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Land Cover Classification through GIS-Based Clustering of Morphometric Terrain Features: The Chepelarska River Basin (Western Rhodopes, Bulgaria)

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Abstract

This paper proposes a GIS-based approach to classifying land cover using key morphometric indicators—slope, aspect, and elevation. The study focuses on the Chepelarska River basin in the Western Rhodopes, Bulgaria, combining CORINE land cover data with digital terrain models. K-means clustering, implemented via the ArcGIS Mapping Clusters tool, was employed to identify natural groupings based on the morphometric variables. The analysis yielded four distinct land cover clusters, each defined by a unique morphometric profile. Among the examined indicators, slope and aspect proved most significant in shaping land cover distribution. The study demonstrates the potential of morphometric clustering as a practical tool for land management in mountainous terrains and highlights its innovative use within GIS-based land cover analysis.

Keywords

Land Cover Classification, GIS-Based Analysis, Mountain Land Management

1. Introduction

Land cover change is primarily driven by human activities such as urbanization, infrastructure expansion, tourism, and shifts in agricultural practices. These transformations impact ecological and hydrological systems by altering biodiversity, carbon cycles, and water regimes (Yang et al., 2024; Toosi et al., 2025). For instance, dam construction and deforestation can disrupt regional water balances and increase pollution risks through land degradation and habitat loss. Numerous studies have analyzed land cover dynamics using remote sensing and GIS across diverse regions—including Iran (Sepehri et al., 2025), Italy (Arcidiaco & Corongiu, 2025), Mongolia (Jin et al., 2025), and Nigeria (Alegbeleye et al., 2024). Geoinformation methods—particularly remote sensing, spatial analysis, and GIS—enable the collection, interpretation, and visualization of land cover changes (Lemenkova, 2021; Sovann et al., 2025). These tools reveal the spatial specificity of land use patterns, shaped by both natural and socio-economic factors (Vatseva, 2015; Gartsiyanova, 2016; Gartsiyanova, 2017). This study applies an unsupervised GIS-based classification approach using morphometric indicators—slope, aspect, and elevation—to test whether terrain variables can effectively group land cover types in mountainous environments, focusing on the Chepelarska River basin in the Western Rhodopes, Bulgaria.

2. Study Area

The Chepelarska River basin, located in the Western Rhodopes of southwestern Bulgaria (**Figure 1**), spans an area of approximately 1017.4 km^2. It lies between latitudes 41˚35' and 42˚10'N and longitudes 24˚30 and 25˚00'E. The average elevation is 1146.8 meters, and the mean slope inclination is about 18.8˚, reflecting the mountainous character of the terrain. These physical features play a significant role in shaping soil formation and the distribution of land cover across the basin. The region has a transitional continental climate (Velev, 2002), which further influences environmental conditions. Vegetation and land use vary with elevation. In contrast, the lower section of the basin, particularly north of the town of Asenovgrad, is primarily occupied by arable agricultural land (Tcherkezova et al., 2023).

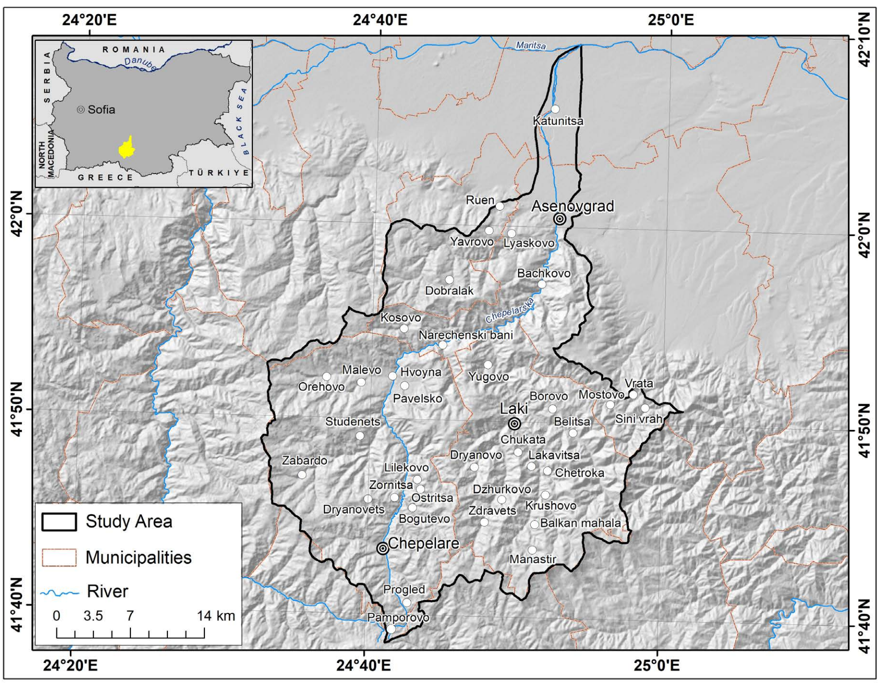

Figure 1. Study area.

3. Methodology

The diagram (Figure 2) illustrates the methodological steps undertaken in the study, from data collection and derivation of terrain parameters to cluster analysis and interpretation of results. Each stage in the workflow reflects a logical progression of spatial analysis tasks using ArcGIS tools, culminating in the unsupervised classification of land cover based on morphometric similarity.

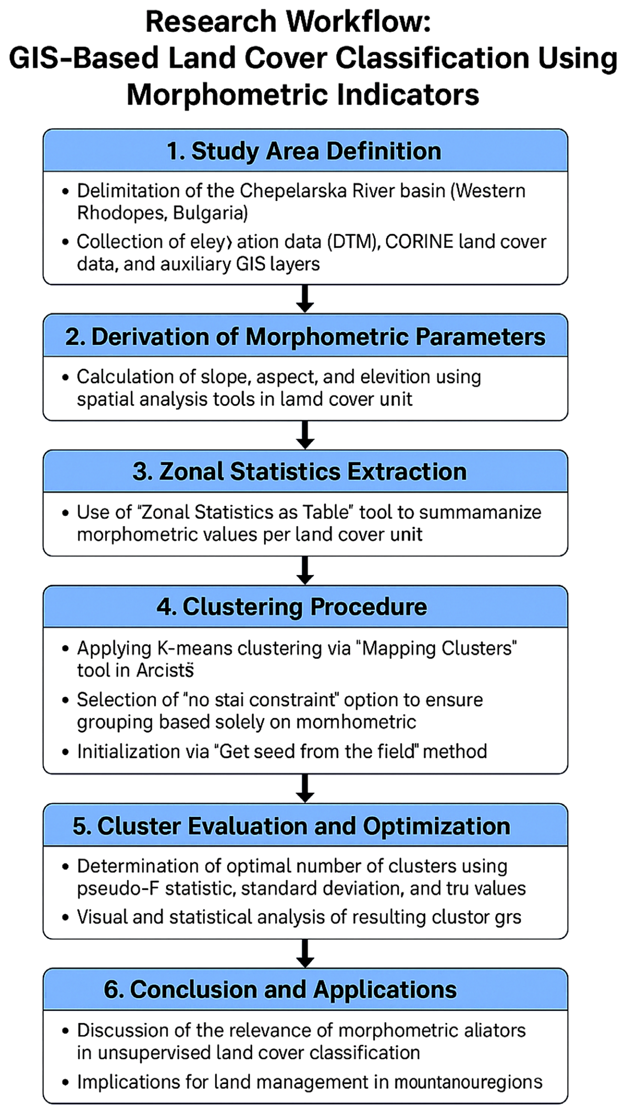

Figure 2. Research workflow for GIS-based land cover classification using morphometric indicators in the Chepelarska River Basin.

4. Results and Discussion

4.1. Morphographic Indicators

Figures 3-5 illustrate the morphographic indicators used for clustering land cover classes in the Chepelarska River Basin: slope (%), aspect (degrees), and elevation (m).

4.1.1. Slope (%)

The slope raster layer was reclassified into 10 classes (Figure 3). Most of the basin area falls into the categories of steep slopes (15 - 30%)—27,461 ha (27.09%), very steep slopes (30% - 45%)—30,759 ha (30.34%), and extreme slopes (>45%)—25,853 ha (25.50%). The steep slope class includes areas such as mineral extraction sites, sport and leisure facilities, complex cultivation patterns, agricultural land with significant natural vegetation, natural grasslands, and sparsely vegetated areas.

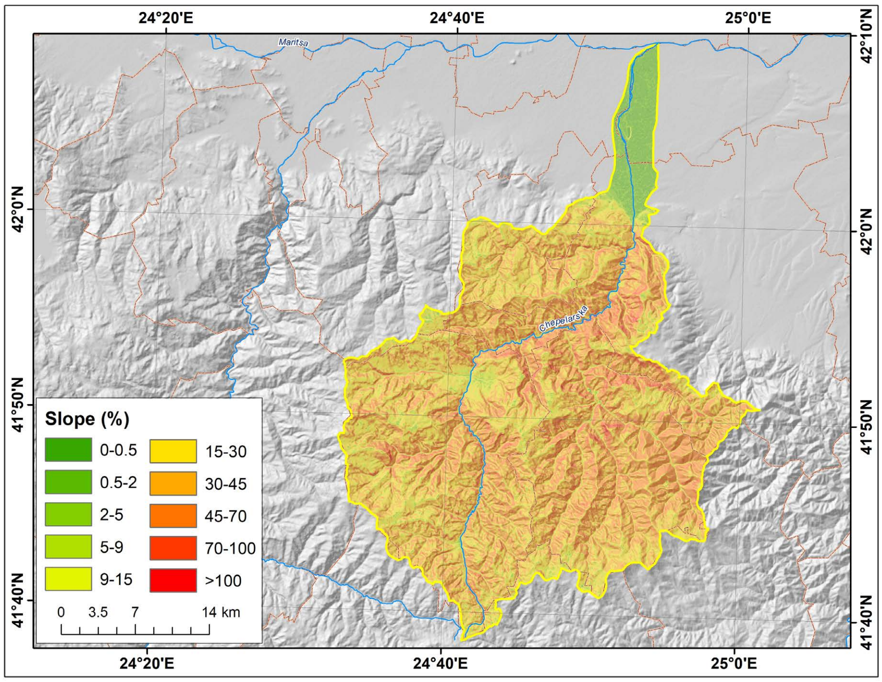

Figure 3. Slope.

4.1.2. Aspect (Degrees)

Aspect refers to the orientation of a slope, measured in degrees from 0 to 360 in a clockwise direction. The study area was divided into nine aspect classes (Figure 4). The largest areas fall under the northeast (22.5˚ - 67.5˚)—15,465 ha (15.25%), north (0˚ - 22.5˚ and 337.5˚ - 360˚)—14,768 ha (14.56%), and east (67.5˚ - 112.5˚)—13,973 ha (13.78%) aspect classes.

4.1.3. Elevation (m)

Elevation was classified based on the hypsometric division of Bulgaria (Aleksiev & Vlaskov, 2002), using five classes: lowlands (<200 m), plains and hills (201 - 600 m), hilly-low-mountain terrain (601 - 1000 m), mid-mountain terrain (1001 - 1600 m), and high-mountain terrain (>1600 m) (Figure 5). The mid-mountain class dominates the basin area—60,467 ha (59.64%), followed by the hilly-low-mountain class—21,712 ha (21.42%), and the high-mountain class—10,301 ha (10.16%). The smallest areas are the lowlands—4205 ha (4.15%) and the plains and hills—5055 ha (4.99%).

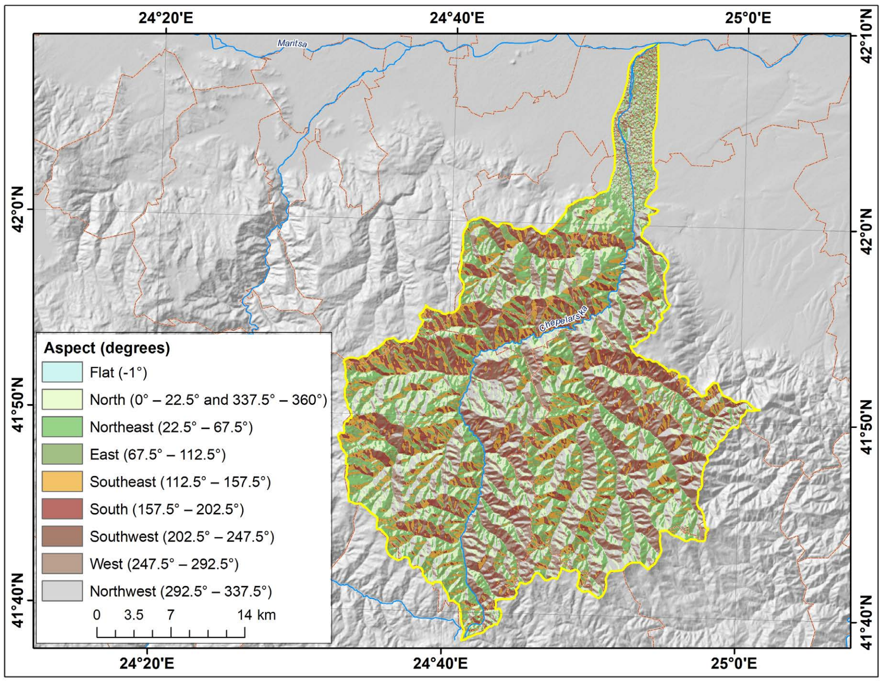

Figure 4. Aspect.

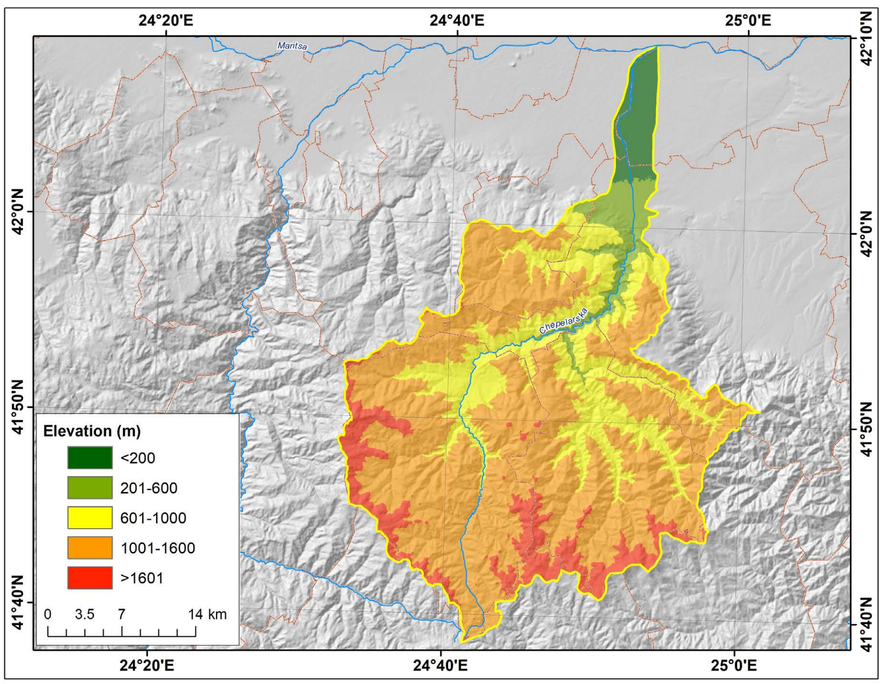

Figure 5. Elevation.

4.2. Land Cover Clusters

Figure 6 presents the clustering of land cover types based on morphographic indicators: slope, aspect, and elevation.

The land cover classes in the Chepelarska River Basin were grouped into four clusters, reflecting similarities in terrain morphology. Specific ranges of the three indicators characterize each cluster. Slope and aspect showed the strongest correlation with land cover distribution, with R^2 values of 0.90 and 0.91, respectively.

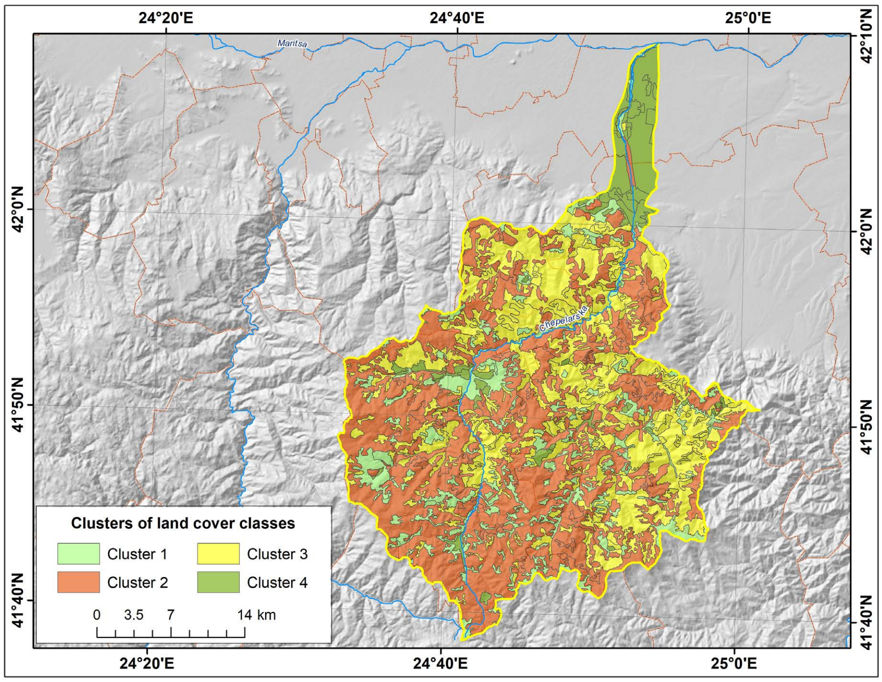

Figure 6. Land cover clusters.

5. Conclusion

This study demonstrates the effectiveness of using morphometric indicators—slope, aspect, and elevation—for land cover classification within a GIS-based framework. Through the application of the K-means clustering method in ArcGIS, four coherent land cover clusters were identified in the Chepelarska River Basin. The high explanatory power of slope (R^2 = 0.90) and aspect (R^2 = 0.91) highlights the strong influence of topographic features on land cover distribution, particularly in mountainous regions. These findings reaffirm the importance of terrain characteristics in shaping land use patterns and provide a terrain-informed alternative to traditional classification approaches that rely solely on spectral or spatial data.

Compared to previous studies that have utilized clustering algorithms such as hierarchical clustering, unsupervised K-means, or fuzzy C-means for land cover mapping, the present study uniquely integrates morphometric variables within the clustering process. This methodological distinction enables the delineation of land cover classes that align more closely with natural geographic boundaries and topographic realities. Moreover, the use of ArcGIS tools ensures that the workflow is both accessible and replicable, even for users without advanced programming skills.

The proposed approach offers practical benefits for land management, including the identification of areas prone to erosion, conservation priorities in high-elevation zones, and better-informed regional planning strategies. However, some limitations should be acknowledged. The lack of spatial constraints in the clustering process may lead to fragmented clusters, and elevation showed lower explanatory power ($R^2 = 0.56$), indicating that its effects may be more localized. Furthermore, the absence of external validation—such as field data or comparison with supervised classification methods (e.g., Random Forest, SVM)—remains a critical gap.

Future research should focus on validating these findings through ground truth data and exploring the integration of additional environmental variables, such as climatic or socio-economic factors. Combining morphometric clustering with AI-based classification and multi-source data fusion holds great potential for enhancing the precision and utility of land cover analysis. This methodology is especially applicable in topographically complex regions and can serve as a robust foundation for preliminary environmental assessments and sustainable land use planning.

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Conflicts of Interest

The authors declare no conflicts of Interest.

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