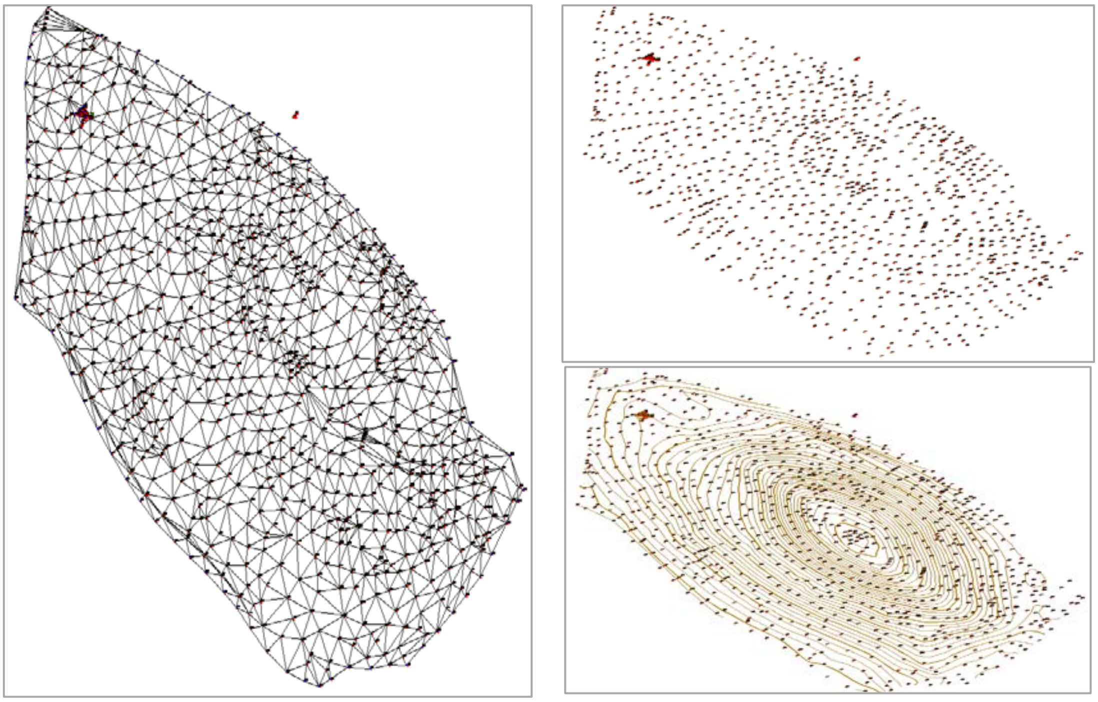

Fig.7. Processing of data collected with the GNSS receiver in GeoniCS

After completing the process of generating and editing the terrain, the final product is obtained. The next step is to process the data in Autodesk Revit to create the 3D model of the object and determine the volume of the mound. The digital model of the mound from GeoniCS is imported into Revit, maintaining the real measurement units of the 3D model. We then create the solid model of the mound in Revit, which allows us to model the terrain shapes and subsequently determine the volume. To accurately calculate the volume of „Movila Țiganului” and delineate the area, additional volumes were excluded. In this case, the reference was initially set to the contour with an elevation of 101.00 m and finalized with the highest elevation of 114.00 m.

After excluding the additional volume area, the 3D model of the mound was obtained with surfaces automatically calculated by Revit software. In Fig. 8, we can view the model of „Movila Țiganului” from different sections and the calculated volume results, where the volume is observed to be 22,368.575 m³.

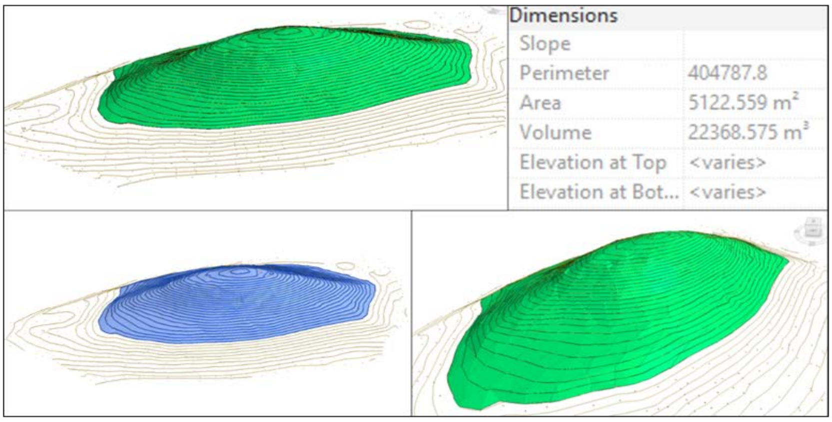

Fig.8. Final volume calculation result from measurements with the GNSS receiver Spectra SP85

For processing the data collected with the Leica FlexLine TS06plus total station and obtaining the final product, the same stages are followed as with the GNSS receiver data collection. Initially, all data collected with the total station will be processed, then imported into GeoniCS software to create the topographic plan. An essential step in the topographic survey is the representation of the terrain, to understand the structure of „Movila Țiganului” and any deformations it may have. This involves creating the digital terrain model (DTM), which is composed of a series of triangular faces constructed on points with three-dimensional coordinates X, Y, Z. These form the triangulation network TIN, as shown in Fig. 9.

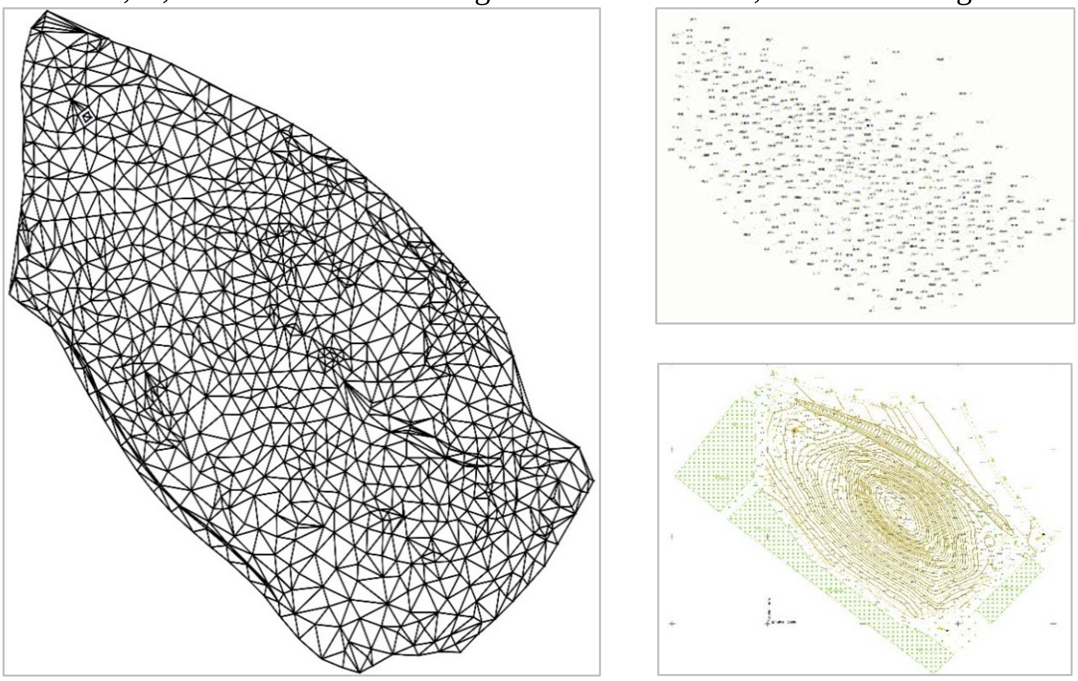

Fig.9. Processing of data collected with the total station in GeoniCS

After finalizing the topographic plan, we can proceed directly to the volume calculation process using Revit software. In the 3D processing software, not all topographic points will be used, only the points with the lowest elevation, from the base of the mound, and those from the top of the mound. Similar to the model generated by Revit software for the Spectra SP85 GNSS receiver, we will use the perimeter defined by the contour with an elevation of 101.00 m. The working steps in Revit software are presented in Fig. 10.

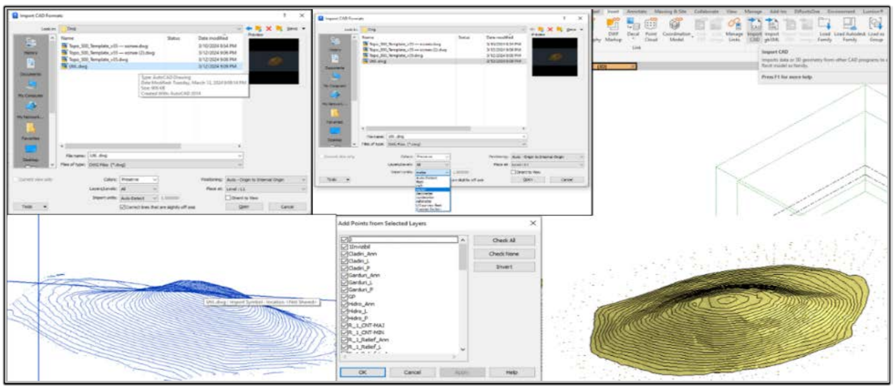

Fig.10. Working steps in Revit software

After excluding the additional volume area, the 3D model of the mound was obtained, resulting from the points collected with the Leica FlexLine TS06plus total station (Fig. 11). Following the automatic volume calculations performed by Revit software, the resulting volume was 22,399.253 m³.

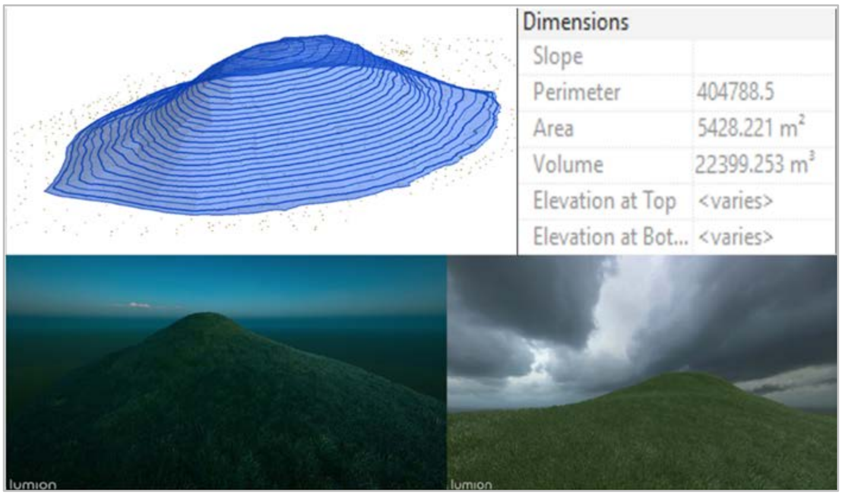

Fig.11. Final volume calculation result from measurements with the Leica FlexLine TS06plus total station

After processing the data collected with the Leica BLK360 laser scanner, it was observed that the data captured during the scanning process in the „Suta de Movile” natural reserve for determining the volume of „Movila Țiganului” was erroneous. The main reason is the excessive dry vegetation covering the mound's surface, with an average height of approximately 50 cm. Due to the abundant vegetation, the captured data is uneven compared to the existing terrain of the mound, and the point cloud generated during office processing has significant deviations from reality. The volume calculations would be much higher than the actual volume.

3. Analyzes and results

Analysis and description of the results obtained using different volume measurement methods for „Movila Țiganului”, namely, the GNSS receiver, total station, and terrestrial laser scanner, provide insight into the differences in results and the accuracy of each method. The GNSS measurements yielded a volume of 22,368.575 m³. On the other hand, measurements with the total station showed a volume of 22,399.253 m³, while the terrestrial laser scanning resulted in an erroneous volume due to the dry vegetation present in the study area. Based on the analysis of these results, it is observed that there is a slight difference in the volume obtained between the first two measurement methods.

Each applied geodetic method has its own characteristics and accuracy in data collection. Other factors to consider include:

- the time required for data collection and processing;
- the cost of instruments and extensions (software, services, programs);
- the number of people involved in the working process;
- the necessity of use (frequency of use);
- the quality of the results obtained.

Figure 12 shows the difference in data collection and processing time for the three methods used to determine the volume of „Movila Ţiganului". Upon analysis, it is evident that terrestrial laser scanning requires less time for data collection in the field, but data processing takes longer compared to the other two methods. Comparing the total station and GNSS receiver, GNSS measurements are faster in the field, while the processing time is approximately the same for both methods.

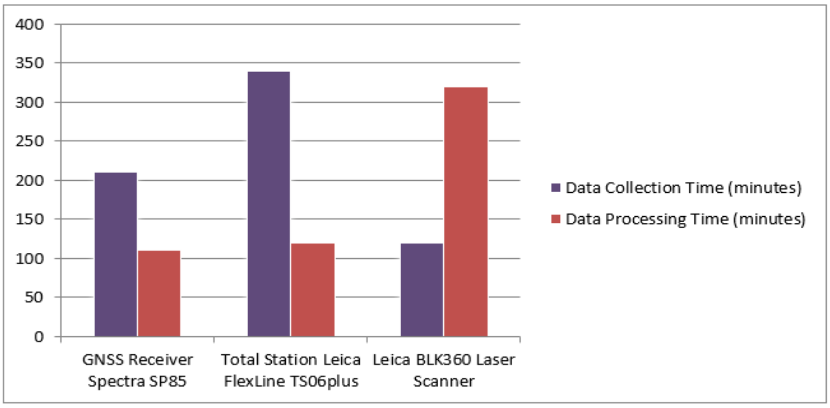

Fig.12. Data Collection and Processing Time

Comparing the costs of the instruments and extensions (software, services, programs) for these methods, we get the situation presented in Figure 13. The total station is the least expensive instrument and extension, while the most expensive, of course, is the terrestrial laser scanner along with its extensions.

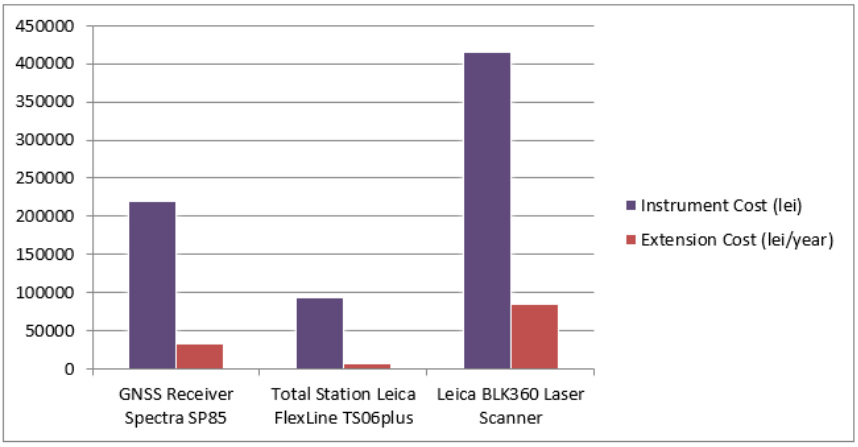

Fig.13. Cost of Instruments and Extensions

If we specify the number of people involved in the process for these three methods, we can say that using the GNSS receiver requires only one person, using the total station requires two people, and using the terrestrial laser scanner requires either one or two people. Currently, the most commonly used method in topographic-geodetic work is GNSS measurements, with terrestrial laser scanning being less frequently used. Analyzing the quality of the results obtained in this study, it is evident that the most efficient method for calculating volumes of this type is the data collection and processing method using the GNSS receiver Spectra SP85.

4. Conclusions

Determining volumes using topographic-geodetic instruments is a common necessity in many activities today. However, the main requirements are typically the time taken to perform the work and its quality. In this regard, a comparative analysis was conducted to determine the volume of „Movila Țiganului” using GNSS measurements with the Spectra SP85 receiver, the Leica FlexLine TS06plus total station, and the Leica BLK360 terrestrial laser scanner. The analysis was based on several criteria: data collection and processing time, cost of instruments and extensions (software, services, programs), number of people involved in the work process, frequency of use of the instrument, and quality of the results obtained.

It has been found that GNSS technology allows for rapid point localization in the field, reducing the time required for topographic surveys over large areas. It has lower costs, provides high-quality results with high precision, and offers faster working speed compared to the other instruments studied.

The total station also allows for precise topographic surveys, but it is more suitable for smaller detailed areas. It requires more time in the field and data processing in the office.

Similarly, terrestrial laser scanning has very high efficiency in calculating volumes over large areas, allowing the collection of a large number of points with high precision. Ideally, the scanning area should be free of obstacles to facilitate the scanning process and obtain accurate results, avoiding errors such as those caused by dry vegetation, as encountered on the surface of „Movila Țiganului”.

In conclusion, selecting a measurement method for volume calculation should primarily be based on precision, result quality, time constraints, and project requirements. Each of the mentioned methods offers its own advantages and can be applied to suitable projects. It is important to consider the characteristics of each technology and make an informed decision about which method to use.

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