

Introducing the Geomorphometric Atlas of Romania: A Publicly Available Database of Landform Classifications and Land-Surface Variables based on FABDEM

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Abstract— This paper introduces the first national geomorphometric atlas of Romania, an open-access database developed to support detailed terrain assessment and landform characterization. The atlas integrates established landform classification frameworks and a broad set of morphometric variables derived from the 30 m Forest and Buildings Removed Copernicus Digital Elevation Model (FABDEM). To accurately represent Romania's diverse topography, land-surface parameters (LSPs) and landform types were computed across multiple spatial scales based on the country's specific topographic grain. The atlas includes both common and lesser-used morphometric indices, derived using automated methods in SAGA GIS and WhiteboxTools' Geomorphometric Analysis toolbox. All processing was conducted in Romania's national coordinate system, Stereo70 (EPSG:31700), and results were reprojected to Web Mercator (EPSG:3857) only for web-based visualization. The derived data layers were produced in full compliance with FABDEM's non-commercial license; no redistribution of the raw elevation data occurs. Available through ArcGIS Online and Google Drive, the atlas provides a standardized, high-resolution resource to support geoscientific research, environmental modeling, and spatial planning. Its open-access design enables users to visualize and analyze terrain properties from national to local scales, contributing to improved understanding and practical use of Romania's geomorphological landscape.

I. INTRODUCTION

Geomorphometric atlases provide standardized datasets for applications in geomorphology, environmental research, and land-use planning. Several global and continental-scale atlases have been developed, such as those by [1], which derived core morphometric variables from the SRTM dataset at 90 m resolution, and [2], which focused on statistical terrain attributes.

More recently, global initiatives like Geomorpho90m [3] have used MERIT DEM at 90 m to generate multi-variable morphometric datasets for hydrological, geological, and environmental modeling.

At the European scale, projects such as the EcoDataCube [4] have created integrated geospatial platforms linking morphometric indicators with open satellite and environmental data. Other studies [5, 6] have explored automated topographic classification using cloud-based tools like Google Earth Engine.

Despite these advancements, no high-resolution, country-level geomorphometric atlas has been available for Romania. To address this gap, the Geomorphometric Atlas of Romania was developed as an open-access database based on the 30 m FABDEM elevation product. This atlas includes landform classification outputs and a broad set of derived morphometric variables computed at multiple spatial scales tailored to Romania's specific topographic grain.

This work builds upon a previous framework introduced by Ioniță et al. [7], which focused on landform classifications from SRTM and MERIT DEM data. In contrast, the present study integrates FABDEM, expands the morphometric parameter set, introduces topographic grain calibration, and improves public accessibility through a standardized WebApp and downloadable datasets. The atlas is designed to support interdisciplinary applications in geomorphological mapping, environmental monitoring, spatial planning, and hazard assessment.

II. METHODS AND DATA

A. Landform classifications

The atlas integrates eight internationally recognized landform classification approaches, alongside Romania's national physiographic delineation [8] and the geomorphons method [9], each based on distinct methodologies and source data (Fig. 1). These include both pixel-based classification techniques [10, 11] and object-based segmentation models [6, 12], capturing a wide variety of topographic forms. Classifications rely on standard morphometric inputs such as slope, surface texture, curvature, local convexity, and hydrological indices.

reached around a window size of 330 m, used as a reference for further derivations.

Key LSVs such as slope, aspect, profile and plan curvature, convexity, and ruggedness were computed in SAGA GIS and WhiteboxTools [17, 18]. Goodness of Fit (GOF) metrics were used to validate the curvature-derived variables [19], while multiscale hillshades helped highlight DEM inconsistencies [20]. The variable suite also includes Stream Power Index, Topographic Wetness Index, and Connectivity Index, as well as more advanced parameters such as elevation deviation, openness, standard deviation of slope, angular deviation, and various curvature-based

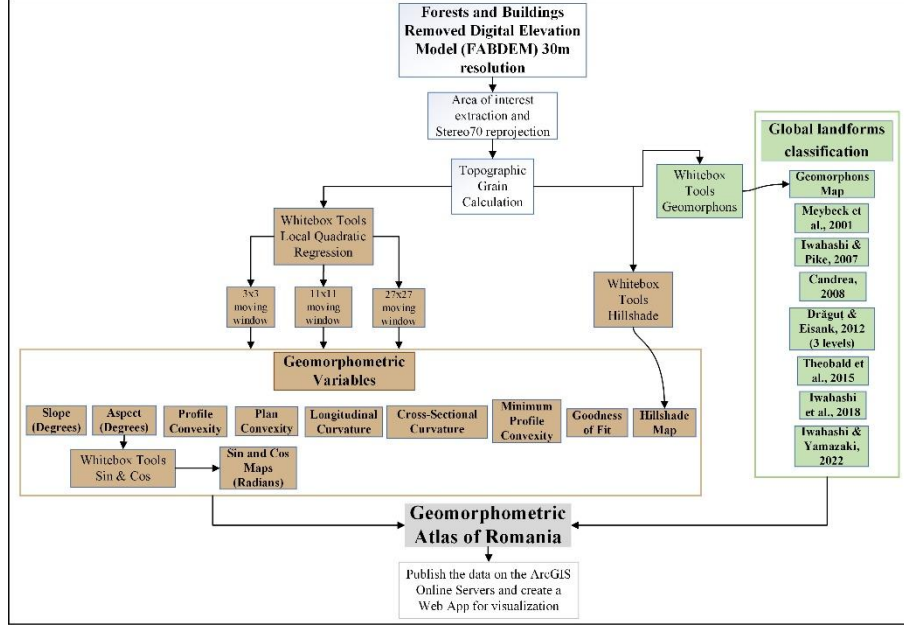


Fig. 1. Workflow used to generate the geomorphometric atlas, including DEM preprocessing, multiscale LSV computation, landform classification, and WebApp integration [7]. Newly derived variables are detailed in Sections II and III.

Among the most widely used frameworks, [13] defined terrain types using GTOPO30 at 1 km resolution, while [11] and [12] applied automated classification models using SRTM and MERIT DEMs. The Romanian national physiographic delineation [8] was digitized from geologic and topographic maps, and the geomorphons method [9] used terrain texture to assign landforms via pattern recognition. Together, these models provide a diverse basis for multiscale terrain unit identification.

All classification layers were reprojected into Romania's national coordinate system, Stereo70 (EPSG:31700, also referred to as EPSG:3844 in updated registries), for consistency in scale-sensitive analysis. Final results were visualized via ArcGIS Online using a new WebApp developed for this version of the atlas.

B. Morphometric variables

The morphometric variables (LSVs) were derived from FABDEM, a global 30 m elevation model corrected for vegetation and buildings [14]. To define Romania's characteristic topographic grain, a moving window analysis was applied using multiple spatial scales, following [15] and [16]. Grain stability was

metrics (e.g., total, mean, Gaussian, minimal, maximal, tangential).

For morphometric computations, the atlas employs WhiteboxTools [19], a geomorphometric analysis software integrated into ArcGIS Pro, utilizing Local Quadratic Regression [20]. The analysis derives Slope, Aspect, Profile Convexity, Plan Convexity, Longitudinal Curvature, Cross-Sectional Curvature,

Minimum Profile Convexity, and Goodness of Fit (GOF). The Hillshade module was also applied to highlight terrain relief and identify potential DEM errors (Fig. 1).

These newly derived LSVs—absent from the earlier Journal of Maps version [7]—were integrated into a new WebApp, allowing users to visualize and compare thematic layers at national and regional scales.

C. Data Distribution and Web Application

To ensure compatibility with web-based platforms, all raster outputs were reprojected from Stereo70 (EPSG:31700) to Web

Mercator (EPSG:3857) for online viewing. Raster datasets were converted to tile layers and vector datasets to vector tiles, enabling smooth multiscale navigation. The updated WebApp, redesigned from the previous [7] version, includes a broader set of thematic layers grouped by LSP type, as well as new tools for base map switching, cross-variable comparison, and location-specific querying.

The full atlas is accessible online via ArcGIS Online and downloadable through Google Drive. All derived products comply with FABDEM's non-commercial license. No raw elevation data is redistributed.

III. RESULTS

Topographic grain analysis identified an optimal analysis window size of 330 m (11×11), with a broader grain threshold observed around 810 m (27×27). A standard 3×3 window was

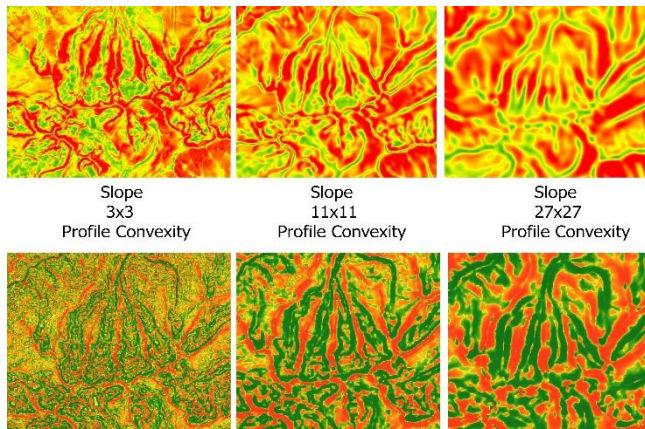


Fig. 2. Comparison of two key land-surface variables—slope and profile convexity—computed at three spatial analysis scales (3×3 , 11×11 , 27×27). The figure illustrates how increasing topographic grain size generalizes terrain detail and affects morphometric expression.

also included for baseline comparison. These three reference scales were used consistently throughout the atlas to compute landform classifications and morphometric variables tailored to Romania's terrain variability.

Based on the methodologies described, a total of twelve landform classification maps were generated, integrating both global models and region-specific frameworks (Fig. 2). Geomorphons-based classifications were computed at all three analysis scales, using a flatness threshold of 1° , to highlight variations in landform structure under different spatial generalizations.

Using WhiteboxTools and SAGA GIS, an expanded set of 27 morphometric variables was derived at multiple scales, including slope, convexity, profile and plan curvature, roughness metrics, and directional derivatives. The core LSVs (Slope, Aspect, PROC, PLAC, LONC, CRSC, PRCM) were initially computed at 3×3 , 11×11 , and 27×27 window sizes, resulting in a total of 21 terrain maps from this base group alone. Additional variables, such as angular deviation, curvature variance, elevation

percentile, elevation extremes, terrain openness, topographic position index, and multiscale deviation indices were computed to support nuanced topographic interpretation.

A notable extension beyond the earlier work [7] is the inclusion of these newly derived LSPs, which were not present in the initial release. These additions substantially enhance the atlas's capacity to represent complex terrain morphologies at both macro and micro scales, supporting a broader range of geospatial analyses.

All results were standardized, thematically grouped, and incorporated into a newly developed WebApp, redesigned from the original version, to support multiscale interactive visualization and spatial exploration.

IV. DISCUSSION

A key innovation introduced by this atlas is the determination of Romania's optimal topographic grain, which is essential for scale-sensitive geomorphometric analysis. By calibrating land-surface parameters across representative spatial windows, the atlas offers a scalable framework applicable to both national and sub-regional studies. The 330 m grain size is tailored to the 30 m FABDEM input and national-scale application; regional analyses or higher/lower resolution DEMs would require recalibration to ensure scale compatibility with terrain variability.

The atlas supports a wide range of disciplines, including geomorphology, hydrology, geology, forestry, environmental sciences, agriculture, and spatial planning. By offering ready-to-use terrain indicators, the database enables users without specialized GIS or DEM processing expertise to access critical morphometric information. This standardization also reduces the need for redundant calculations and facilitates the integration of terrain variables into applied research.

Despite these advantages, certain limitations exist. The atlas is constrained by the 30 m resolution of FABDEM, as no higher-resolution open-access DEM currently exists for Romania.

The WebApp is accessible at the address: <https://experience.arcgis.com/experience/9be599ab17c049c9bf1a93203197156f> (Fig. 3).

The original dataset can be downloaded publicly from the following address:

https://drive.google.com/drive/u/1/folders/1FHn_Jb-QmmiSop0wM77IMLbzAaHt1zTt

V. CONCLUSION

This study addresses a key data gap in Romania by providing a national-scale, open-access geomorphometric atlas based on 30 m FABDEM data. Through the derivation of standardized land-surface parameters and landform classifications across multiple spatial scales, the atlas enables accurate topographic assessment for diverse environmental and geoscientific applications.

By integrating newly derived morphometric variables—such as elevation deviation, curvature variance, and topographic position indicators—the atlas expands its utility for advanced terrain analysis. It supports interdisciplinary research by facilitating integration with variables from fields such as biology,

chemistry, physics, and geosciences, while also serving as a resource for national and regional planning efforts.

The atlas provides decision-makers and practitioners in agriculture, forestry, hydrology, hazard management, and environmental policy with accessible, pre-processed terrain information. Its open-access format encourages reproducibility, promotes cross-sector collaboration, and enhances Romania's capacity for data-driven environmental monitoring and spatial policy development.

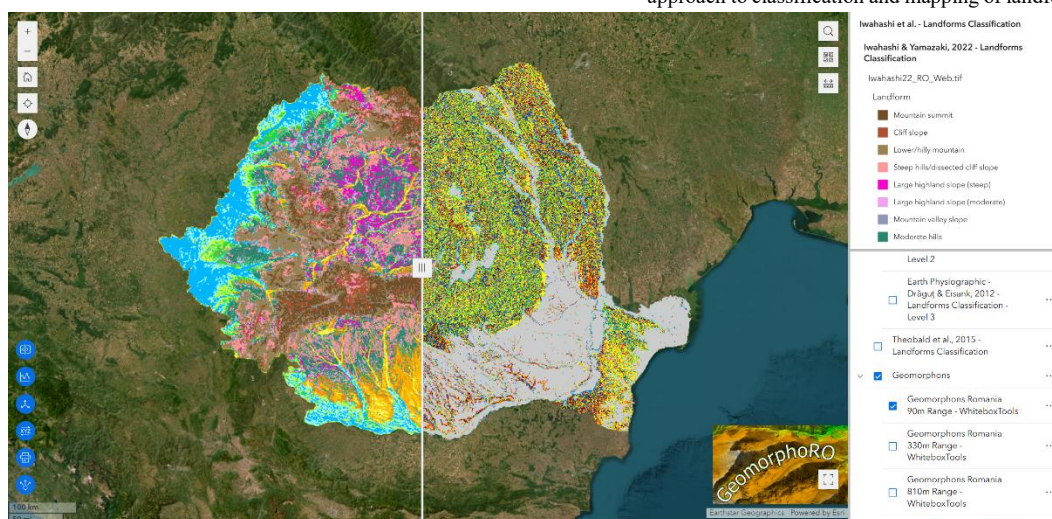


Fig. 3. The interactive WebApp for visualizing the atlas

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