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COMPARATIVE ANALYSIS OF REMNANT SURFACES MAPPED USING TRADITIONAL AND DIGITAL METHODS IN THE BOGÁCS-CSERÉPFALU BASIN PILOT AREA

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Abstract: Mapping remnant surfaces is essential in geomorphologic research because it allows us to deduce the surface-forming processes. Compared to the traditional methods, the suggested GIS-based method is an effective, faster, and more objective way of geomorphological mapping. However, the prerequisites of the applicability and reliability of the GIS method have not been fully examined yet. The study compared the results of traditional and GIS-based geomorphological mapping in a pilot area by analyzing the histograms of absolute and relative elevation and the slope conditions of remnant surfaces. It can be concluded that despite its errors, the GIS-based method yielded satisfactory results, showing the locations of these remnants similarly to the traditional map.

Keywords: *remnant surface, comparative analysis, DEM, pediment, terrace*

1. INTRODUCTION

Mapping of hilltops, interfluves, and gentle slopes has high importance in paleogeographic and geomorphological research, as they provide insights into important stages and processes of surface development when interpreted as remnants (surface planation, peneplain, pediment, terrace) [1, 2]. Recently, numerous Hungarian [3, 4, 5] and foreign [6, 7, 8] studies have focused on the development and improvement of geomorphological mapping methods based on digital terrain models and geospatial morphometric analysis, as they offer faster and more objective results than traditional methods. However, this GIS-based method's applicability, conditions and reliability have not yet been fully explored. In this study, we examine the effectiveness of a geomorphological mapping method based on morphometric analysis of a digital terrain model developed in a previous study [1] in the Bükkalja pilot area. We compare the visually and statistically analysed remnant surfaces mapped using this method with those mapped using traditional methods.

2. MATERIALS AND METHODS

The digital terrain model used for the geomorphological mapping using geospatial morphometric methods was created from 1 : 10,000 scale topographic maps' contour lines, elevation points, and drainage network. This was completed by applying the *Topo to Raster* interpolation tool in ArcGIS 10.1 software package, with a spatial resolution of 25 m.

The mapping (identification) of the remnant surfaces was carried out using the method described by Pecsmány [1]. The essence of the procedure is to derive several morphometric parameters (slope, curvature, Multiresolution Index of Valley Bottom Flatness [MrVBF], Multiresolution Index of the Ridge Top Flatness [MrRTF], Topographic Position Index [TPI], Morphometric Features) from the digital terrain model and then combine them into a multiband image. Subsequently, unsupervised classification is performed on the composite dataset, quantitatively grouping the individual morphological units. The optimal number of clusters is determined by examining the dendrogram.

The geomorphological map of the sample area was created by Dobos [9] using traditional mapping methods. This map was georeferenced, and the depicted remnants were digitized. By visually comparing the two types of maps and using our experience in geomorphological mapping and analysis of digital terrain models, we sought to identify possible reasons for the differences. We prepared boxplot diagrams of the remnants' slope, absolute, and relative height for the statistical analysis. We also created histograms based on the two types of heights and calculated their fitting functions.

3. STUDY AREA

The Bogács-Cserépfalu Basin is the largest and most complex basin in the Bükkalja region *(Figure 1)*, which was formed by structural movements and selective denudation due to the different rock quality [9, 10].

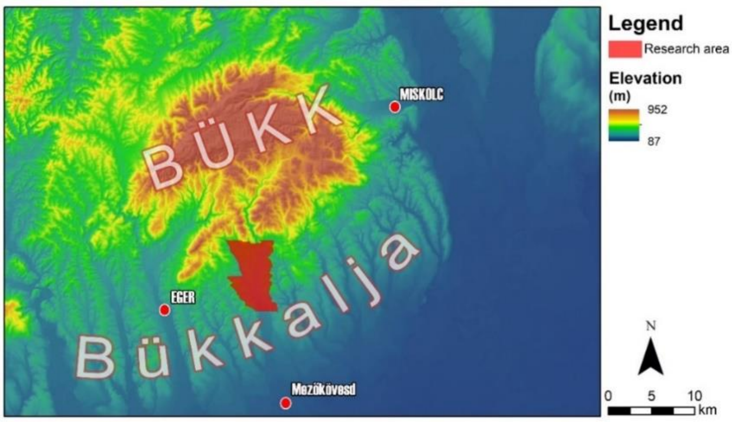

Figure 1
The location map of the pilot area

Its northern rim is composed of Mesozoic sedimentary rocks (Berva Limestone Formation, Oldalvölgy Formation) and Tertiary sedimentary rocks (Szépvölgy Limestone Formation) [11]. The western and eastern rims are made up of Miocene rhyolite (Harsány Rhyolite Lapillituff Formation, Tihamér Rhyolite Lapillituff Formation) and dacite lapillituffs (Bogács Rhyolite Lapillituff Formation) [12]. Sediments from the former Pannonian Sea are also preserved in the basin's downfaulted block (Csákvár Clay Formation), representing the northernmost occurrence in the Bükkalja [13]. Moving towards the basin's interior, Pleistocene and Holocene terrace materials cover the plains parallel to the Hór Creek and its tributaries [9, 14].

The oldest surface remnants of the basin and its periphery, which can be interpreted as the older remnants of the dual pediment of Bükkalja, began to develop during the Sümegien-Bérbaltavárian (MN 11-13) period (Pannonian-Pliocene). At that time, the climatic conditions were conducive to surface planation. As a result of structural movements during the Pannonian period, the area began to fragment, and the basin likely started to take shape. However, the climate became cooler between the Ruscinian (MN 14) and Csarnótan (MN 15) periods (Pliocene), and pedimentation was interrupted. During the Pliocene, due to tectonic movements, the area experienced uplift again, and it was likely during this time that the Hór Creek, the largest watercourse in the basin, emerged [9, 10, 14]. The climate changed radically during the Villányian (MN 17) period (boundary of Pliocene and Pleistocene). Following the cool and dry period of the Pliocene, the conditions were favourable for forming the second (younger) pediment during the climatic deterioration of the Quaternary period. Sequential climatic changes and structural movements during the Quaternary period formed parallel plains and terrace surfaces along the basin's streams. Dobos [9] identified three terrace surfaces in the Hór Valley (II/b, II/a, Holocene). The basin is dissected by erosional, derasional (bowl shaped valleys, formed by slow mass movements, instead of linear erosion), and erosional-derasional valleys, while extensive alluvial and debris cones have been formed [9].

4. RESULTS

The total extent of the remnants (pediments, terraces) digitized from Dobos's [9] maps is 5.49 km^2, while the surface area identified using the digital method is 4.55 km^2. The overlap between the two, i.e., the area successfully identified using both methods, is 2.57 km^2 *(Figure 2)*. This represents 47% of the surfaces mapped using the traditional method and 57% of the digitally identified ones.

Analyzing the elevation and relative height of the remnants mapped by Dobos [9] and those identified by the GIS method, we can observe that the range of values is similar. The elevation of Dobos's [9] remnants ranges between 176 and 379 m, while those identified by us are limited to 160 to 343 m. The standard deviation of elevation is the same for both the traditionally and digitally mapped surfaces (28 m). The interquartile range and median values (255 and 251 m) are also roughly similar *(Figure 3)*.

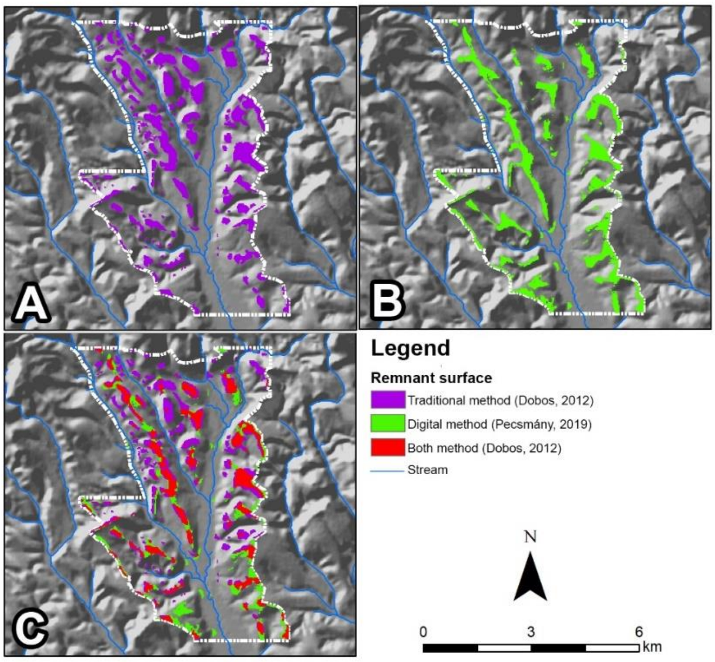

Figure 2
A: Remnants mapped by the traditional method, B: remnants identified by the GIS-based method, C: Difference map

Regarding the relative height values above the erosion base, Dobos's [9] map ranges from 0 to 141 m, while the values in our map range from 0 to 104 m. The empirical standard deviation of data is greater for the surfaces mapped using traditional methods (21 m) compared to the ones identified using the digital method (19 m), while the median is higher for the latter (47 m) *(Figure 3)*.

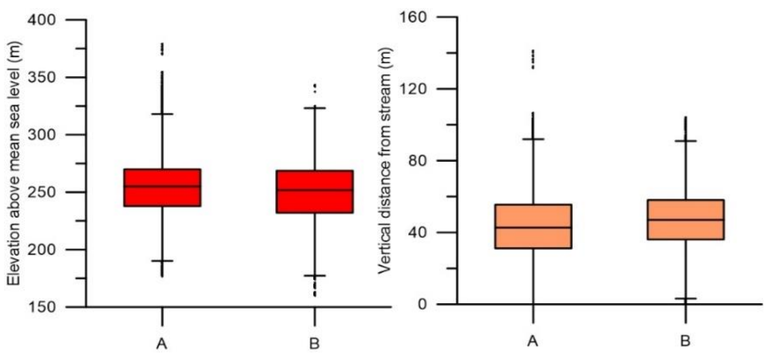

Figure 3
Boxplot diagrams of the remnants' absolute and relative elevation (A – remnants mapped by the traditional method, B – remnants mapped by the digital method)

The probability density functions fitted to the histograms of the traditionally mapped surfaces *(Figure 4)* have a kurtosis (γHa) of 1.03, a skewness (μHa) of 0.04 for absolute height, and a kurtosis (γHr) of 0.37 and skewness (μHr) of 0.60 for relative height. In comparison, the digitally selected surfaces have a kurtosis (γDa) of 0.28 and skewness (μDa) of –0.32 for absolute height, and a kurtosis (γDr) of 0.12 and skewness (μDr) of 0.09 for relative height, respectively *(Figure 4)*.

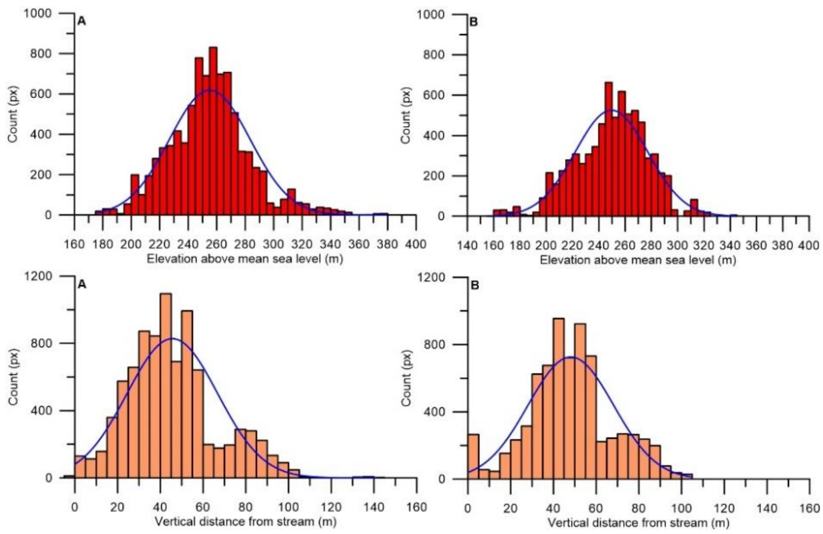

Figure 4

Histograms of remnant surfaces' absolute and relative elevation (A – remnants mapped by the traditional method, B – remnants mapped by the digital method)

In the traditionally mapped surfaces, 37% contain slopes steeper than 5°, and the maximum slope steepness exceeds 26°. In contrast, in 100% of the digitally identified surfaces, the steepness is a maximum of 5°. The median for the traditional method is 3.86°, while for the digital method, it is 2.85° *(Figure 5)*.

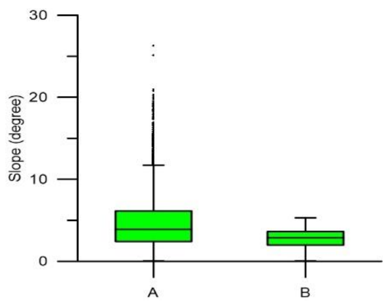

Figure 5

Boxplot diagrams of the slope of remnant surfaces (A – remnants mapped by the traditional method, B – remnants mapped by the digital method)

In some cases, the digitally identified surface remnants appear in areas where they do not exist, such as in the reservoir (Halastó) *(Figure 6A)*. On the other hand, the method fails to identify the terraces in the Szoros Valley, which are easily recognizable in the field and are included in the traditional geomorphological map *(Figure 6B)*. However, the method does mark areas as surface remnants that are not included in the traditional map but could exist in reality, such as the ridge and saddle of an interfluve *(Figure 6C)*, remnants of an alluvial cone *(Figure 6D)*, and a gently sloping valley side with eroded gullies *(Figure 6E)*. Notably, the traditional and digital surface remnants are sometimes directly adjacent with minimal overlap, for example, on the ridge between the Szoros and Hór Valleys *(Figure 6F)*.

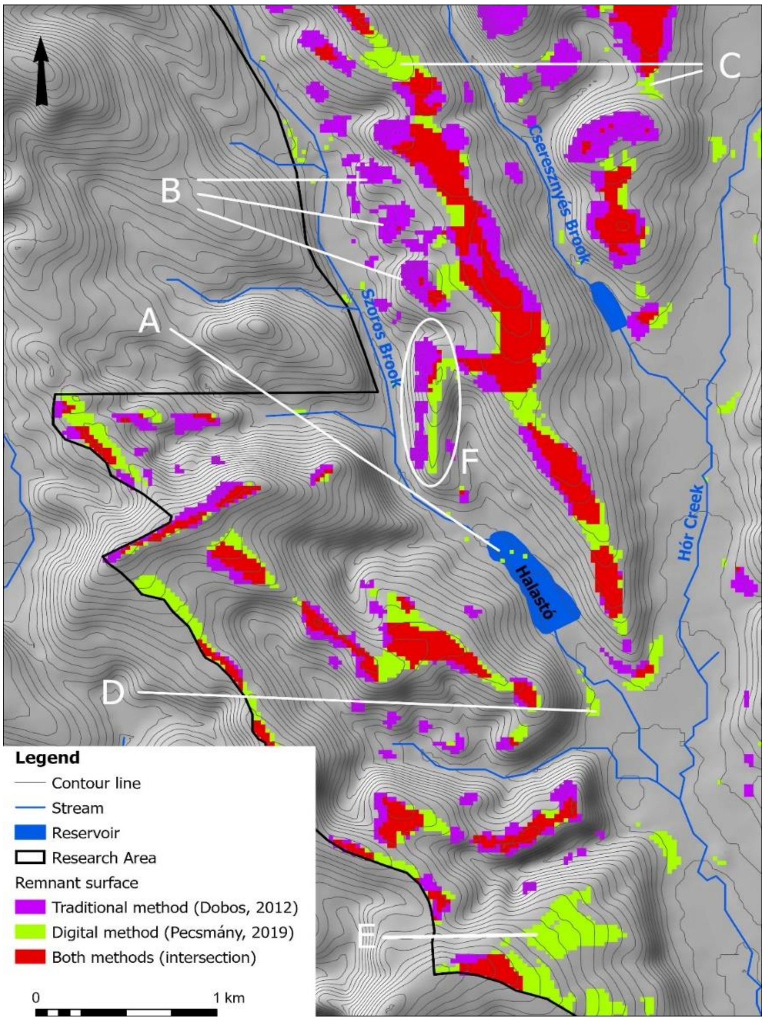

Figure 6
The remnants on the Western part of the pilot area
(A – F: detailed explanation is in the text)

5. DISCUSSION

Significant differences can be observed between the surface remnants mapped using the traditional and digital methods, with a coincidence rate of only around 50%. Analyzing the reasons for these differences, it can be concluded that the two methods have no significant difference in elevation and relative height. Most differences stem from the fact that a significant portion of the surface remnants mapped using the traditional method falls on slopes steeper than 5°, while the parameterization of the digital method (based on literature data) excludes the steeper slopes.

The functions fitted to the histograms of the surface remnants have a relatively small kurtosis and skewness, indicating normally (Gaussian) distributed data for both the traditional and digital methods. The relative occurrence of surface heights is similar for both methods.

Minor differences arise from the properties of the digital terrain model used as the basis for the digital mapping method. The interpolation used in creating the terrain model does not accurately represent the real surface but provides an approximation with varying accuracy from pixel to pixel. The effectiveness of the digital method is highly dependent on the accuracy of interpolation, which significantly decreases in flatter areas, according to our observations. This may result in the appearance of small-scale (one or two pixels) surface remnants in the valley bottoms and the reservoir (Halastó) that do not exist in reality. Furthermore, the spatial and geometrical resolution of the digital terrain model determines the level of detail in the digital identification process and can lead to selection errors. Smaller remnants like narrow terraces may not be detected in a low-resolution terrain model.

Further differences arise from the subjectivity of the traditional mapping method. This may lead to the inclusion of areas as surface remnants by the digital method that the field expert would not consider as such based on personal judgment (e.g., ridges, debris cone remnants) or areas that were not observable in the field due to dense vegetation *(Figure 6E)* and/or densely built-up environment *(Figure 6D)*. However, it is also possible that the field mapper takes into account field experiences (such as the presence or absence of terrace deposits) that have not yet been taken into account in the algorithm of the digital method.

The case of the interfluve between the Szoros and Hór Valleys *(Figure 6F)* is peculiar. The majority of its ridge has been extensively quarried, making it impossible to determine its precise location and extent. Dobos [9] undoubtedly attempted to infer the original surface based on the contour lines, while the digital terrain model depicts the current (quarried) surface.

6. CONCLUSIONS

Overall, it can be concluded that the digital method used for identifying surface remnants, despite its flaws, yielded satisfactory results on the sample area, as it provided possible locations for remnants in many cases similar to the traditional geomorphological map. The main difference between the two methods lies in the precise location and extent of the identified surface remnants. Based on this, the method facilitates and complements traditional geomorphological mapping by drawing attention to the possible locations of surface remnants. By increasing the spatial resolution and accuracy of the digital terrain model and refining the parameterization of the selection method, its effectiveness can be further improved.

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