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THE IZVORUL DORULUI RIVER BASIN (ROMANIA)–A STUDY OF APPLIED GEOMORPHOLOGY

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Abstract: Applied geomorphology plays an important role in understanding the landscape dynamics and the effects of human activities on relief. In this context, the study presents an applied geomorphological assessment of the Izvorul Dorului River basin (Romania), focusing on relief dynamics and human-induced geomorphological instability. The methodology is based on the analysis of a 10 m resolution Digital Terrain Model (DTM), Geographic Information Systems (GIS)-derived morphometric parameters, and field validation, aimed at identifying geomorphological processes and areas sensitive to anthropogenic impact. The results show an active mountain relief, with steep slopes, a dense hydrographic network, areas of intense erosion, and frequent torrential processes. The effects of anthropogenic activities, such as road infrastructure, ski slopes, and other tourist facilities, on relief stability are also analyzed. The tourism and infrastructure map of the basin illustrates the geomorphological tourism potential of the area, but also its vulnerability to anthropogenic pressures. The conclusions highlight the need for sustainable management of tourist activities in order to maintain morphological balance.

Keywords: applied geomorphology; river basin; Izvorul Dorului; geomorphological processes; anthropogenic impact

1. Introduction

The Izvorul Dorului River basin is one of the most dynamic areas in the eastern part of the Bucegi Mountains (Romania). From a geomorphological point of view, there are processes that shape the relief but also have implications for anthropogenic activities, as they are closely related. The area is subject to natural factors, such as varied lithology, high altitudes, most of which are over 1,600 m a.s.l. (Micalevich-Velcea, 1961), mountainous climatic conditions, as well as to increased anthropogenic involvement, determined by the existence of tourist resorts in the area and their expansion in the Prahova Valley (Oprea & Oprea, 2001).

While the Bucegi Mountains and the Prahova Valley have been extensively studied in regional research (Comănescu & Nedelea, 2010; Comănescu et al., 2014; Micalevich-Velcea, 1961; Orghidan, 1931; Vâlsan, 1939), the Izvorul Dorului River basin itself has rarely been analyzed at the basin scale (Oprea, 2002; Oprea & Oprea, 2001), often being indirectly included in studies of the larger units of which it is a part. Moreover, in the absence of a recent

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study of the investigated area, the research provides an update on the state of the relief and the relationship between people and nature in the context of the expansion of infrastructure and tourism, as the area is heavily trafficked throughout the year.

The aim of this study is to analyze the river basin from an applied geomorphology perspective. Relief analysis based on Geographic Information Systems (GIS), complemented by field observations, are used to identify active geomorphological processes and the impact of anthropogenic activities and infrastructures at the basin scale.

1.1. Study area

The Izvorul Dorului River is located in the central southern part of the Bucegi Mountains, on the eastern syncline of the massif, as can be seen in Figure 1A. It is thus located within the Southern Carpathians, in the Bucegi Mountains Group, and is also partially covered by Mount Gurguiatu, located south of the basin and bordered on the eastern side by the Prahova Valley and the Baiului Mountains. The surface area of the Izvorul Dorului River basin is approximately 33 km², being classified as a small basin (Costache et al., 2021). The average altitude of the basin is 1,600 m a.s.l., which shows its higher position in relation to the Ialomița and Prahova valleys (Micalevich-Velcea, 1961).

The river basin extends between 45°24′24′′ north latitude (recorded at Babele peak) in the north and 45°18′5′′ north latitude in the south. In the east it is limited by the meridian of 25°27′21′′ east longitude (Blana peak), and in the west by the meridian of 25°33′54′′ east longitude (at the river's confluence in Prahova). The coordinates represent the extreme points between which the river basin extends (Figure 1A), based on GIS analysis of Topographic Map of Romania 1:25,000 (Military Topographic Directorate, 1975–1980).

From a geomorphological point of view, the first references to the Izvorul Dorului River appear in the work of Orghidan (1931), dedicated to the study of the morphology of the Bucegi Mountains, in which the observations are discussed without detailed analyses that would support the existence of structural forms, differential erosion, and other identified processes. This was due to the lack of a detailed geological study. Later, Vâlsan (1939) provides an important description of the leveling surfaces and, most importantly, an analysis of the course of the Prahova River, which also includes the course of the river currently studied, the Izvorul Dorului, a right tributary of the Prahova. Detailed aspects of the Bucegi area from a physical-geographical point of view and a clarification of the geomorphological problems in the Izvorul Dorului River basin were defined by Micalevich-Velcea (1961). Thus, regarding the characteristics of the relief in the studied basin, it is evident that, due to its location, mostly within the Bucegi Mountains, there are complex components that together form the natural framework specific to the area. Therefore, within the basin, at over 2,000 m a.s.l., there are high plateau areas, corresponding to the Bucegi plateau, cliffs, and rugged slopes, which, together with the descent of the river and the presence of conglomerates, hard rocks that are difficult to erode, result in waterfalls and erosion thresholds.

The Izvorul Dorului Valley is crossed by two large structural units belonging to the Eastern Massif: Bucegi Massif (its eastern part), consisting of crystalline Mesozoic rocks, belongs to the southern compartment of the Central Carpathian area, and the second unit, the Cretaceous flysch, known as the Sinaia Strata, which runs along the lower course of the river (Micalevich-Velcea, 1961). According to Mutihac et al. (2004), the Bucegi Mountains belong to the Eastern

Massif, and the boundary between it and the Southern Massif is given by the Dâmbovița Valley, not the Prahova Valley.

The Geological map of the Romanian Socialist Republic, scale 1:200,000: Brașov sheet L-35-XX and Târgoviște sheet L-35-XXVI published by the Geological Institute of Romania (1960–1969), indicates that the Izvorul Dorului Valley crosses a geological complex. It is formed predominantly of Bucegi conglomerates, found in the upper part of the basin (Figure 1B), which provides a relatively higher structural stability. In the middle, in the steep area, there are formations of schistose-gresose and calcarenitic flysch (Figure 1B), more prone to erosion processes and landslides. Marls, sandstones, and conglomerates are found in the lower part of the river course, up to the mouth of the Prahova River, while sand and marl are found locally in small proportions. Unconsolidated deposits such as sands, gravels, and loess deposits are located in the minor riverbed (Figure 1B), close to the mouth, where it is constantly fed with water, thus presenting fine sediments deposited over time as a result of flow fluctuations in different seasons.

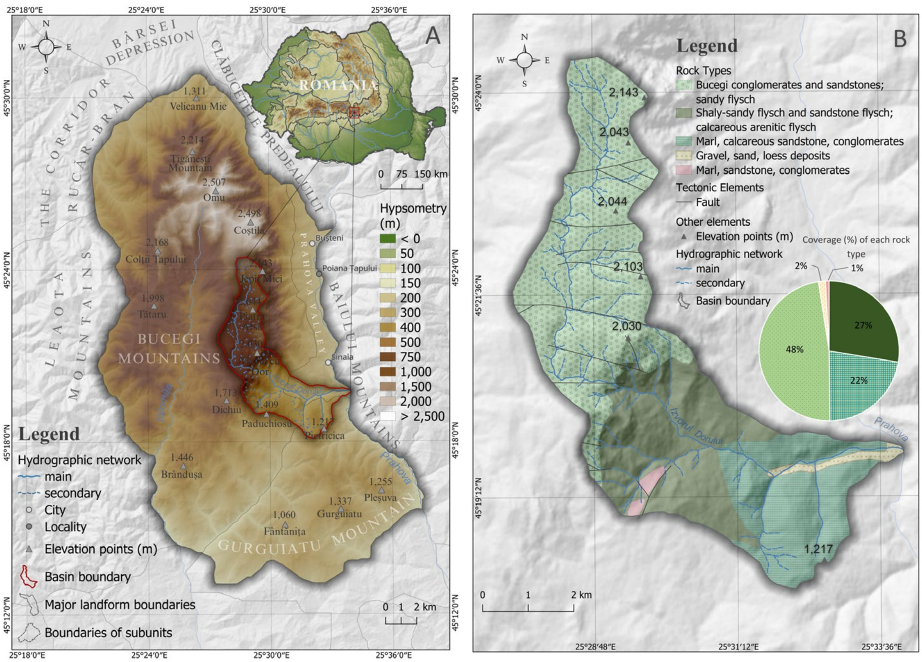

Figure 1. Panel A: Location of the study area within the Bucegi Mountains. Panel B: Geology of the Izvorul Dorului River basin, based on the *Geological map of the Romanian Socialist Republic, scale 1:200,000: Brașov sheet L-35-XX and Târgoviște sheet L-35-XXVI*, by Geological Institute of Romania, 1960–1969 (https://geo-spatial.org/vechi/download/harta-geologica-a-romaniei-scara-1-200-000). Copyright 1960–1969 by Geological Institute of Romania.

The location of the studied basin in a mountainous area and the geological structure, presented in Figure 1A and 1B, provide the regional context for understanding the geomorphological characteristics of the main river and its tributaries in different seasons. This is illustrated through field photos presented in Figure 2.

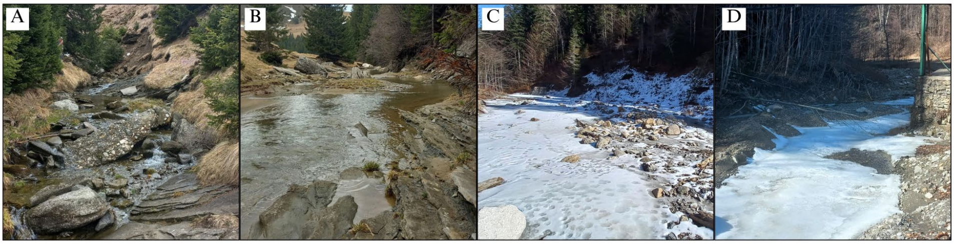

Figure 2. Course of the Izvorul Dorului River in different conditions.
Note. Panel A and Panel B: upper course during high-flow periods (April 2025). Panel C and Panel D: lower course affected by freezing (January 2025).

The most recent studies on the Bucegi Mountains include several works that specifically address the Izvorul Dorului River basin. Significant contributions regarding geomorphosites, geomorphological hazards, and public perception of them are presented by Comănescu and Nedelea (2010, 2015) and Comănescu et al. (2014), emphasizing the importance of preserving geomorphological heritage. The basic concepts of applied geomorphology and analysis methodology are supported by the geomorphological lexicon compiled by Ielenicz and Nedelea (2009) and Ielenicz et al. (2013). These provide the conceptual framework for understanding modeling processes, assessing geomorphological risks, and integrating the anthropogenic factor into relief analysis.

2. Materials and methods

The methodology used in this study aims to analyze the geomorphology of the Izvorul Dorului River basin by combining field observations with modern digital methods (Figure 3). The goal was to identify landforms, dominant geomorphological processes, and the influence of anthropogenic factors on the physical environment.

2.1. Data acquisition and sources

The main source of data used in the study is the Topographic Map of Romania 1:25,000, published by the Military Topographic Directorate (1975–1980). Based on the interpolation of contour lines and altimetric points from this map, a Digital Terrain Model (DTM) was generated with a spatial resolution of 10 m. Although global elevation datasets are currently available (such as SRTM or FABDEM), this approach was chosen to ensure scale-dependent accuracy and improved representation of local morphometric characteristics.

The Topographic Map of Romania 1:25,000 can be accessed by students and teaching staff of the Faculty of Geography (University of Bucharest) through the WMS service, following an agreement with the Military Topographic Directorate (currently Defense Geospatial Information Agency (AIGA)). Based on this map, other relevant thematic layers were obtained through vectorization, such as hydrography, land use, and anthropogenic elements. To update the information, Orthophotomaps of Romania, 1:5,000, produced by the AIGA (2017–2020), were used.

In addition to topographic map and ortophotomaps, the Geological map of the Romanian Socialist Republic, scale 1:200,000: Brașov sheet L-35-XX and Târgoviște sheet L-35-XXVI, published by the Geological Institute of Romania (1960–1969) was used for extracting essential information regarding the lithological substract. This cartographic resource can be accessed through the community website geo-spatial.org, which offers georeferenced version of the map for research and educational purposes.

2.2. GIS analysis

Spatial analysis and thematic mapping were performed using QGIS 3.40.0 software (QGIS Development Team, 2024). The processing workflow integrated some modules from GRASS, accessed through the QGIS Processing Toolbox GUI. Statistical reports generated from QGIS were imported into Excel to create pie charts showing the distribution of phenomena within the study area.

Based on the DTM, the main landforms were extracted and a series of morphometric parameters (hypsometry, slope, slope orientation, density of landform dissection, and depth of landform dissection) were calculated. The landform classes have been extracted using the algorithm developed by Jasiewicz and Stepinski (2013), "which uses spatial pattern recognition and variation in the DEM relief to extract 10 landform classes based on the distribution and structure of neighboring pixel values, depending on the selected analysis scale" (Ioniță et al., 2024, p. 3). According to these authors, the topography is divided into: flat, peak, ridge, shoulder, spur, slope, hollow, footslope, valley, and pit.

The slope and slope aspect were calculated using the r.slope.aspect module, which used an algorithm based on the determination of a 3 x 3 neighborhood around each cell in the raster elevation map (GRASS Development Team, 2025). For the classification of the slope gradients in different classes the Grigore's (1979) classification was used, a national system that divides slopes into six classes, from 0° to 90°. Each class is associated with a specific type of morphological surface and is associated with potential geomorphological processes (Săndulache, 2015). Slope orientation is calculated counterclockwise from the east with values in degrees indicating the slope direction: 90° corresponds to north, 180° to west, 270° to south, and 360° to east (GRASS Development Team, 2025). The density and the depth of landform dissection were calculated by the method of squares.

2.3. Field observations and final interpretation

To validate the GIS-based results and to collect additional observational data, field observations were made between January and April 2025. During these surveys, active geomorphological processes (landslides, erosion, and torrentiality) were identified, as well as changes caused by human activities (deforestation and tourist developments). The final interpretation involved synthesizing and correlating bibliographic documentation, GIS analysis, and field observation. This approach allowed for a complex understanding of the relief and active processes in the Izvorul Dorului basin, highlighting the applicability of modern geomorphological methods in the analysis of mountainous areas.

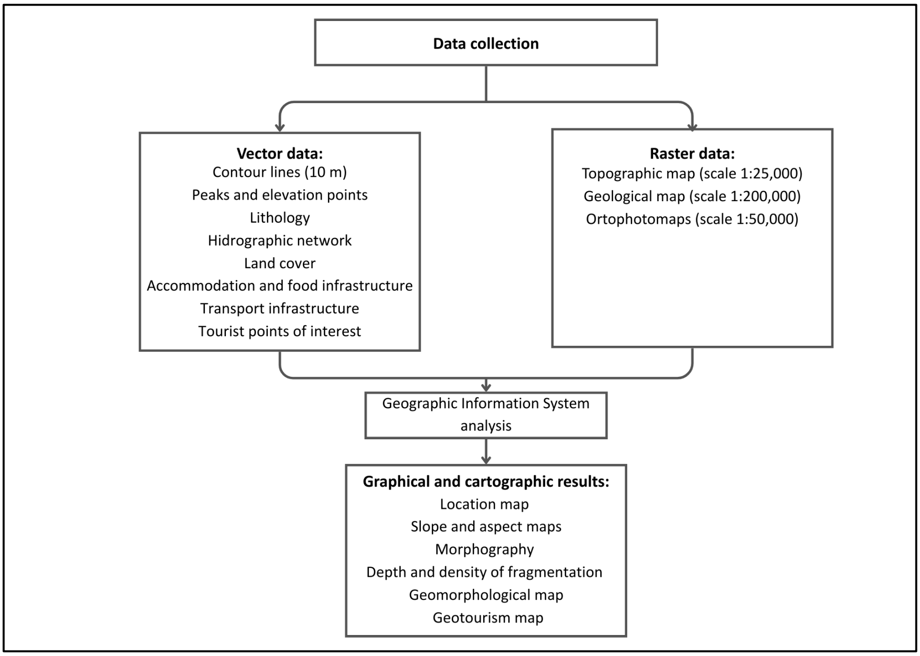

Figure 3. Methodological workflow.

3. Results

3.1. Landforms classification map

The landforms classification map (Figure 4A) illustrates the general aspect of the relief in the studied basin, dividing it into 10 classes: flat, peak, ridge, shoulder, spur, slope, hollow, footslope, valley, and pit (Jasiewicz & Stepinski, 2013). The classes occupy significant areas, but among the predominant ones are slopes and peaks, each occupying approximately 26% of the total area of the river basin. This is due to the location of the area, which is situated in a mountainous region with pronounced altitudes, most of which are between 1,000 and 2,200 m a.s.l. Continuing the analysis based on the cartographic representation, the next predominant class, covering 19.87% of the area, is the valley. This landform is characterized by a complex morphology as it has a cross-section with two distinct sectors (a wide upper sector and a narrow inner sector), thus forming a minor negative relief. As a rule, gully erosion results from torrential erosion and water runoff on the slope, leading over time to the formation of torrents, which are also extremely present in the Izvorul Dorului basin.

Other elements such as interfluves and valleys occupy approximately 7–8% of the total area. These have different characteristics depending on their profile, both transverse and longitudinal. For example, the valleys inside the Bucegi Massif have a wide-open transverse profile, due to fluvial erosion processes in accordance with the gentle slope. Opposite to this situation are the valleys outside the steep Bucegi, defined by steeply sloping valleys, often found in longitudinal profile in the shape of the letter V, being narrow, due to the steep slope of the relief with slopes of 40°.

The interfluves are also similar to the valleys in terms of their characteristics, being wide open, located inside the massif, and having a specific structure. They are best highlighted on the left slope of the Izvorul Dorului Valley, where the geodetic values are low, between 3° and 10°. Also, in the northern part of the massif, the interfluves are more pronounced, due to the lithological nature of the area. To a lesser extent, there are flat surfaces, peaks, pits, and bases of slopes, all of which are specific to the natural environment of the area, but their consequences are less significant than the morphological elements mentioned and developed above.

3.2. Slope

Regarding the slope, in most of the basin area, values between 3° and 10° predominate. These correspond to surface with low to moderate inclination being associated with diffuse streamflow processes and weak gravitational processes. The highest values are found strictly in the steep area, where the slope has values between 56° and 90° (Figure 4B). Also, in the case of average values, these are mainly found on the slopes of the valleys, accentuated by fluvial erosion over time, but also on the slopes of the massif, slightly accentuated in the central area, especially the plateau area.

3.3. Slope orientation

Closely related to climate and slope is the orientation of the slopes, which is one of the defining elements of a study involving the geomorphological analysis of an area. Therefore, a map of the slope orientation in the Izvorul Dorului basin was created (Figure 4D), which classifies them into eight distinct classes.

South-facing slopes (S, SE, SW, and E) predominate in the eastern and southern half of the basin, being exposed to solar radiation for a longer period of time. They also have poorly developed and discontinuous vegetation due to high evaporation. In line with the above, there are steep slopes that over time lead to the formation of torrents and an increased risk of hazard.

North-facing slopes (N, NW, NE, and W) are found mainly in the northern half of the basin as well as in high areas. They are characterized by high humidity, as indicated by the presence of dense forest vegetation, but also by the presence of landslides and the risk of them, due to the clay layers that store water, which, together with the steep slopes, lead to risk areas. Also, from an anthropogenic point of view, which is positive for development purposes, ski slopes can be built on this type of slope, thus creating areas that can be used for recreational purposes.

3.4. Hypsometry

In order to develop a correct analysis of aspects related to the morphometry of the basin, it is necessary to include quantitative elements based on mathematical data, including the density and depth of relief fragmentation, which together reflect geographical processes. Hypsometry also underpins the above, through the altimetric indicators that were used, among other things, to establish the overall geomorphological processes present in the basin.

The altitude of the relief, as shown in Figure 4C, decreases from north to south but also from east to west due to the series of peaks and summits found at the outer edges of the Bucegi Massif. The maximum altitude in the Bucegi Massif is over 2,220 m a.s.l., but the highest peak in the analyzed basin is Jepii Mici, with a height of 2,143 m a.s.l. Of course, the lowest values are recorded in the river valley, with altitudes rarely falling below 1,000 m a.s.l.

3.5. Density of landform dissection

The classes of relief fragmentation density values were classified into five categories as follows: 0–3 km/km^2, 3–5 km/km^2, 5–7 km/km^2, 7–9 km/km^2, and 9–20 km/km^2 (Figure 4E). Thus, following an analysis of the spatial distribution, a predominance of average values of 5–7 km/km^2 is observed, occupying a large part of the basin surface. Therefore, a moderate degree of relief fragmentation is identified, the distribution being relatively uniform in the central sector of the basin.

In the southern and southwestern, as well as in northern sectors, high values of fragmentation density are identified, of 7–9 km/km^2 and 9–20 km/km^2. Therefore, in light of the high values, it is indicated that the valley network is more accentuated and the relief more fragmented in relation to other sectors.

In the case of classes with low values, 0–3 km/km^2 and 3–5 km/km^2, the distribution is restricted, being rarely encountered within the area. It is found in the central and eastern sectors, which indicates the limited development of the hydrographic networks, overall being a temporary hydrographic network and implicitly the fragmentation of the reduced relief. On the whole, the values alternate depending on the presence of the hydrographic network and its temporality, a fact previously demonstrated by the density values, reduced in the case of areas adjacent to the hydrography and accentuated in the case of areas crossed by the main river analyzed.

3.6. Depth of landform dissection

Following on from the previous point, the depth of relief fragmentation is the final morphometric element. In the steep area, minor fragmentation (caused by the depth of the Izvorul Dorului Valley) ranges between 100 and 200 m (Figure 4F), and in some places it is completely absent, with major fragmentation (the front of the tectonic-erosive ridge) being present.

For the internal area, on the flank of the syncline, there is a fragmentation depth of 150 m for the Izvorul Dorului Valley, which is located perpendicular to the eastern flank of the Bucegi syncline, the situation being reversed for its consequent tributary valleys (Călugărului Valley, Dorului Valley). For the tributaries in the flysch area, there is a fragmentation depth of over 200 m, which is due to the lithographic constitution in which the rivers here have deepened (rocks belonging to the flysch).

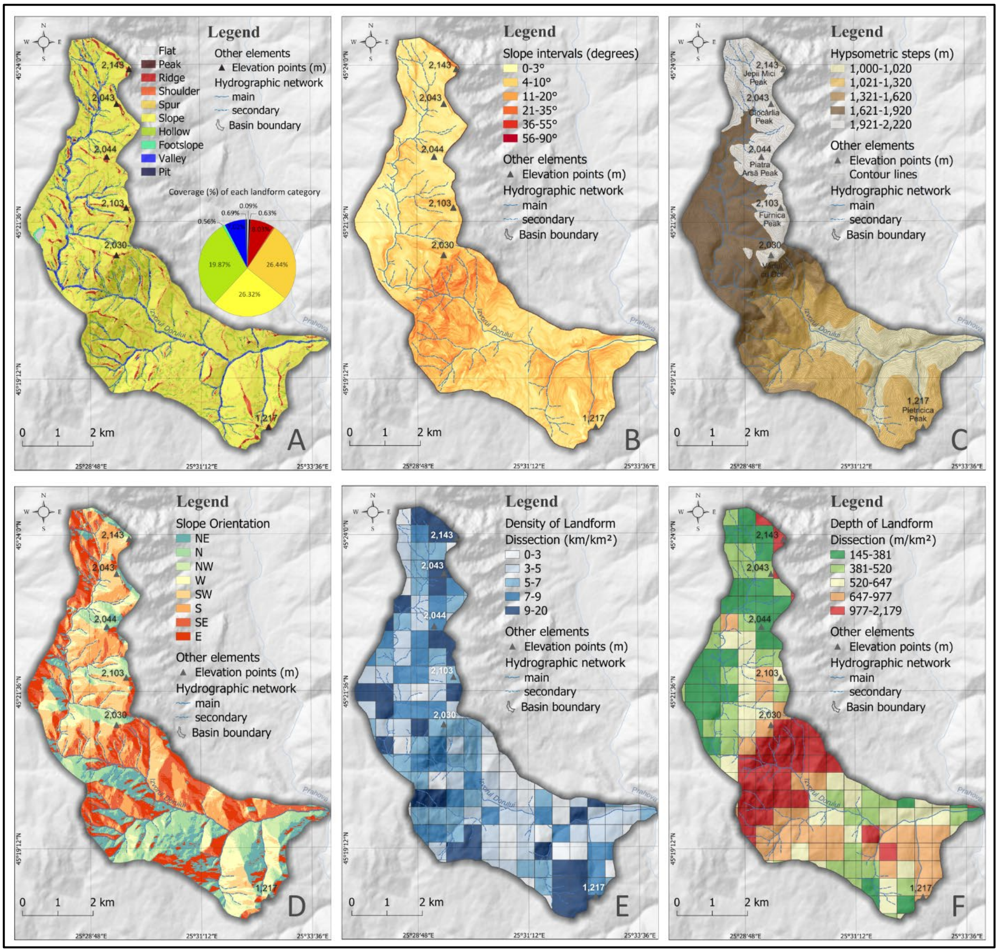

Figure 4. Morphographic and morphometric maps.
Note. Panel A: Morphography. Panel B: Slope. Panel C: Hypsometry. Panel D: Slope orientation. Panel E: Density of landform dissection. Panel F: Depth of landform dissection.

3.7. Active geomorphological processes

The Izvorul Dorului River flows through an area with active geomorphological dynamics, marked by high altitudes, steep slopes, diverse lithological substrate, and a mountain climate characterized by large temperature ranges and significant precipitation (Oprea & Oprea, 2001). Its hydrographic basin is strongly influenced by a series of current geomorphological processes, which contribute to the continuous shaping of the relief and the generation of natural hazards, especially in areas close to human settlements.

3.7.1. Avalanches and avalanche paths

Avalanches are common in the upper part of the Dorului Valley, at altitudes above 1,600 m a.s.l., usually on slopes with values between 30–40° and on the shaded and semi-shaded slopes of the Bucegi Mountains. They often cause intense erosion, natural deforestation, changes in the appearance of the relief, and in some cases, loss of human life. During the holiday season, especially in the winter months, the number of victims increases, most often due to carelessness in practicing winter sports (Avalanșe în Carpați, 2018).

3.7.2. Landslides and slope failures

In the study area, landslides often occur on slopes between 15–30°, while the steeper slopes of the Bucegi Mountains, over 35°, are more prone to collapses and rockfalls due to the steep incline and gravitational processes. The triggering agents can be natural, in most cases, landslides being triggered by the infiltration of a significant amount of water into the soil, following precipitation or anthropogenic causes, such as deforestation in the forest zone.

Field observations revealed the presence of landslides and slope collapses, especially along the main communication routes. Gabions were installed along county road 713 to reduce the risk of landslides and rockfalls, which pose a risk to users of this transport network, primarily tourists.

3.7.3. Cryonivation (freeze–thaw weathering)

Cryonivation refers to a periglacial geomorphic process driven by repeated freeze–thaw cycles, which over time leads to the creation of landforms, sediment accumulation processes, and specific structures such as scree (Ielenicz, 2004). Such processes occur along the riverbed. Cracks form in the rocks, gradually becoming more pronounced due to the repeated process of frost action, eventually leading to the complete fracturing of the rock blocks and ending with their capture and transport by the river (Nedelea et al., 2009).

3.7.4. Torrential erosion and alluvial transport

Sediment transport occurs constantly, as gravity and the presence of the main agent, water, provide the minimum energy sufficient to ensure flow from the springs to the mouth (Ielenicz, 2004). Following the capture of sediment from tributaries or snowmelt, the Dorului Spring transports coarse and fine sediments to the mouth of the river, where they are deposited in the alluvial cone. When certain sections of the river have extra energy (Ielenicz, 2004; Oprea, 2002), erosion happens either along the riverbed (upper course) or sideways (lower course).

3.7.5. Silting processes and changes to the riverbed

Due to the intensified alluvial transport during the snowmelt period, processes of channel silting and changes in the riverbed occur (Micalevich-Velcea, 1961). These are often found at the mouth of the river in the Prahova catchment basin, where the input of fine and coarse sediments is significant. The morphological map of the Izvorul Dorului Valley shows a complex mountainous relief, deeply influenced by the geological structure and active geomorphological processes (Figure 5). The territory is dominated by a dense network of torrential valleys, organized radially around the main course, Izvorul Dorului, which collects water from the steep slopes of the basin. In the upper part of the basin, there are cuestas—elongated structural forms that indicate the influence of inclined geological stratification on the shaping of the terrain. These alternate with relatively flat structural surfaces, reflecting the differentiated resistance of rocks to erosion. Gorges can also be distinguished—narrow sectors, deeply carved by water into hard rock, which mark high relief energy and significant tectonic activity.

The entire geomorphological landscape is marked by a series of torrential organisms and catchments that indicate an active dynamic of the hydrographic network, characteristic of unstable mountain areas. The altitude level of approximately 1,000 m a.s.l. represents a morphological boundary between the upper zone, characterized by accumulation and active erosion, and the lower zone, characterized by sedimentation (Micalevich-Velcea, 1961). Thus, the map provides an overview of the studied mountain basin, where the relief is closely linked to the structure, lithology, and current geomorphological processes.

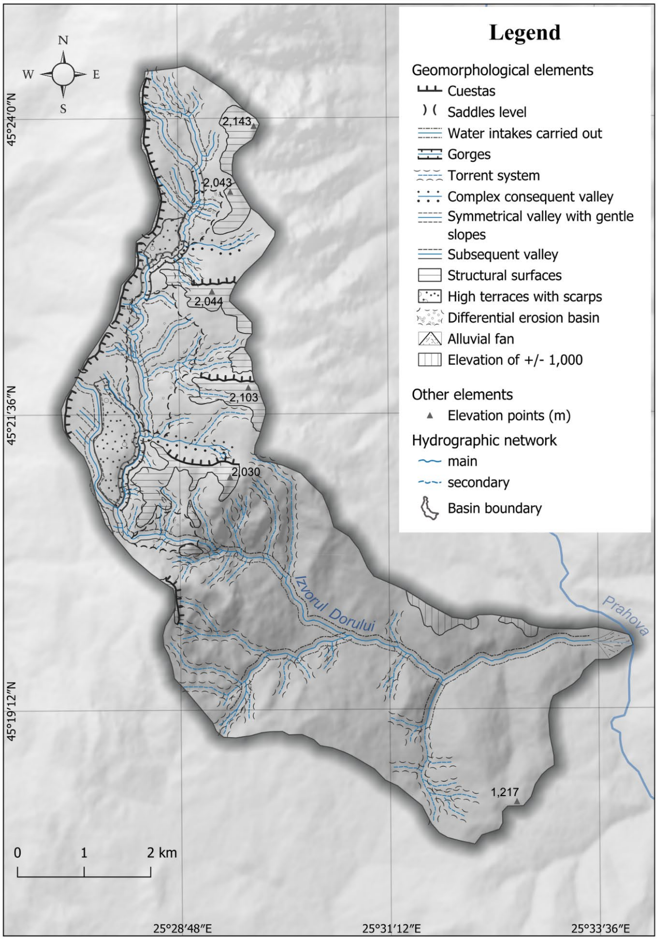

Figure 5. Morphological map of the Izvorul Dorului Valley.
Note. Adapted from *Masivul Bucegi. Studiu geomorfologic* [The Bucegi Massif. Geomorphological study] (pp. 104–105, unnumbered page) by V. Micalevich-Velcea, 1961, Editura Academiei Republicii Populare Române. Copyright 1961 by Editura Academiei Republicii Populare Române.

4. Discussion

4.1. Interpretation of results in the context of the literature

The GIS based analysis on morphometric parameters provides a quantitative approach to understand the distribution and intensity of geomorphological processes in the Izvorul Dorului River basin. The analysis of slopes, relief fragmentation, and altitude distribution highlights the influence of relief characteristics on the development of erosion processes, sediment transport, and slope instability within the basin. For a more comprehensive interpretation, this research was complemented by bibliographic documentation and field observations.

Morphometric analysis and current processes in the Izvorul Dorului basin confirm the morphometric model identified by Micalevich-Velcea (1961), which separates the slopes of the Bucegi Massif into two distinct categories: the major class (over 40°), located at the edge of the massif, and the minor class (under 40°), located inside the massif. Those slopes are the result of the relationship between erosion, transport, and accumulation, with tectonics, the position of the base levels, structure, lithology, and morphoclimatic processes, which over time have conditioned the formation of the eastern, northern, and western cliffs. As for the slopes located inside the massif, it can be said that they have low values, with mostly small inclinations of a few degrees (up to 10°), increasing toward the steep area to inclinations of 30–40°, characterized by scree that masks the pronounced unevenness. As shown in Figure 4B, slopes with low values (up to 10°) were identified, which progressively increase toward steep areas up to 40° and even above this value. This spatial distribution of the slope can be related to the evolution of the drainage network and to the fragmentation of the relief. For the eastern flank of the syncline, largely superimposed on the Izvorul Dorului basin, the density of fragmentation can be established based on the connection of the saddles to the old drainage lines. Thus, a much lower degree of fragmentation can be estimated for the pre-Quaternary and Quaternary phases, its magnitude being conditioned by the appearance of higher-order valleys. According to the calculations made, taking into account the hydrographic network, the fragmentation density reached values between 0.5 and 1 km/km^2.

While old fragmentation indices are found in the interior of the massif, on its edge there is a hydrographic network whose routes are inherited by the current network. This fact can be explained by the steep slope formed by the ends of the eastern flank of the syncline, so that the established network could not oscillate as in the case of the eastern flank, and rearrangements were excluded (Micalevich-Velcea, 1961). The fragmentation of the interfluves is due to the old hydrographic network (as is the case for the saddle in Cocora, Pietrosu, Lăptici, Nucet, etc.), i.e., the tributary valleys of the syncline axis.

The presence of differential erosion basins in certain areas indicates the alternation between hard and soft rocks, leading to the formation of structural and morphological depressions. In the lower areas of the basin, there are high plateaus with ridges, i.e., flat, elevated surfaces separated from the slopes by breaks in the slope, suggesting old levels of erosion. Along the slopes, complex valleys have developed, following the direction of the strata's inclination, along with subsequent valleys, perpendicular to the geological structure, which demonstrate a more recent evolution, controlled by regional drainage. In the lower part of the basin, there is a well-defined debris cone, formed by the accumulation of sediments transported by torrents in areas with a gentle slope (Figure 5).

The current geomorphological processes are influenced by human interventions, especially in areas with high tourist intensity. This aspect has also been identified by Comănescu and Nedelea (2015), who highlighted the impact of deforestation and tourism-related infrastructure development on geomorphological stability. In this context, the infrastructure related to winter sports, such as slopes, cable transport facilities, and access roads, can cause changes in surface runoff, favoring the concentration of flows on certain paths and triggering torrential phenomena (Costache et al., 2021). In addition, local deforestation, the reconfiguration of tourist routes, and soil compaction due to pedestrian traffic accentuate slope erosion (Comănescu & Nedelea, 2015), especially in areas with marl-gravel substrate, contributing to increased instability where relief energy is already high.

4.2. Human activities and infrastructure

An important aspect to mention is that recently, recreational activities, especially in mountain areas, have gained momentum. Certainly, the Prahova Valley and, implicitly, the mountain ranges in the area are some of the most frequent locations chosen by tourists for spending their free time. Of course, constant contributions have been made in these areas to develop road infrastructure, accommodation and dining facilities, as well as skiing infrastructure, in order to attract as many tourists as possible (Comănescu & Nedelea, 2015). Therefore, the following is an analysis of these anthropogenic activities in relation to their impact on the landscape.

4.2.1. Road and ski infrastructure

Within the studied area, there are several types of road and recreational facilities, both of which are obviously intended for transport. In most of the basin, specifically in the part covered by the Bucegi Plateau, there are tourist trails connecting natural attractions such as geomorphological sites and man-made attractions such as cabins, ski slopes, and the Piatra Arsă sports complex.

The trails are developed and classified according to their degree of difficulty using tourist markings established at the national level (Ministry of Entrepreneurship and Tourism, 2023). Most of them connect impressive natural attractions, peaks, saddles, viewpoints, nature reserves, and geomorphological sites. Specifically, as shown on the geotourism map (Figure 6), there are eight types of trails:

1. The red trail connecting the Laptici Saddle to the Valea Soarelui forest cabin, the former Valea Dorului cabin, the weather station at an altitude of 1,500 m, and the town of Sinaia;
2. A yellow cross trail, which crosses the Bolboci Lake area and intersects with the aforementioned trail in the Valea lui Soare Cabin and former Valea Dorului Cabin sector;
3. A yellow band between the Valea Dorului Cabin and the Babele Cabin, with the trail continuing further;
4. Blue strip route, which starts near Peleș Castle, crosses the well-known “royal path” reaching Poiana Stânii, then passes through Șaua Cocora and ends at the intersection with the blue cross at the Peștera Ialomiței Monastery;
6. Blue triangle, a route that connects Bușteni and Cantonul Jepilor and continues past Vârful Ciocârlia, but connects through the juniper reserve between the canton and the Piatra Arsă National Sports Complex;
7. Yellow dot, a circular route, on which tourists can reach Vârful cu Dor;
8. The route marked with a red dot, the only one that passes through the river valley, in the gorge sector, and which was validated in the field during the study analysis.

As for the transport network, the main road is DJ713, known as Transbucegi, which is translated as "the road that crosses the Bucegi Mountains". This is one of the most frequented roads by tourists, the main reason being natural elements such as the landscapes, viewpoints, and recreation. The road opens in April and closes during the winter due to the constant snowfall, which poses a potential danger to people. At the same time, due to frequent use and vibrations caused by cars, concrete walls and gabions have been installed in places prone to landslides, both designed to protect road users from possible accidents.

In addition to the tourist trails and paved roads, there are forest roads within the basin, which is a mountainous area covered mostly by forest. These are mainly used by the authorities in the field, rarely by tourists or locals.

Last but not least, the ski infrastructure is well developed in the Bucegi Mountains. The factors that positively influence their development are the steep slopes and their location on the shaded slopes. Some of them coincide with tourist trails and, in most cases, practitioners use them instead of paths to shorten the route. An example of this is the slope at Cota 1,400, which coincides with the red trail.

To connect the towns (Sinaia and Bușteni) and the slopes, cable cars, gondola lifts, chairlifts, and ski lifts have been installed. The first two are located in the eastern part of the massif, crossing the steep area, and the latter are located within the slopes to facilitate the ascent/descent routes. Among the most well-known are the Babele cable car, which transports tourists to the geomorphosite, the 1,400-meter cable car, and the Carp gondola lift, the latter two serving the main purpose of transporting people to the slopes.

In conclusion, the road and ski infrastructure developments contribute to facilitating tourist activities and are themselves points of interest for recreational purposes. They also contribute to the economy of the area, being sources of income for locals and employees in the field. However, it must be taken into account that these developments can have a significant impact on the relief, as the removal of vegetation, soil compaction, or slope modification can increase surface erosion, alter drainage patterns, and affect slope stability.

4.2.2. Tourist and pastoral facilities

Certainly, closely related to the previous subsection, with the presence of roads and investments in the area, points of interest for tourists have also appeared, targeting several facilities such as accommodation, food, sports, and recreation to help them. Thus, there are tourist cabins such as Cabana Babele, Cabana Cota 1,400, and Cabana Valea Dorului. In the sphere of recreational facilities is also the Piatra Arsă Cabin, a place of significance for athletes, as it is the headquarters of the sports base, hosting annual training camps. According to CSN Piatra Arsă (n.d.), training at high altitudes contributes to improving the body, due to the low pressure and rarefied air, as these factors force the body to adapt and work in favor of blood circulation. Therefore, thousands of athletes visit the area every year and train in camps or individually.

The Bucegi Plateau, due to its characteristics, also favors pastoral activities, as the area is covered with dwarf vegetation, especially grass, and over time, sheepfolds have been developed and arranged. Many of these are only used in the summer, immediately after the snow melts, with shepherds bringing their animals down to nearby villages or settlements located at lower altitudes, the main reason being, of course, the low temperatures that come with thick snow cover, blizzards, heavy rainfall, and the lack of vegetation, which is the main source of food for sheep, goats, and cattle (Huband et al., 2010). There are several sheepfolds in the analyzed river basin (Figure 6), located in the southern part of the massif due to its favorable conditions during transhumance, lower altitudes, and proximity to the localities, aspects in accordance with the pastoral model identified in the Carpathians (Huband et al., 2010).

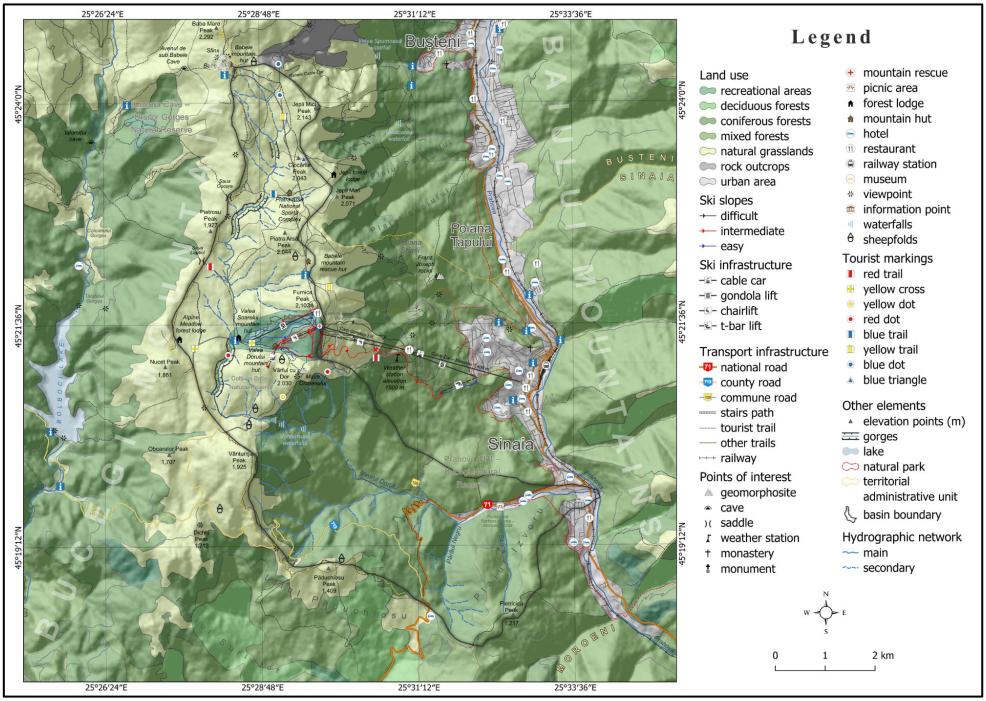

Figure 6. Tourism and infrastructure map of the Izvorul Dorului hydrographic basin and its surroundings.

5. Conclusion

The main objective of the study was to analyze the Izvorul Dorului River basin from a geomorphological perspective, using methods specific to applied geomorphology, as well as data, graphic and cartographic materials, and images obtained through field validation. Related elements such as relief, geology, hydrography, and the impact of anthropogenic activities were analyzed due to their influence on the morphological balance of the basin.

In this approach, the study of morphometric parameters and active geomorphological processes helped to find areas with high vulnerability to erosion and slope instability. This happens especially in areas with very steep slopes and highly fragmented reliefs, but also in areas affected by torrent networks. From the point of view of applied geomorphology, the identification of these fragile areas is of particular importance. This is especially true when discussing tourism development and the necessary infrastructure in a mountainous area such as the Izvorul Dorului Valley. The information obtained can help make important decisions regarding the location or management of tourism infrastructure, access roads, or other human activities. Thus, the results of the study can help identify measures to reduce risks related to the existence of geomorphological processes. These measures include monitoring vulnerable sectors, limiting human activities in sensitive areas, or adjusting land use planning according to the geomorphological characteristics of the basin. Through these actions, natural disasters can be prevented and the environment is protected at the same time. Geomorphological risks can be reduced by adopting prevention and land management strategies. The present study has some limitations, mainly related to the sequential field observations. The lack of instrumental monitoring of the geomorphological processes present in the basin was another weak point. From a scientific point of view, the study provides preliminary support for future research aimed at assessing risks and integrating them into the territorial planning of the area.

In conclusion, the applied geomorphological study of the Izvorul Dorului River basin highlights the complexity of the interactions between natural and anthropogenic factors. The purpose and objectives of the study have been achieved and they emphasize the importance of understanding the dynamics of the relief in the context of human activities and pressures. In the case of future research, it is desired to observe active geomorphological processes in the field for a longer period of time. Therefore, following the collection of data taken over time, a detailed assessment of the active processes would be possible and the risks involved in the study area would be better exposed. It is also intended to carry out a study of anthropogenic impact on geomorphological dynamics by correlating the pressures generated by tourist infrastructure with consequences in the geomorphological system in order to identify and reduce the risks present in the basin area.

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