PMAS

Vol. 63 No 03 (247) 2023

DOI: https://doi.org/10.5564/pmas.v63i03.3402

ARTICLE

Dissection indices and their distribution over Mongolia

Bayanjargal Bumtsend*, Purevsuren Munkhtur and Odbaatar Enkhjargal

Division of Physical Geography and Environmental study
Institute of Geography and Geoecology, Mongolian Academy of Sciences
Ulaanbaatar, Mongolia

ARTICLE INFO: Received: 13 Sep, 2023; Accepted: 29 Nov, 2023

Abstract: The main objective of this study was to create much more accurate maps of the 'dissection depth' and 'dissection density' in Mongolia, considering both the vertical and horizontal directions. To achieve this, two digital evetation models (DEMs) were used: the MERIT DEM with a spatial resolution of 90 meters and the ASTER DEM with a resolution of 30 meters. Some adjustments were made to rectify errors in relatively flat areas. The entire territory of Mongolia was selected as the study area, resulting in the creation of 2,865,000 grids with a resolution of 1 km. For each grid, the minimum and maximum values, as well as the length of dissection, were estimated. Finally, an interpolation method was used for mapping the depth and density of the dissection. The utilization of digital elevation models in the dissection map has exposed certain inaccuracies in flat areas. Consequently, the MERIT DEM has been selected as the favored alternative. Furthermore, this study emphasizes the disparities between the dissection depth map and the relative elevation map, as both play a vital role in comprehending and applying the concept of dissection depth. The maps of the dissection density and depth have proven to be highly valuable in the field of geomorphological and landscape research, as well as in the classification of origin groups and typological classification.

Keywords: *Dissection depth, Dissection density, MERIT DEM, Mongolia;*

INTRODUCTION

Relief dissection is expressed in two types, including the concept of horizontal dissection or 'dissection density' and vertical dissection or 'dissection depth'. In the field of geomorphological and landscape research, it is important to map both the depth and density of relief dissection. The maps of the depth and density of relief dissection in Mongolia were created by Jigj [1]-[3] in the1970s. However, since the publication of these studies, limited focus was given to further research regarding relief dissection. Dissection density refers to the erosion of the Earth's surface caused by permanent or temporary water flow per unit area, such as stream, ravine, and ditch.

The former Soviet Union researchers Chentsovim (1948), Volkov (1949), Spiridonov (1952), Sobolev (1955), Samoilenko (1962), Nikolaev (1978), The Atlas of Irkutsk Oblast (1962), Academy of Sciences of the USSR (1978), and Alexandrov (2009) initiated the development of mapping the dissection depth and density. They employed their own methods and approaches.

***Corresponding author, email:** bayanjargalb@mas.ac.mn https://orcid.org/0000-0001-5683-8070

DOI: https://doi.org/10.5564/pmas.v63i03.3402

Additionally, Mongolian researchers, particularly geomorphologist S.Jigj (1975; 1979), National Atlas of Mongolia (1990) contributed to the development of the dissection depth and density map of Mongolia.

In certain literature, a map illustrating the depth of dissection has been referred to as either a map of dissection of surface depth or depth intensity of surface. Russian scientists, particularly Sobolev (1955) defined it as the depth of the erosion base of the area. However, the commonly used scientific term is a map of the relative elevation of the area [4]. Nevertheless, it is important to note that the relative elevation map and the surface dissection depth map represent distinct concepts. The relative elevation map quantifies the difference in elevation between the lowest and highest points of the region and the watershed, while the dissection depth map measures the difference in elevation per unit area in m/km². In the past few years, major research works failed to incorporate maps illustrating dissection density and depth. Instead, these maps have only been briefly mentioned in certain literatures, thereby overlooking a fundamental factor in landscape and geomorphological research. Hence, the primary aims of this study are to differentiate between the two concepts of dissection depth and density, and to highlight the importance of these concepts in the realm landscape and geomorphological research.

MATERIALS AND METHODS

Dissection density

The main purpose of determining the dissection density is related to defining the total length of erosion per unit area. To estimate this, first, the total erosion types of the surface are calculated based on the Digital Elevation Model (DEM), and then the sum of the erosion network is estimated at one square kilometre. The resolution of the maps is directly related to the square root [4]. Another point to consider for the resolution of the mapping process is to define, as accurately as possible, the erosion types formed by permanent or temporary water flow. In this research, dissection forms, ravines and gullies with lengths of more than 200 metres were mapped due to the vastness of the country's territory and the landscape features of the mountains with plains. In this way, the ratio of the length of the erosion process and the area of surface as described in Equation 1 can be estimated. In some cases, it includes deep faults originating from earthquakes [1], [2].

$$F = L/S \qquad (1)$$

Here, F – dissection density (km/km^2), L – length of dissection (km)

S – area (km^2) [3]–[5]

Dissection depth

Dissection depth is defined as an elevation ratio of the lowest and highest points of the region or watershed, and relief dissection (both depth and density) is a parameter that indicates the intensity of relief. Dissection depth is determined by the elevation difference between the upper and lower elevations of one square kilometre or defined as the elevation difference per unit area, and it is expressed in m/km^2 or vertical section [6]. Moreover, dissection depth determines the manifestation or intensity of endogenous processes in the area, and there is a redistribution of energy depending on the nutrient cycling and geopotential depending on the elevation [7], [8]. In this study, the average dissection depth was estimated applying the method proposed by (Chentsov,1948).

$$h_p = \frac{h_1+h_2+h_3+h_{m+1}}{m+1} \qquad (2)$$

Vol. 63 No 03 (247) 2023
DOI: https://doi.org/10.5564/pmas.v63i03.3402

If the total number of points on the profile is m, and the difference is higher from two adjacent inflections of the profile line *h1*, *h2*, ... *hm + 1*, then the dissection depth is estimated as shown in Equation 2.

RESULTS AND DISCUSSION

Dissection density

The use of software, such as ArcGIS for estimating morphometric maps from ASTER and SRTM DEM, does not result in significant errors and typically fulfills the requirements for small and medium scaled maps. However, it was observed that there were some topographical errors in relatively flat surfaces and large depressions.when the types of dissection caused by permanent or temporary water flow were calculated using the Digital Elevation Model. The current study identified these errors as being particularly prevalent in plains and depressions such as the Great Lakes Depression, Vthe alley of the Lakes, the Menen plain and the Dornogovi Depression. To address this problem, researchers used the MERIT DEM (Multi Error Removed Improved Terrain - Digital Elevation Model), which has been improved through the identification and removal of various error types. The MERIT DEM was developed by eliminating multiple error components, including absolute bias, stripe noise, speckle noise, and tree elevation bias, from the existing spaceborne DEMs (SRTM3 v2.1 and AW3D-30m v1). It represents the terrain elevations with a resolution of 3 arc seconds, which is equivalent to approximately 90 meters at the equator. The coverage includes land areas between 90 degrees north and 60 degrees south, and the elevations are referenced to EGM96 geoid[9]. In order to ensure high accuracy, researchers from the Global Hydrological group at the University of Tokyo used a global DEM with a resolution of 3-arc second, which corresponds to approximately 90 meters at the equator. They achieved this accuracy by eliminating major error components from existing DEMs, namely, NASA SRTM3 DEM, JAXA AW3D DEM, and Viewfinder Panoramas' DEM. After removing these errors, these researchers observed a significant improvement in the accuracy of the mapped land areas. The percentage of land areas with a vertical accuracy of 2 metres or better, increased from 39 to 58 per cent. Significant improvements were found in flat regions, where elevation errors were larger than the variability of topography. Additionally, the representation of landscapes, such as river networks and hill-valley structures, also improved [9].

The findings presented in Figure 1, highlight the impact of improvements made in the Great Lakes Depression, including the Uvs Lake Depression, which exhibited the most significant errors. Analysis reveals that although the estimation of gullies, ravines and river diversions on the north eastern slopes of the Khankhukhii Mountain Ridge was consistent with expectations, inaccurancies emerged when transitioning to the relatively flat terrain of the Uvs Lake Depression. Consequently, unanticipated straight lines of gullies were formed, as depicted in Figure 1.

PMAS
Proceedings of the Mongolian Academy of Sciences
Vol. 63 No 03 (247) 2023
DOI: https://doi.org/10.5564/pmas.v63i03.3402

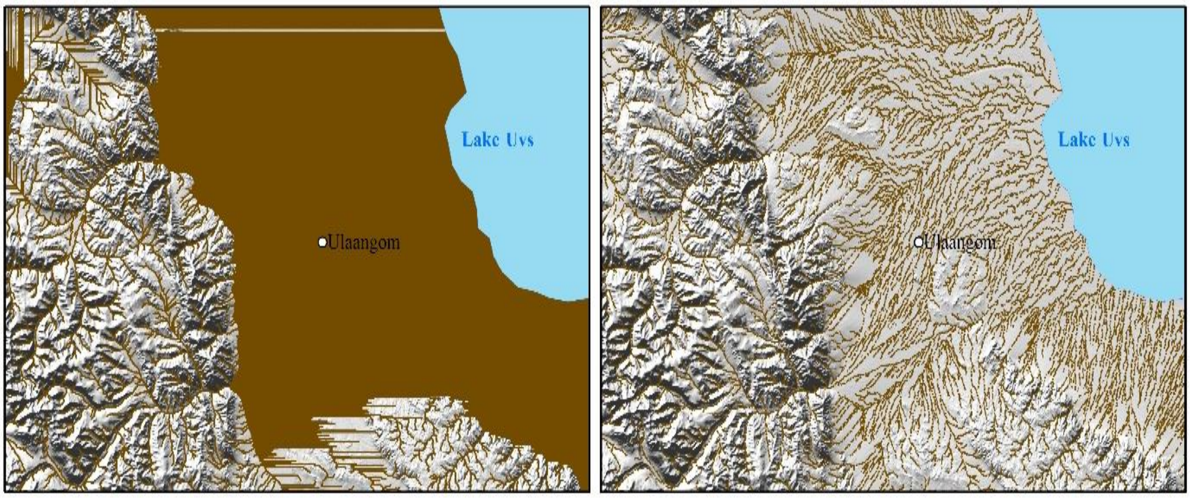

Figure 1. Gullies data estimated from ASTER DEM and error indication in relatively flat area and Gullies data estimated from MERIT DEM

As mentioned earlier, errors occured a lot in the entire territory of Mongolia, particularly on relatively flat surfaces. However, the use of MERIT DEM has effectively rectified these errors, thereby contributing to the accuracy of estimating dissection density in Mongolia (Figure 2). The accuracy of the resulting dissection density map is influenced by several factors, including the grid size chosen, the spatial resolution of the DEM, and the improvements made in addressing errors related to the estimation of flow networks on flat surfaces, such as, large depressions and plains.

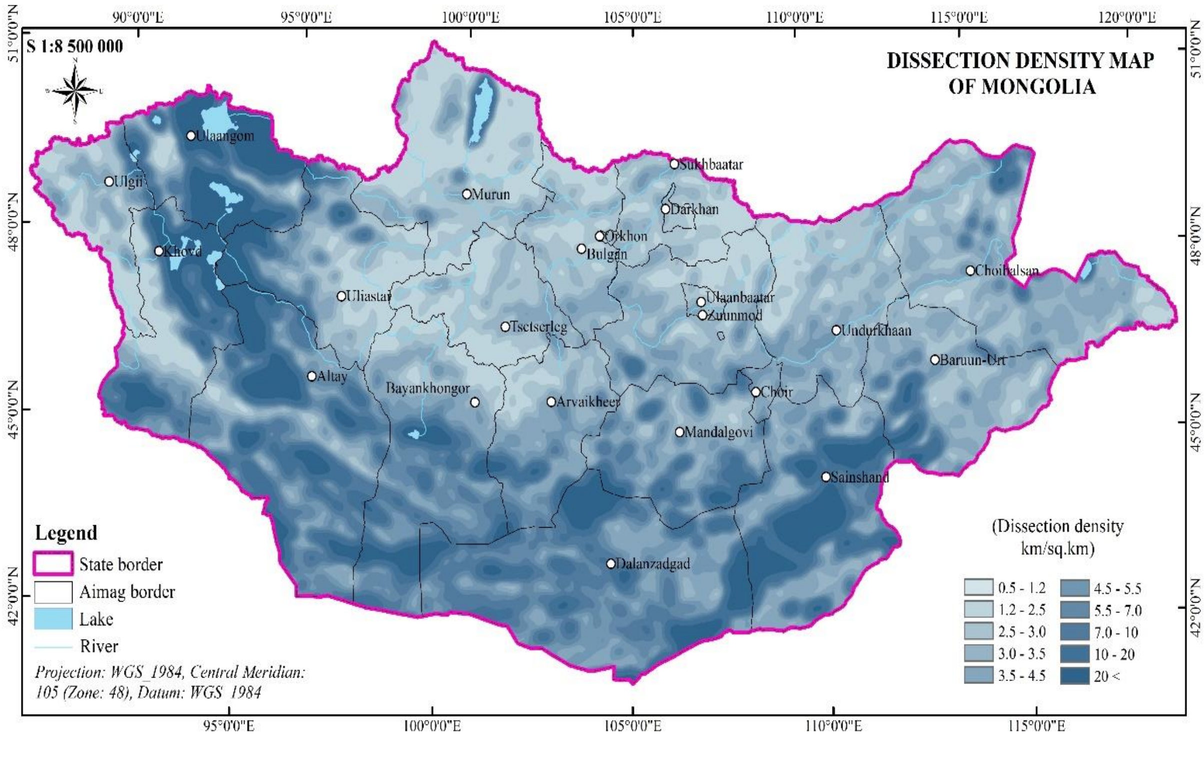

Figure 2. Dissection density map of Mongolia

Vol. 63 No 03 (247) 2023
DOI: https://doi.org/10.5564/pmas.v63i03.3402

Table 1. Area allocation of dissection density

Dissection density (km/ km^2)	Area	
	km^2	%
0-1.2	184565.7	11.8
1.2-2.5	228360.9	14.6
2.5-3.5	211155.7	13.5
3.5-4.5	256515	16.4
4.5-5.5	128257.5	8.2
5.5-7	123565.2	7.9
7-10	139206.3	8.9
10-20	154847.5	9.9
>20	137642.2	8.8

Dissection depth

Generally, the result of the dissection depth map varies between units due to the varied approaches used for developing it. Thus, as a result of the research, the results of the maps developed by the following two methods were briefly described. The dissection depth map created, based on the relative elevation approach (hereafter referred to as the map of relative elevation), generally shows the elevation difference between the lower and higher elevations of the watershed in units of meters. Thus, the result of the map of relative elevation can be more accurate for the mountainous areas as opposed to the steppe, plain, gobi or desert areas. This is because the approach provides more possibilities to indicate the elevation difference in the mountainous region, but the spatial difference in the plains and steppe regions is not clearly defined due to its lack of variation in surface elevation.

Whereas, the map of dissection depth has the advantage of determining the difference in the elevation of the surface in a unit area, and it can be exceptional compared with the relative elevation map due to the reason of showing the elevation difference in the same spatial distribution both for the mountainous or plain areas. Furthermore, the comparison of these two maps in the form of results and spatial resolution is shown in Figure 3 (relatively higher areas in elevation such as Khankhukhii, Kharkhiraa, Turgen Mountain Ridges, Uvs Lake Depression) and in Figure 4 (relatively lower areas in elevation such as Dornogovi Depression, Dornod Mongol plain, and Buir Lake). As part of the research, the map of the dissection depth of Mongolia was developed based on ASTER DEM with a spatial resolution of 30 meters by creating a one-kilometer grid and calculating the difference in elevation of each grid.

In the process of mapping the dissection depth and density, the gridline with 2,865,000 units of 1 km was created covering the entire and adjacent territories of Mongolia. The total lengths of ditches, ravines and river valleys per 1 km^2 area, and the values of elevation difference between the highest and lowest points of the Digital Elevation Model per one square kilometre area were chosen to estimate the dissection density and dissection depth, respectively. Finally, 2,865,000 grids with numerical values were converted to point values and the results were obtained using the interpolation method.

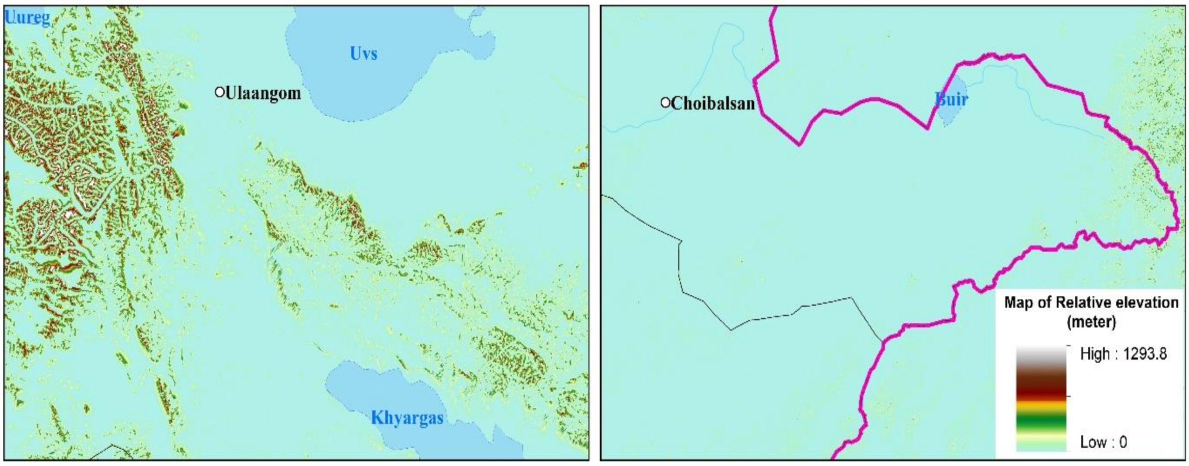

Figure 3. Relative elevation map of Uvs and Steppe of Eastern Mongolia Source: Dai Yamazaki's website. http://hydro.iis.u tokyo.ac.jp/~yamadai/MERIT_DEM/

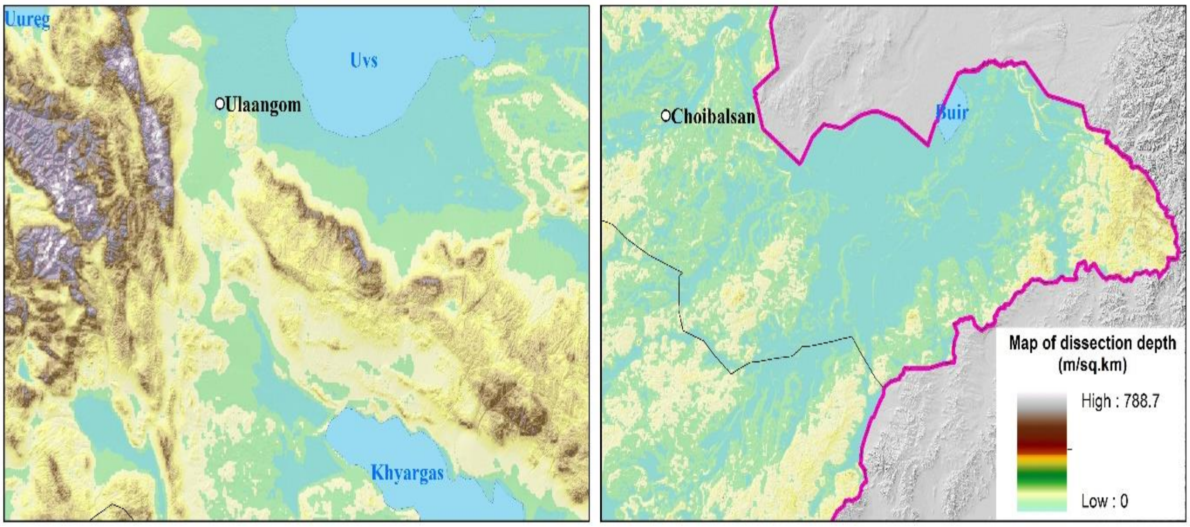

Figure 4. Dissection depth map of Uvs and Steppe of Eastern Mongolia

Comparing the results of these two maps, the relative elevation map (Figure 3) shows that there is no clear spatial difference in the plains and steppe regions, while spatial differentiation is evident in the mountainous areas. As mentioned earlier, the relative elevation map is the result expressed by elevation difference between the lower and the higher points of the watershed, therefore, it is related to the non-uniform spatial distribution of watersheds in the steppe area compared to that of the mountainous area. In other words, there is not much spatial differentiation between plains, relatively flat valleys and depressions because the distance between different elevation level lines in flat areas is far. However, the spatial differentiation is illustrated as outstanding, even in the relatively flat surface of the plains and the mountainous areas as shown in Figure 4. It represents the elevation difference of each 1 km^2 area of Mongolia in numerical terms, so it has an advantage over the relative elevation map as it can show the spatial differences with the same accuracy for both the plains and the mountainous areas. In addition, the results of the dissection depth map are directly dependent on the selected grid size and the spatial resolution of the chosen Digital Elevation Model.

PMAS
Vol. 63 No 03 (247) 2023
DOI: https://doi.org/10.5564/pmas.v63i03.3402
Proceedings of the Mongolian Academy of Sciences

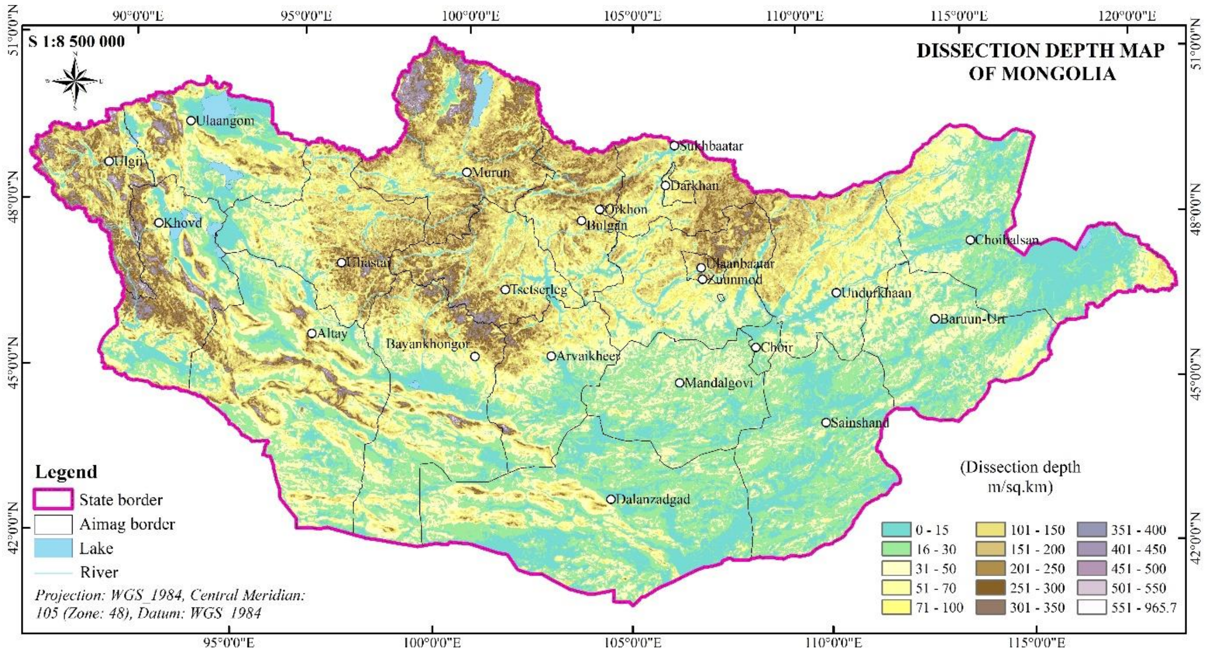

Figure 5. Dissection depth map of Mongolia

According to Table 2, the majority of the total territory of Mongolia (57.4 per cent) was covered with a dissection depth of less than 50 m/km^2. In addition, the surface with the lowest dissection depth ranging from 0 to 5 m/km^2 was observed in a small area near the tributaries of Tes River, Uvs Lake, while the larger area was spread over the Menen plain.

Moreover, the surface with a maximum dissection depth of up to 965.7 m/km^2 was found in the Altai Soum of Bayan-Ulgii aimag (province), near the state border of Mongolia in the extreme west, and around the area of Zurkhen Mountain (a.s.l. 3,645 meters), which is one of the ridges of the Mongolian Altai Mountains.

Table 2. Area allocation of dissection depth

Dissection depth (m/km^2)	Area	
	km^2	%
0-15	245566.2	15.7
15-30	400413.7	25.6
30-50	251822.7	16.1
50-100	229925.1	14.7
100-200	269028	17.2
200-500	164232.2	10.5
500-965.7	3128.232	0.2

Some of the maps created by Russian scientists and the dissection density map of Mongolia were developed based on topographical maps and they were determined by calculating the difference in elevation between the lowest and highest points of the watershed.

The biggest disadvantage of this method had been the difference in the distance between the selected points within the given watershed and the relative difference in spatial resolution. In mountainous regions, the dissection density was estimated to be less than 1 km apart

Vol. 63 No 03 (247) 2023
DOI: https://doi.org/10.5564/pmas.v63i03.3402

between the points, whereas in the flat plain areas or regions with limited hydrological networks, the difference between points was approximately 15-20 km or even greater. As a result, it was not feasible to accurately determine the dissection depth of the per unit area in certain specific locations. Therefore, the mentioned maps were initially based on the relative elevation method. The legends of these maps provided the dissection depth in meters as the unit of measurement. The error in this approach was first recognized by a Russian scientist Sobolev in 1955, when he created a dissection depth map for the eastern part of the Soviet Union. Sobolev placed 12,340 evenly spaced points on the elevation map and calculated the elevation difference in the per unit area using the elevation value of each point [4]. The method employed during that time was innovative, and subsequent studies by Smith (1935) and Miller (1948) used this method to create the map of relative elevation of the surface and relief dissection [10]. However, some researchers have argued that even though this method can be effective in estimating the relative elevation and relief dissection by creating a grid with uniform size, the application of the interpolation method cannot show the research results in a more realistic manner [11], [12]. Recently, researcher Tabunshchik (2019, 2020) developed the dissection density and depth maps of the Crimean Peninsula using gridlines with 1 km interval and the interpolation method [13, 14]. However, these results have the limitation of solely considering the erosion forms created by permanent water flow for estimating of dissection density. Nonetheless, this study may have the advantage of considering all gullies over 200 meters in length that have been eroded by both permanent and temporary water flow.

CONCLUSIONS

The objective of this research was to develop a dissection density and dissection depth map of Mongolia. The dissection density map was developed by creating gridlines with a 1 km interval and estimating the erosion forms that were longer than 200 meters. Subsequently, a dissection depth map of Mongolia was generated using a Digital Elevation Model with a spatial resolution of 30 meters. Furthermore, the dissection depth, which represents the difference in elevation, and the dissection density, which indicates the total length of the dissection, were calculated per unit area. The outcome of the dissection density map is theoretically influenced by the chosen grid size, the spatial resolution of the DEM, and the improvement of error estimation of flow networks on flat surfaces, such as large depressions and plains. Similarly, the result of the dissection depth map also directly depends on the grid size and spatial resolution of DEM.

Based on the generated maps, it was observed that the density of dissection in Mongolia exhibited an inverse relationship with surface elevation and slope. This was evident in various regions, such as the Great Lakes Depression, Valley of the Lakes, Dornogovi Depression, as well as the foothills and low slopes of the Mongolian Altai and Gobi Altai mountains, including the valleys between them. These areas displayed a high occurance of dissection, exceeding 20 km/km^2. The dense dissection was primarily attributed to extensive erosion and accumulation of both permanent and temporary water flows, resulting in the formation of ditches, ravines, and gullies. However, the depth of dissection showed a direct correlation with certain morphometric parameters, such as surface elevation and slope, despite its inverse relationship with dissection density. For example, the Menen plain and other flat plains exhibited the largest areas with the lowest dissection depth, ranging from 0 to 5 m/km^2. On the other hand, mountainous regions, such as Altai, Khangai, and Khentii Mountain Ridges, with elevations exceeding 3,300 meters above sea level, displayed surfaces with a dissection depths surpassing 600 m/km^2.

DOI: https://doi.org/10.5564/pmas.v63i03.3402

Furthermore, a noteworthy finding was the identification of a surface with a maximum dissection depth of up to 965.7 m/km^2, exclusively located around the area of Zurkhen Mountain (a.s.l. 3,645 meters). The mountain, situated in the Altai Soum of Bayan-Ulgii aimag near the state border, is a part of the Mongolian Altai Mountain ranges. Notably, Zurkhen Mountain is renowned for its proximity to the headwaters of the Sagsai River, a tributary of Khovd River.

REFERENCES

1. S. Jigj, *The main features of the depressions in Mongolia*. Ulaanbaatar, 1975.
2. S. Jigj, *The basic issues in engineering geography of Mongolia*. Ulaanbaatar, 1979.
3. Institute of Geography, *National Atlas of Mongolia*. Moskva-Ulan Bator, 1990.
4. A. I. Spiridonov, *Geomorphological mapping*. Publishing House of Geographical Literature, 1952.
5. W. Luo, J. Jasiewicz, T. Stepinski, J. Wang, C. Xu, and X. Cang, “Spatial association between dissection density and environmental factors over the entire conterminous United States,” *Geophys. Res. Lett.*, vol. 43, no. 2, pp. 692–700. Jan. 2016. http:/doi.org/10.1002/2015GL066941
6. V. Y. Alexandrov and T. V. Belova, *Nature of Belarus Encyclopedia*. Minsk, 2009.
7. D. V. Vorobyov and I. Fedets, *Atlas of natural conditions and natural resources of the Ukrainian SSR*. 1978.
8. I. P. Kopylov, “Thematic map: Hunting,” compiled by Geography Faculty of Moscow University and by the East Siberian Branch of the Academy of Sciences USSR, Moskow-Irkutsk, 1962.
9. Yamakazi, “MERIT DEM: Multi-Error-Removed Improved-Terrain DEM.” [Online]. Available: http://hydro.iis.u-tokyo.ac.jp/~yamadai/MERIT_DEM/.
10. G. H. Dury, “Quantitative Measurement of Available Relief and of Depth of Dissection,” *Geol. Mag.*, vol. 88, no. 5, pp. 339–343, Oct. 1951, http:/doi.org/10.1017/S0016756800069776.
11. A. A. Miller, “The Dissection and Analysis of Maps: Presidential Address,” *Trans. Pap. Inst. Br. Geogr.*, no. 14, p. 1, 1948, http:/doi.org/10.2307/621257.
12. G. H. Smith, “The Relative Relief of Ohio,” *Geogr. Rev.*, vol. 25, no. 2, p. 272, Apr. 1935, http:/doi.org/10.2307/209602.
13. V. A. Tabunshchik and Ye. A. Petlyukova, “Density of the relief dissection on the territory of the Crimean Peninsula,” *Izv. Vuzov Sev.-Kavk. Reg.*, no. 1 (201), pp. 95–100, 2019.
14. V. A. Tabunshchik, “Depth of the relief dissection on the territory of the Crimean Peninsula,” *InterCarto InterGIS*, vol. 26, no. 2, pp. 95–105, 2020, http:/doi.org:10.35595/2414-9179-2020-2-26-95-105.