Quantitative morphometric characteristic of the relief in the Ialpug hydrographic basin, Republic of Moldova

Caractéristique morphométrique quantitative du relief du bassin hydrographique de l'Ialpug, République de Moldavie

Angela CANȚÎR[1]*

[1] Moldova State University, Institute of Ecology and Geography, Republic of Moldova

* Correspondence to: Angela CANȚÎR. E-mail: angelamadan87@gmail.com.

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ABSTRACT: The aim of our study was to determine the morphometric characteristics of the Ialpug hydrographic basin. Morphometric parameters are essential for a complete understanding of the relief in a given territpry. Morphometry provides key elements for describing geomorphological conditions. Classical morphometric parameters were calculated and analyzed using spatial analysis in geographic information systems (GIS), based on the SRTM digital elevation model for the Republic of Moldova. The main results include relief parameters such as hypsometry, slope, aspect, and relief dissection (horizontal and vertical amplitude). GIS technologies allowed the creation of thematic maps for the key morphometric relief indicators. Each parameter was analyzed quantitatively and represented graphically for better comprehension. The results, supplemented by soil and geomorphological data, can be used for detailed geomorphological and pedological analysis of the basin area.

KEY WORDS: morphometric characteristics, hydrographic basin, digital elevation model, south region, Republic of Moldova.

RÉSUMÉ : L'objectif de notre étude était de déterminer les caractéristiques morphométriques du bassin hydrographique de l'Ialpug. Les paramètres morphométriques sont essentiels pour une compréhension complète du relief d'un territoire donné. La morphométrie fournit des éléments clés pour décrire les conditions géomorphologiques. Les paramètres morphométriques classiques ont été calculés et analysés à l'aide de l'analyse spatiale dans des systèmes d'information géographique (SIG), basés sur le modèle numérique d'élévation SRTM pour la République de Moldavie. Les principaux résultats incluent des paramètres de relief tels que l'hypsométrie, la pente, l'aspect et la dissection du relief (amplitude horizontale et verticale). Les technologies SIG ont permis de créer des cartes thématiques des principaux indicateurs morphométriques du relief. Chaque paramètre a été analysé quantitativement et représenté graphiquement pour une meilleure compréhension. Les résultats, complétés par des données sur les sols et les processus géomorphologiques, peuvent être utilisés pour une analyse géomorphologique et pédologique détaillée du territoire du bassin.

MOTS CLÉS : caractéristiques morphométriques, bassin hydrographique, modèle numérique d'élévation, région sud, République de Moldavie.

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1. Introduction

Morphometric analysis is a set of procedures that characterize the geometric and compositional aspects of environmental systems, serving as indicators of the related shape, structural arrangement and interaction between the morphometric aspects and the totality of soil data and geomorphological processes in a watershed in situations and values that intensify pedological and geomorphological problems. (Horton, 1945; Mishra & Nagrajan, 2010).

Morphometric parameters, including length, slope, and slope shape, act as key determining factors in the landscape, interacting with other elements such as the type and intensity of various processes. These characteristics of the land surface are influenced not only by the dynamic behavior of these factors but also by the ongoing changes within the landscape over time. As such, the evaluation of morphometric features reflects both the direct impact of these processes and the subsequent transformations that occur in the terrain as a result of these interactions.

Morphometry implies the measurement and quantitative analysis of various parameters, which outline the shape and configuration of landforms. It provides valuable information on the triggering features of erosion, landslides and other land surface shaping processes. In particular way, a correct understanding of river morphometry (river drainage, river density) is important in studying and interpreting these aspects (Shekar & Mathew, 2022).

This method gives a complex characteristic of the relief of the researched territory based on the topographical material: the characteristic of the altitudes (hypsometry), the angle of the slope, the depth and the density of the fragmentation of the relief, etc. (Cantir & Ciolacu, 2023).

Morphometric studies of the relief in the Republic of Moldova are crucial for understanding the geomorphological processes shaping the territory, providing valuable information for land management, spatial planning, and natural hazard assessment. Although morphometric research has been conducted in various areas of the country (Bejan et al., 2018), most of it focuses on general relief characterization or are carried out on relief units, physical-geographic areas, but less on hydrographic units (Țîțu, 2019) with limited applicability in detailed analysis of geomorphological processes at a regional scale due to methodological constraints (Volcov, 1950; Marcov, 1948).

The original contribution of this study lies in the first integrated and systematic morphometric characterization of the Ialpug hydrographic basin at a 30 meter resolution. This research focuses on a large basin in the southern part of the republic of Moldova, contributing to filling gaps in the existing literature by providing a regional scale relief characterization. It highlights key aspects for future ecological analyses, land use planning and hydrotechnical plannig in the southern region od the country.

2. Study area

The Ialpug River starts from the northern part of the Ialpug village (Cimișlia district, Republic of Moldova), runs a length of 142 km until it flows into the Ialpug lake (Bolgrad region, Ukraine) (Cazac, 2017; Eremia, 2018). The reception basin of the Ialpug river is 3180 km2 (of which 3165 km2 are located on the territory of the Republic of Moldova), and its 142 km long, 135 km are on the territory of our country. (Report of the Ministry of the Environment of the Republic of Moldova, 2002).

From the point of the geomorphological division, the Ialpug river basin is located on the Ialpug Depression (the largest part of the basin), the Tigheci Hills and the Cahul Plain (Figure 1) (Sîrodoev and Boboc, 2006; Sîrodoev and Boboc, 2019). Thus, the relief of the basin is characteristic a relief of a dismembered plain, strongly fragmented by valleys.

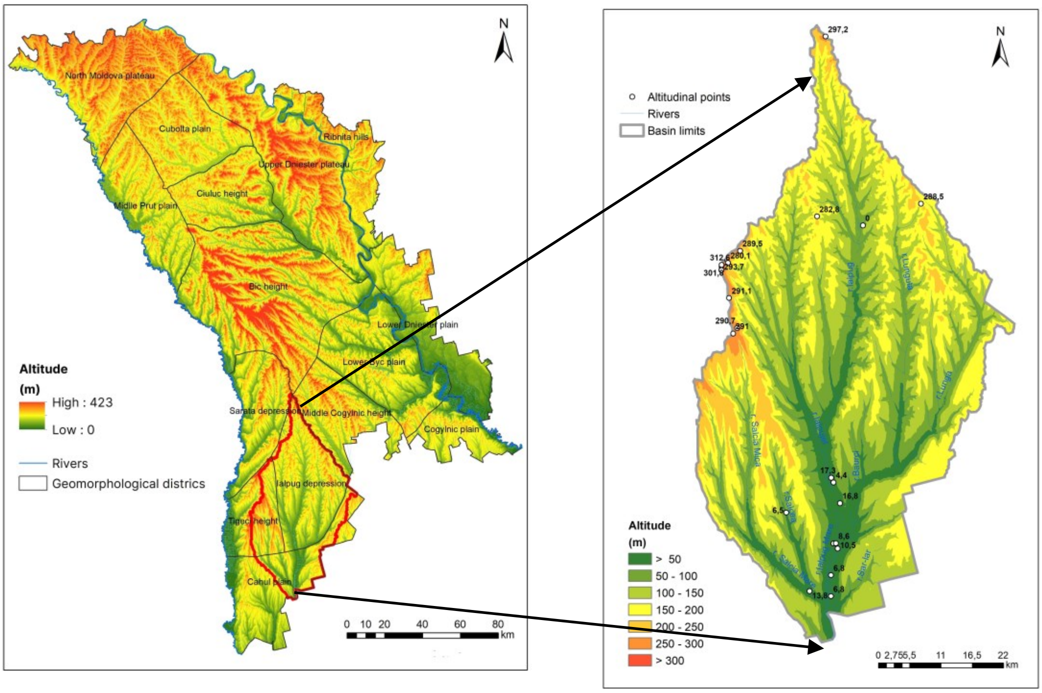

Figure 1. The geographical position of the Ialpug hydrographic basin

The maximum altitudes (312 m) are recorded in the western extremity of the basin, and the minimum (0,64 m) are recorded in the river valleys, tributaries of the Ialpug, more precisely in the meadow of the Salcea river and the lower course of the Ialpug river.

3. Methods

The cartographic support of the Geographical Information System was provided by SRTM – Republic of Moldova (30 m). The SRTM data for Republic of Moldova (as primary data) was obtained by visiting the NASA SRTM page (https://www2.jpl.nasa.gov/srtm). After downloading the SRTM data at 90-meter resolution, the transformation to a 30-meter resolution was performed using a process called resampling. Some datasets were processed to fill data voids, enhancing their usability for analysis. For example, elevation points were corrected for errors (singularities), and the corrected points were georeferenced from the MOLDREFF coordinate system to the WGS 84 – UTM 35 system (https://www.betastudio.eu/0750_moldavia/).

The territory of the Ialpug hydrographic basin was extracted using the "Extract by Mask" tool in the ArcToolbox window in ArcGIS 10.8.2 by following these steps: First, in the ArcGIS project, the input raster and the polygon feature representing the basin boundaries were added. Then, navigate to Spatial Analyst > Extraction > Extract by Mask in the ArcToolbox window. For the Input raster, select the SRTM, for the Feature Mask Data, select the basin polygon, specify the name and location for the Output raster, and click OK (https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/extract-by-mask.htm).

For the morphometric analysis of the studied region, was used the same software, that allows the development of high-precision maps within the limits of the cartographic base taken as a starting point. All developed maps are made with the help Spatial analyst tool.

To enable the calculation and statistical analysis of the morphometric parameters, the raster layers were transformed into vector layers (polygons). This transformation allowed the quantification of these indices for a more detailed analysis. The raster-to-polygon transformation was performed using the Conversion Toolbox > Raster to Polygon tool. The attribute table was then exported to Excel, where all mathematical calculations were carried out. The processing of quantitative statistical data related to the morphometric parameters and their graphical representation was made possible with the help of the Excel program and its built-in graphical visualization tools.

4. Results and discussion

Morphometric indicators allow us to provide a comprehensive characterization of the relief of a region. These characteristics are an important tool in the geomorphological analysis of a territory, offering both quantitative and qualitative data related to the surface of the studied area (Craciun, Bejan, 2019).

Any characterization of the relief of a territory, in this case, the Ialpug hydrographic basin, begins with data on its hypsometry. From a morphometric perspective, the relief of the Ialpug hydrographic basin is relatively fragmented. The maximum altitude (312 m) is recorded at the western extremity of the basin (west of the town of Capaclia, Cantemir district), while the minimum altitude (0, 6.4 m) is found in the river valleys, tributaries of the Ialpug, more precisely in the meadow of the Salcea river and the lower course of the Ialpug river. The average altitude is 158 m. The hypsometric map (Figure 3) shows seven altitudinal steps, which are categorized in 50-meter altitude intervals.

This type of categorization is more convenient in terms of linking the elevation of the relief to other morphometric indicators and their relation to geomorphological processes. It is also a categorization commonly used in all models encountered in the Republic of Moldova. The histogram of areas by hypsometric classes (Figure 2) shows that the largest surface area of the basin is located within the 100-150 m altitude range (36.27%), while the smallest area corresponds to territories with altitudes greater than 300 m (0.03%).

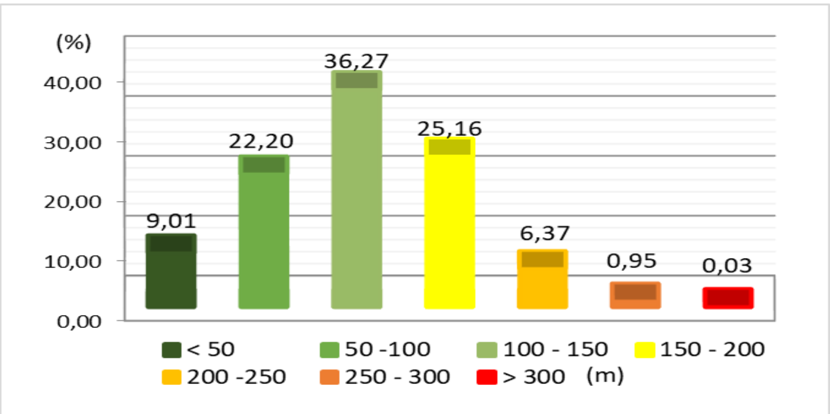

Figure 2 Histogram of areas by hypsometric classes.

Lands with altitudes of 50-100 m and 150-200 m are distributed approximately equally, with weights of 22.2% and 25.16%, respectively. About 10 percent of the territory lies at altitudes of up to 50 m. The altitudinal step between 200-250 m has a weight of 6.37%, while the territories with altitudes between 250-300 m represent less than 1%.

An important indicator in relief analysis is **the slope** or **declivity** (Figure 4). The term "declivity" is used instead of "slope" in some works (Roșian, 2011) when the analysis refers to the inclination of slopes or relief forms and aims to evaluate whether a territory is suitable for certain anthropogenic activities, particularly construction. This parameter is also evaluated in terms of slope, considering whether it serves as a triggering factor for slope processes (in our case, landslides) or as a factor that favors the formation of new relief forms by promoting drainage and erosion processes (Dănuț and Bilașco, 2014).

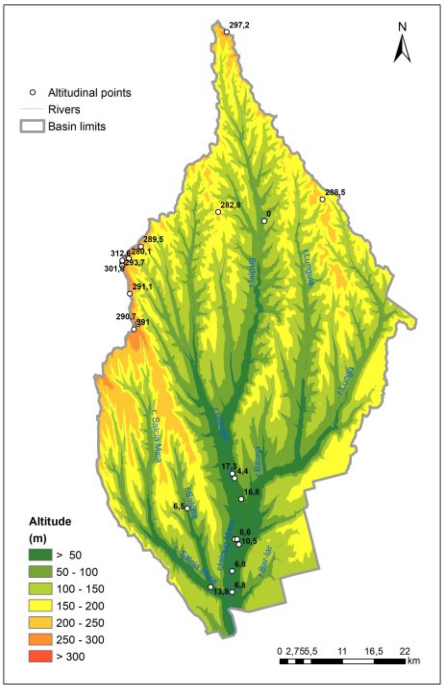

Figure 3 Hipsopmetric map of the basin.

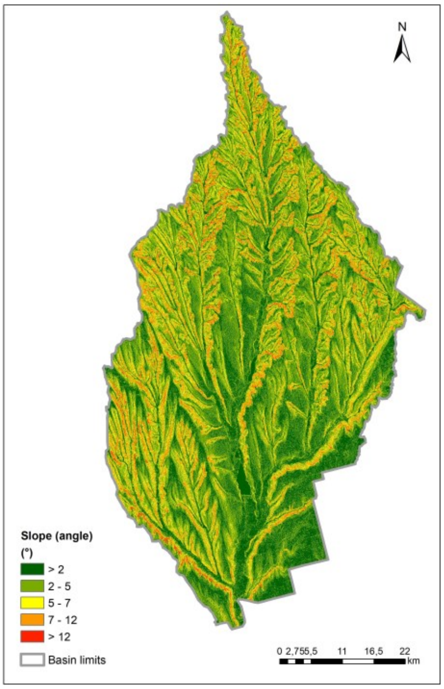

Figure 4. Slope map.

The slope map was created based on the numerical terrain model. In the Ialpug basin, the slope values were classified into five classes (Figure 5). According to the histogram, it can be seen that slopes below 2° cover approximately one-quarter of the entire surface of the basin, with the highest percentage found in surfaces with a slope angle between 2-5° (48.26%). According to Irimus Ioan Aurel's classification (Irimuș, 2005), these surfaces are moderately inclined, on which geomorphological processes such as landslides and linear erosion can be identified. Restrictions on agricultural activities are imposed on these territories, as well as on areas intended for construction.

As for the next two categories, 5-7° (14.92%) and 7-12° (11.83%), these are considered inclined surfaces. Linear geomorphological processes and landslides are well developed here, and they also impose restrictions on agricultural activities. Surfaces with a slope angle greater than 12° are already considered areas with steep inclines, imposing major restrictions on the construction of buildings and the access of agricultural machinery. In the basin area, these surfaces are associated with landslide escarpments.

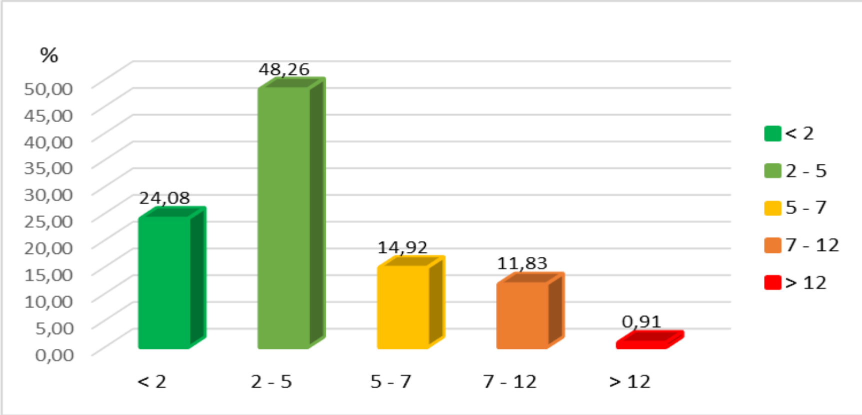

Figure 5 Histogram of ereas by slope classes.

The development of human activities and their expansion across the hydrographic basin depend to a considerable extent on the density and depth of relief fragmentation (Figures 6, 7). For example, the density of relief fragmentation can affect agricultural fields or areas for the construction of communication and transport routes, even on surfaces with low altitudes.

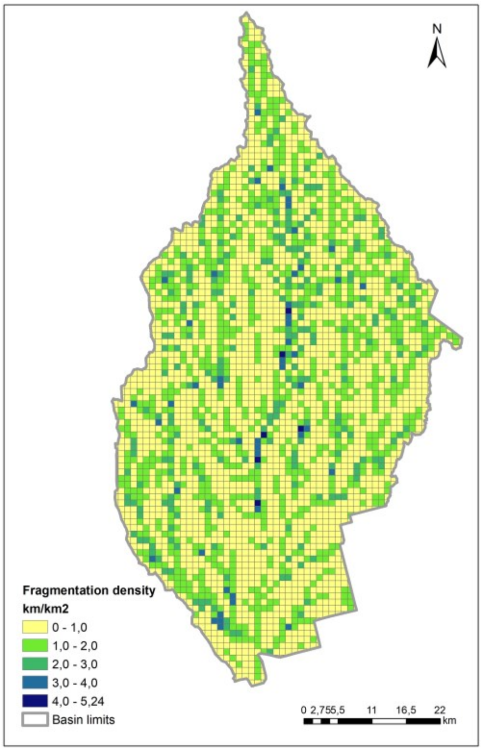

Figure 6 Drenaige density map.

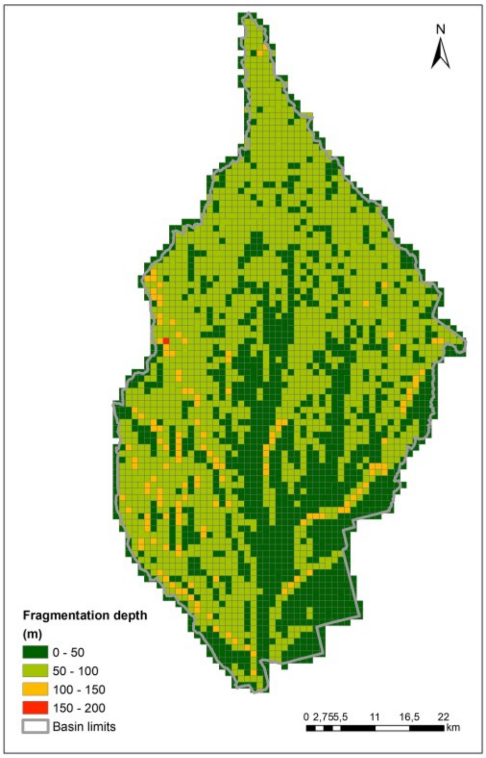

Figure 7 Relief depth fragmentation map.

The relief fragmentation density map was created using the cartogram method, with the ArcGIS program. Relief fragmentation density, or the horizontal fragmentation of the relief, is defined as the total length of the hydrographic network relative to the total surface area of the territory, with the unit of measurement being km/km². Lands that do not exceed a value of 1-1.5 km/km² are considered to belong to the category of lands with low fragmentation density (Bilașco et.al, 2013). Following the classification used in this article, more than 60% (Figure 8) of the basin's territory falls into the category of lands with low relief fragmentation density. This suggests that these areas are suitable for agricultural and other anthropogenic activities, provided they are not restricted by other morphometric parameters. About 30% of the basin area falls into the category of lands with low to medium-density horizontal fragmentation, while high-density lands account for approximately 10% of the total basin area (2-3 km/km², 7.74%; 3-4 km/km², 1.5%; >4 km/km² represents only 0.19%).

Vertical fragmentation of the relief represents the difference in elevation between the maximum and minimum altitudes within a square with a side length of 1 km. For the 50 x 50 meter classification, the surface of the Ialpug basin was divided into four classes (Figure 9). The average value of vertical fragmentation is 65 m. The territories with fragmentation up to 50 m and those with fragmentation between 50-100 m have the highest values in the studied area (42.1% and 54.06%, respectively). Territories with fragmentation greater than 100 m occupy negligible areas, constituting less than 4% of the basin's total area.

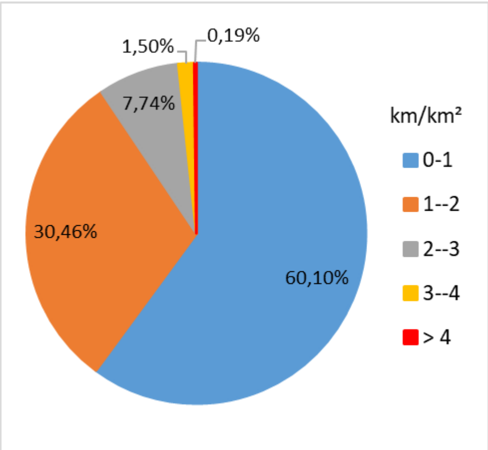

Figure 8 Share of relief fragmentation density.

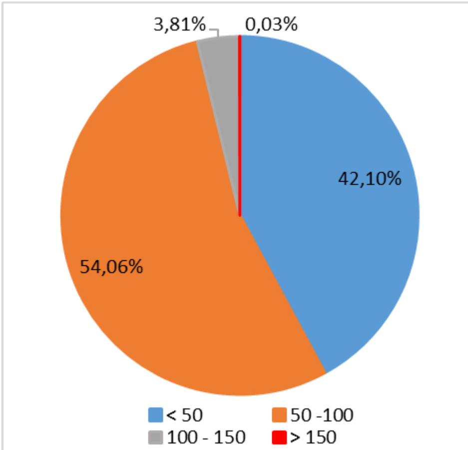

Figure 9 Share of the relief fragmentation depth.

The last morphometric index, though not least important for relief analysis, is slope orientation or slope exposure (Figure 10). This index plays a very important role in territorial planning, particularly in the fields of construction and land use. By studying the distribution of surfaces with different orientations (Figure 11), it can be observed that the largest areas are occupied by lands with predominantly eastern (20.72%) and western (16.64%) orientations, together representing more than one-third of the hydrographic basin. The lands with southwest (13.59%), northeast (13.10%), and southeast (12.12%) orientations occupy approximately equal areas. The smallest areas are those with southern (8.25%), northern (7.89%), and northwestern (7.69%) orientations, each of which covers roughly equal surface areas.

The orientation of the slopes also influences the development of geomorphological processes, depending on the amount of solar radiation and temperature, which are unevenly distributed across the land surface. A clear example is the fact that slopes with northern exposure are shaded (Andron, 2017; Irimuș, 1997). Because of this, they are more humid, and under the presence of clay-sand rocks, they are more prone to landslides.

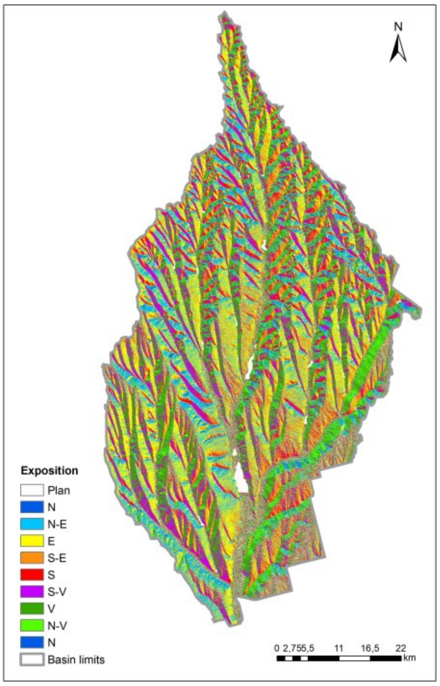

Figure 10 Slope exposure map.

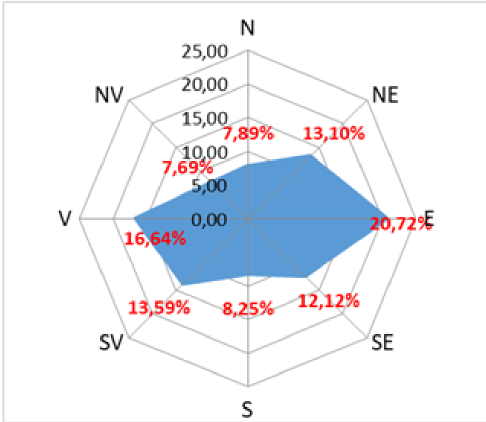

Figure 11 Slope exposure.

5. Conclusion

The morphometric analysis of the Ialpug hydrographic basin reveals that approximately 26% of the basin is composed of inclined surfaces, where geomorphological processes such as landslides and erosion are active.

The slope distribution shows that more than 40 % of the basin is characterized by moderate slopes (2-5°), which are favorable for agricultural use but prone to geomorphological processes. Steeper slopes (above 7°) account for about 26 % of the basin. These areas, predominantly located at medium altitudes (100–200 m), are subject to restrictions for construction and agricultural activities.

High-density fragmentation areas (2-3 km/km²) cover about 8% of the basin, and these areas are associated with more pronounced vertical fragmentation (above 100 m). These features highlight the discontinuity of the relief, which is critical for planning transportation routes and evaluating land stability for construction.

The morphometric study of the basin provides essential data for evaluating geomorphological risks and planning land development activities, such as agriculture, construction, and infrastructure development. It is an indispensable step in the initial phase of any territorial study, guiding the suitability of land for various anthropogenic uses.

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