Research Journal of Agricultural Science, 57 (1), 2025; ISSN: 2668-926X

http://doi.org/10.59463/RJAS.2025.1.22

USING GEOMATICS TECHNIQUES FOR RELIEF ANALYSIS IN THE CONTEXT OF SOIL EROSION

Silviu MUȘAT[1]

[1]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author: musat.silviu92@gmail.com

Abstract. *This article explores the application of advanced geomatic techniques for detailed relief analysis to better understand soil erosion processes. The study utilizes Digital Elevation Models (DEMs) provided by ALOS PALSAR, which offer an adequate spatial resolution for geomorphological analysis. These data are processed and analyzed in the open-source software QGIS, enabling the generation of accurate information on the topographical features of the watershed. An important aspect of the research is slope analysis, a key factor in triggering water erosion. Slope distribution within the watershed is mapped and statistically analyzed to identify high-risk areas. The study also examines the degree of relief fragmentation, an important indicator of how water runoff and sediment transport are influenced by terrain morphology. Furthermore, the research includes the analysis of the Topographic Position Index (TPI), a valuable tool for classifying landforms and identifying areas prone to water accumulation or dispersion. This analysis contributes to a deeper understanding of the interaction between surface hydrological processes and terrain morphology, influencing susceptibility to erosion. The aim of the study is to demonstrate the usefulness of geomatic techniques in the accurate and detailed evaluation of relief characteristics, providing essential information for identifying critical areas at risk of erosion. The results can serve as a basis for informed decision-making regarding sustainable land management, the implementation of soil conservation measures, and territorial planning to reduce the negative impact of erosion.*

Keywords*: Soil erosion, DEM, ALOS PALSAR, Topographic Position Index, QGIS.*

INTRODUCTION

Soil erosion represents a significant global environmental challenge, adversely affecting agricultural productivity, water quality, and ecosystem stability (BORRELLI ET AL., 2020). In regions characterized by complex topography, such as Romania's Subcarpathian areas, erosion processes are intensified by steep slopes, heavy rainfall, and unsustainable land use practices (PANAGOS ET AL., 2015). These regions face considerable challenges, including reduced soil fertility and increased sediment loads in water bodies, necessitating robust strategies for land management (ALEWELL ET AL., 2019). Understanding the topographic factors driving erosion is critical for developing effective conservation measures. Geomatics, an interdisciplinary field integrating Geographic Information Systems (GIS), remote sensing, and spatial analysis, provides advanced tools for mapping and analyzing terrain characteristics,

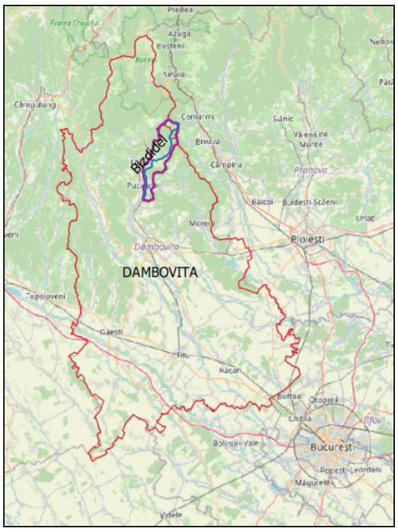

Figure 1 - Location of the Bizdidel watershed

enabling precise identification of erosion-prone areas (NEARING ET AL., 2017).

Digital elevation models (DEMs), such as those provided by ALOS PALSAR, facilitate accurate characterization of topographic features, including slope, relief fragmentation, and landform distribution, which are key drivers of water erosion (MORGAN, 2005). Open-source GIS software, such as QGIS, enhances accessibility to these analyses, allowing researchers to generate thematic maps that support decision-making in land management (QGIS DEVELOPMENT TEAM, 2023). The application of geomatics techniques has revolutionized erosion studies by offering cost-effective and scalable solutions for assessing terrain vulnerability (DE VENTE ET AL., 2013). This study focuses on the Bizdidel River basin, located in Dâmbovița County, Romania, a region characterized by varied topography and significant erosion risk. The objective is to demonstrate how geomatics techniques can be applied to analyze relief characteristics and support sustainable land management by identifying areas vulnerable to erosion. The methodology is designed to be replicable in other regions, contributing to broader efforts to mitigate land degradation and promote environmental resilience.

MATERIALS AND METHODS

The study was conducted in the Bizdidel River basin, located in Dâmbovița County, Romania, covering an area of approximately 9,527 ha. The basin exhibits diverse topography, with altitudes ranging from 400 to 1,200 m and slopes predominantly exceeding 15° in the upper sector (PANAGOS ET AL., 2015). The analysis relied on a digital elevation model (DEM) from ALOS PALSAR, with a spatial resolution of 12.5 m, obtained from NASA's EarthData platform (ASF, 2023). This DEM was selected for its accuracy in capturing topographic variations essential for geomorphological analysis.

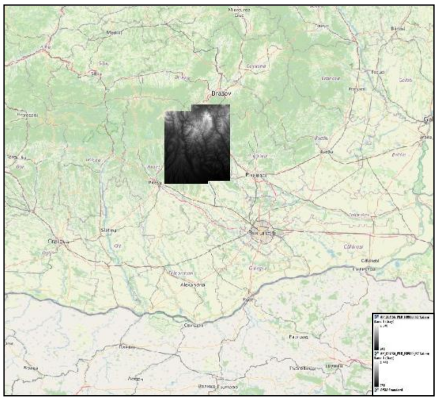

Figure 2 - Translating raw data into QGIS – Open Street Maps Basemap

Data processing and analysis were performed using QGIS (v.3.28), an open-source GIS software chosen for its robust spatial analysis capabilities and accessibility. The methodology involved the following steps:

1.Data Preprocessing: The ALOS PALSAR DEM was imported into QGIS and reprojected to the Stereo 70 projection system (EPSG:3844), Romania's official coordinate system. Artifacts and missing values were corrected using the "Raster Calculator" tool to ensure data integrity.

2.Slope Analysis: Slope was calculated using the "Slope" function in QGIS, with values classified into three categories: <5° (low risk), 5–15° (moderate risk), and >15° (high risk). Slope distribution was analyzed statistically to identify areas prone to water erosion.

3.Relief Fragmentation: Terrain fragmentation was assessed by calculating relief energy, defined as the difference between maximum and minimum altitudes within a 1 km² grid, using the "Zonal Statistics" tool. This parameter reflects the influence of topography on runoff and sediment transport.

Research Journal of Agricultural Science, 57 (1), 2025; ISSN: 2668-926X
http://doi.org/10.59463/RJAS.2025.1.22

4.Topographic Position Index (TPI): TPI was computed using the SAGA plugin in QGIS, with a 500 m radius, to classify landforms into crests (TPI > 1), uniform slopes (TPI between -1 and 1), and valleys (TPI < -1).

Thematic maps were generated for slope, relief energy, and TPI, providing a spatial representation of topographic characteristics. These maps were overlaid to identify areas with high erosion risk, focusing on the interaction between steep slopes, fragmented terrain, and landform distribution. Field observations conducted in 2023 validated the spatial data, confirming the presence of erosion features in areas with steep slopes.

RESULTS AND DISCUSSION

The geomatics analysis conducted in this study provided detailed insights into the topographic characteristics of the Bizdidel River basin, enhancing the understanding of soil erosion processes. The results, derived from processing the ALOS PALSAR DEM in QGIS, highlighted the distribution of slopes, the degree of relief fragmentation, and the topographic position of landforms, offering a robust foundation for identifying vulnerable areas.

Slope Analysis

The slope map (Figure 3) generated in this study revealed a varied distribution of inclinations in the Bizdidel basin, with steep slopes (>15°) dominating the majority of the area, particularly in the upper sector above 700 m. Moderate slopes (5–15°) are concentrated in the median sector (400–700 m), while gentle slopes (<5°) are limited to the lower sector (<400 m). These findings reflect a predominantly rugged terrain typical of the Dâmbovița Subcarpathians, which amplifies the risk of water erosion, as noted in the literature (García-Ruiz et al., 2017). The slope map enabled the identification of critical areas, particularly in the upper sector, where steep slopes necessitate urgent conservation measures, such as afforestation or terracing.

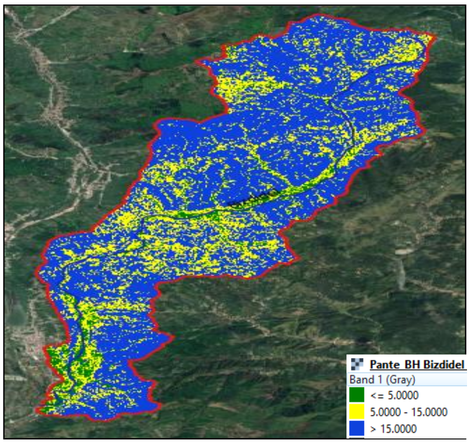

Figure 3 - Slope map of the Bizdidel River basin, generated in QGIS based on the ALOS PALSAR DEM

Relief Fragmentation

The relief energy map (Figure 5) highlighted a high degree of fragmentation in the upper sector, with values exceeding 200 m/km², correlated with steep slopes. In the median sector, relief energy ranges between 50–150 m/km², while in the lower sector, it drops below 50 m/km², indicating a more uniform terrain. These variations underscore the influence of topography on runoff dynamics, with fragmented areas being more prone to erosion. The relief energy maps were used to prioritize areas requiring land stabilization interventions.

Topographic Position Index (TPI)

The analysis conducted in this study generated the TPI map (Figure 4), which classified landforms into crests (TPI > 1), uniform slopes (TPI between -1 and 1), and valleys (TPI < -1). In the upper sector, crests predominate, associated with steep slopes and high erosion risk due to water dispersion. In the lower sector, valleys with negative TPI indicate sediment accumulation zones, less prone to erosion but vulnerable to excessive sedimentation.

The median sector features uniform slopes with moderate erosion risk. The TPI map complemented the slope and fragmentation analyses, providing a detailed view of the interplay between relief morphology and hydrological processes.

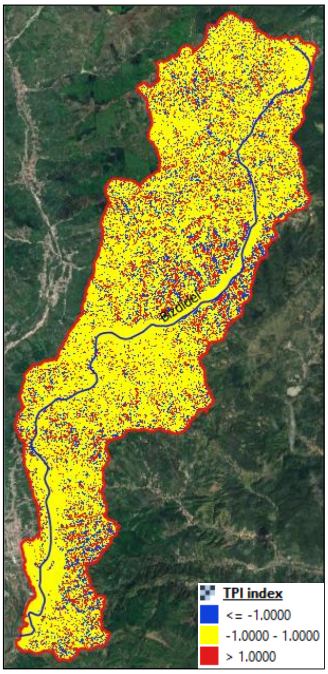

Figure 4 -Topographic Position Index (TPI) map of the Bizdidel River basin, generated in QGIS based on the ALOS PALSAR DEM

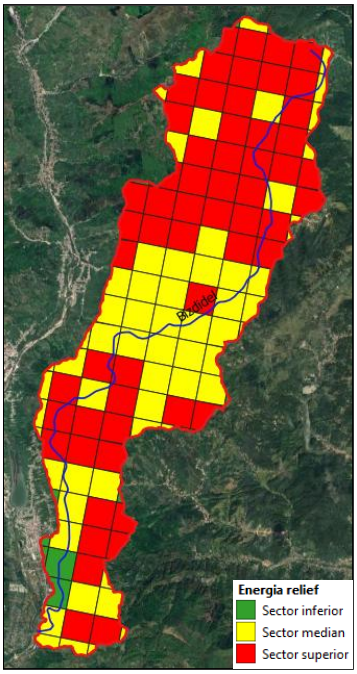

Figure 5- Relief energy map of the Bizdidel River basin, generated in QGIS based on the ALOS PALSAR DEM

Discussion

The results of this study demonstrate that the geomatics techniques employed enable a precise assessment of topographic factors influencing soil erosion. Unlike traditional methods requiring extensive field measurements, the geomatics approach is efficient and replicable, applicable to other river basins with similar topography (TÎRLĂ, 2012). The use of QGIS offers significant advantages over proprietary GIS software, including cost-effectiveness and flexibility, making it an ideal tool for researchers and land managers (KARYDAS ET AL., 2014). The generated maps provide local authorities and farmers with critical information for implementing conservation measures, such as planting perennial vegetation or terracing, thereby reducing erosion's impact on agricultural productivity and soil quality (XIONG ET AL., 2019). The methodology's replicability extends its utility to other erosion-prone regions, supporting regional planning and sustainable land use (DE VENTE ET AL., 2013). By integrating multiple topographic parameters, this study highlights the potential of geomatics to inform evidence-based decision-making, ensuring effective prioritization of conservation efforts. A limitation of the study is its reliance on the DEM's resolution, which may overlook fine-scale relief details, but the 12.5 m resolution of ALOS PALSAR is suitable for basin-scale analysis.

Figure 6 - Severe erosion on steep slopes in the Bizdidel Basin, 2023 (45°09'59.0"N, 25°32'03.8"E)

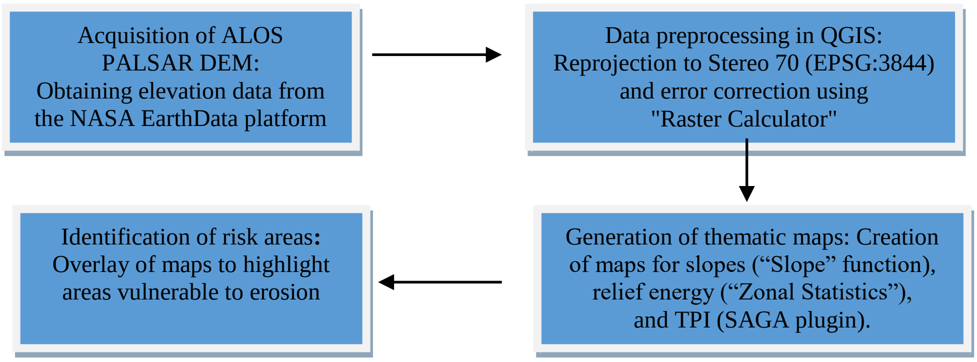

Figure 7 - Schematic diagram of the geomatics methodology used in the study

CONCLUSIONS

This study demonstrated the effectiveness of geomatics techniques in detailed relief analysis for understanding and managing soil erosion processes. The use of the ALOS PALSAR digital elevation model and open-source QGIS software enabled the generation of precise thematic maps, highlighting the distribution of slopes, relief fragmentation, and topographic position of landforms.

These maps provide a robust foundation for identifying high-risk erosion areas, particularly in regions with rugged topography, such as the Bizdidel River basin. The results are valuable for local authorities and farmers, facilitating the implementation of conservation measures, such as afforestation, terracing, or the establishment of vegetative buffer strips, to mitigate erosion's impact on agricultural land and enhance soil resilience (XIONG ET AL., 2019).

A limitation of the study is the DEM's resolution, which may overlook fine-scale details, but this is offset by the methodology's accessibility and accuracy. Future research could integrate additional data, such as high-resolution satellite imagery or predictive erosion models, to refine assessments and incorporate dynamic environmental factors. The proposed methodology is replicable in other river basins, offering a scalable approach to sustainable land

http://doi.org/10.59463/RJAS.2025.1.22

management and soil degradation reduction, with potential applications in regional and national conservation strategies.

ACKNOWLEDGMENT

This article is based on doctoral research carried out within the PhD thesis entitled "Research on Monitoring Erosional Processes Using Geomatics Techniques for the Sustainable Management of Sloped Agricultural Lands. A Case Study," developed at the University of Agronomic Sciences and Veterinary Medicine of Bucharest. The study presented here reflects the original processing of field data and spatial analyses conducted in the Bizdidel River basin, aimed at assessing erosion risk through relief analysis using geomatics techniques. This research is currently under development as part of the PhD thesis.

BIBLIOGRAPHY

1.Alewell, C., Borrelli, P., Meusburger, K., Panagos, P., 2019, Using the USLE: Chances, challenges and limitations of soil erosion modelling, International Soil and Water Conservation Research, Elsevier, China, pp. 203-225.

2.Asf (Alaska Satellite Facility), 2023, ALOS PALSAR digital elevation model (DEM), NASA EarthData, USA.

3.Boardman, J., Poesen, J., 2006, Soil erosion in Europe, John Wiley & Sons, Chichester, United Kingdom, pp. 1–855.

4.Borrelli, P., Robinson, D. A., Panagos, P., Lugato, E., Yang, J. E., Alewell, C., Wischmeier, D., Ballabio, C., 2020, Land use and climate change impacts on global soil erosion by water (2015-2070), Earth-Science Reviews, Elsevier, Netherlands, pp. 1–15.

5.De Vente, J., Poesen, J., Verstraeten, G., Govers, G., Vanmaercke, M., Van Rompaey, A., Arabi, M., Boix-Fayos, C., 2013, Predicting soil erosion and sediment yield at regional scales: Where do we stand?, Earth-Science Reviews, Elsevier, Netherlands, pp. 16–29.

6.García-Ruiz, J. M., Beguería, S., Lana-Renault, N., Nadal-Romero, E., Cerdà, A., 2017, Ongoing and emerging questions in water erosion studies, Land Degradation & Development, Wiley, United Kingdom, pp. 5–21.

7.Hengl, T., Reuter, H. I., 2010, Geomorphometry: Concepts, Software, Applications, Elsevier, Netherlands, pp. 1–765.

8.Karydas, C. G., Panagos, P., Gitas, I. Z., 2014, A classification of water erosion phenomena using high-resolution DEMs and orthophotos, Catena, Elsevier, Netherlands, pp. 183–192.

9.Montgomery, D. R., 2007, Soil erosion and agricultural sustainability, Proceedings of the National Academy of Sciences, National Academy of Sciences, USA, pp. 13268–13272.

10.Moore, I. D., Grayson, R. B., Ladson, A. R., 1991, Digital terrain modelling: A review of hydrological, geomorphological, and biological applications, Hydrological Processes, Wiley, United Kingdom, pp. 3–30.

11.Morgan, R. P. C., 2005, Soil erosion and conservation (3rd ed.), Blackwell Publishing, Oxford, United Kingdom, pp. 1–304.

12.Nearing, M. A., Xie, Y., Liu, B., Ye, Y., 2017, Natural and anthropogenic rates of soil erosion, International Soil and Water Conservation Research, Elsevier, China, pp. 77–84.

13.Panagos, P., Ballabio, C., Barbosa, P., Borelli, P., Lugato, E., Montanarella, L., 2015, The new assessment of soil loss by water erosion in Europe, Environmental Science & Policy, Elsevier, Netherlands, pp. 438–447.

14.Panagos, P., Katsoyiannis, A., 2019, Soil erosion modelling by using GIS and remote sensing: A review, International Journal of Digital Earth, Taylor & Francis, United Kingdom, pp. 754–768.

15.Qgis Development Team, 2023, QGIS user guide, OSGeo Foundation, USA, pp. 1–500.

16.TANG, Q., XU, Y., BENNETT, S.J., LI, Y., 2015, Assessment of soil erosion using RUSLE and GIS: a case study of the Yangou watershed in the Loess Plateau, China, Environmental Earth Sciences, 73(4), 1715–1724

17.TÎRLĂ, L., 2012, Elaboration of climatic maps using GIS. Case study: Olănești drainage basin, Romania, Journal of Environmental Biology, Triveni Enterprises, India, pp. 449–454.

18.WEISS, A. D., 2001, Topographic Position and Landforms Analysis, Poster presentation at ESRI User Conference, San Diego, USA, pp. 1–5.

19.XIONG, M., SUN, R., CHEN, L., 2019, Effects of soil conservation techniques on water erosion control: A global analysis, Science of The Total Environment, Elsevier, Netherlands, pp. 753–760.