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A GIS-based approach in the morphometric analysis of incised meanders on the Dnister River (Ukraine)

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SUMMARY

This study aims to show the possibility of using GIS modelling of several basic morphometric indicators for assessing the relief, ravine and gully network of the certain territory, particularly Podillia Upland (Ukraine), and the preconditions for the development of erosion processes. The Horoshovetsky meandering node on the Dnister River (Ukraine) is a unique work of nature that requires substantive, additional and specific geomorphological research, which will help to establish certain patterns of their origin. During the study, the main morphometric maps were constructed for a more detailed relief assessment: vertical (interfluvial dimension) dissection, horizontal (amplitude altimetry) dissection, slope angle, slope aspect. Morphometric indicators are unevenly distributed throughout the territory. The main feature of this relief is its significant vertical and horizontal dissection in the Dnister River valley and its tributaries. The regularity of the channel processes distribution and the scale of the river's incision into rocks are clearly visible. A characteristic feature is the spread of linear landforms, which are very clearly cut by tributaries of the Dnister. Morphometric indicators of the study area clearly demonstrate the full range of complex tectonic and geological interaction of geological and geomorphological processes, which ultimately led to the emergence of various landforms, especially polygenetic incised meanders.

Introduction

Morphometry is a branch of geomorphology devoted to methods of determining the numerical characteristics of the forms of Earth's surface relief (length, area, volume, height, depth, dissection density, etc.). The morphometric method is one of the methods of geomorphological researches, where the quantitative characteristics of landforms are determined using special measurements and study the patterns of their geographical distribution. The set of such characteristics varies depending on the purpose of morphometric analysis and the study area (Berezka 2013).

According to the main reasons for the origin of meanders, which are of great importance for understanding the functioning of not only the water flow, but also the entire river valley and even the catchment area, there are primary and secondary meanders. There are three types of secondary meander depending on their origin: forced, free (or wandering) and incised meanders (Stetsiuk, Kovalchuk 2005; Shchukin 1960).

The Horoshovetsky meandering node on the Dnister River (Ukraine) is a unique work of nature that requires substantive, additional and specific geomorphological research in combination with other meandering nodes in this area, which will help to establish certain patterns of their origin. In particular, morphometric methods are used to search for existing tectonic structures.

Method and Theory

Morphometric methods are based on the quantitative study of relief. Morphometric indicators provide precise objective criteria for determining various landforms. In practice, maps of dissection density, dissection depth, and steepness of the Earth's surface are most often used.

The starting materials for morphometric constructions were topographic maps at scales of 1:50 000 and 1:25 000 and ArcGIS software (Andreichuk, Yamelynets 2015).

The first stage of morphometric research is the construction of a digital elevation model (DEM) for a specific study area. DEM is a model formed by a discrete array of numbers that describes and characterizes the space position of points, lines and relief surfaces of the same order of magnitude. For its creation the data reflecting a relief and an erosion network are important.

The construction of a digital elevation model and a series of morphometric maps of the study area was performed using the ArcGIS 3D Analyst module (ESRI ArcGIS Desktop software package). Maps of the main morphometric parameters of the relief of the Horoshovetsky meander were constructed on the basis of the DEM: a map of the horizontal (amplitude altimetry) dissection – using the *Line Density* function of the Spatial Analyst module of the *ArcToolbox* toolbar; a map of the vertical (interfluvial dimension) dissection – using the *Focal Statistics* function of the Spatial Analyst module of the *ArcToolbox* toolbar; a map of the slope angle – using the *Slope* function of the *Spatial Analyst* toolbar and a map of the slope aspect – using the *Aspect* function of the *Spatial Analyst* toolbar.

Examples

On the hypsometric map of the Horoshovetsky meander territory constructed during the research (fig. 1) it is visible what a sharp contrast there is in the differences in height over a relatively small area. It can be concluded that most of the territory has a height of more than 200 m, only within the river valley they reach less than these values. The regularity of the channel processes distribution and the scale of the river's incision into rocks are clearly visible. A characteristic feature is the spread of linear landforms, which are very clearly cut by tributaries of the Dnister. They extend from north to south, and there is a tendency to increase their elevation in the northern direction, which coincides with the statement of K. Herenchuk that the last cycle of erosion in Podillia had its centre in the north, near the Kremenets Mountains (Herenchuk (Ed.) 1979).

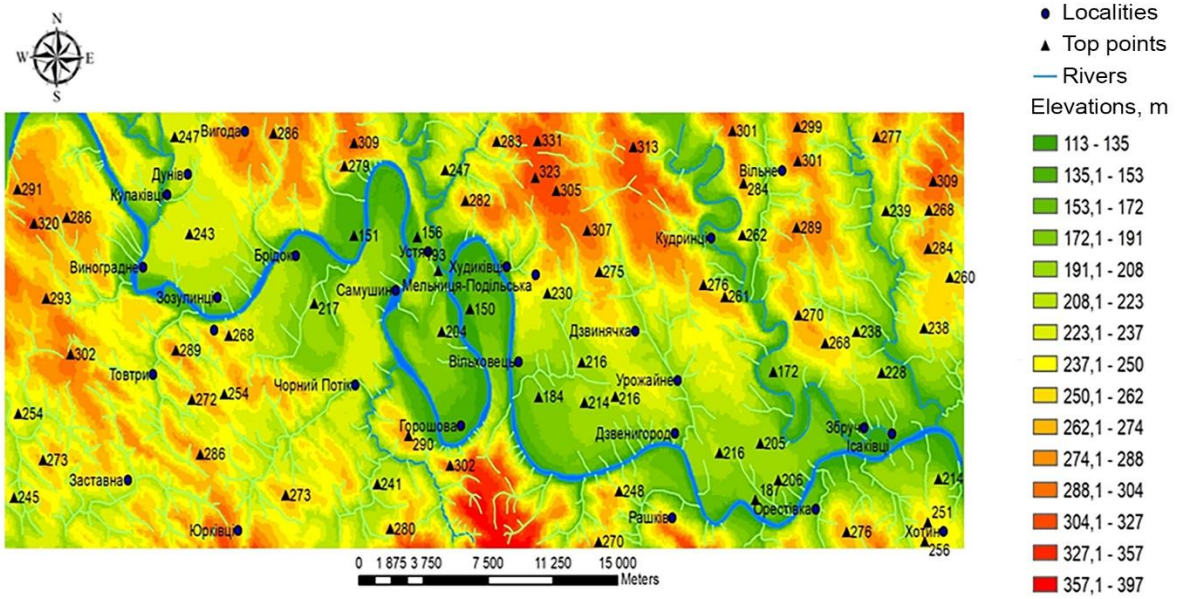

Figure 1 *Hypsometric map of the Horoshovetsky meander of the Dnister River*

Tributaries of the Dnister flow in very narrow river valleys, forming very steep meanders here, which is explained by neotectonic movements in this part of Podillia and rock resistance to erosion. In the very centre of the study area you can see its uplift, which is not typical for this area. The uplift is very clear, which may indicate that it was the tectonic movements that led to the formation of one of the largest incised meanders on the Dnister – Horoshovetsky meander. The elevations here reach more than 350 m a.s.l., and the depth of the cut is about 200 m. It can be seen by analysing the constructed hypsometric map. The relief depicts the former oxbow lake of the Dnister, which disappeared due to a breach in the meander's neck in the recent geological past, possibly in the Holocene.

The slope map is a supplement to the previous morphometric maps and once again demonstrates the relation between the depth of the cut, the steep slopes distribution and incised meanders (fig. 2). The slope steepness is divided into gradations. The following gradation was chosen for the slope map of the territory: 0-1° – subhorizontal surfaces; 1-3° – very slightly inclined; 3-5° – slightly inclined; 5-7° – inclined; 7-9° – sloping; 9-13° – moderately steep; 13-23° – steep.

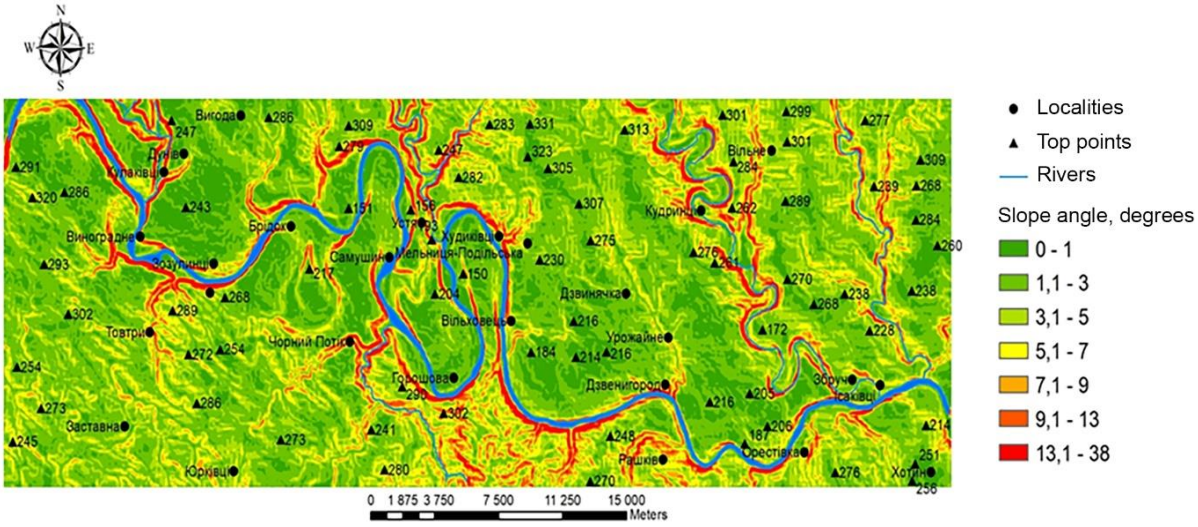

Figure 2 *Slope map of the Horoshovetsky meander of the Dnister River*

The density of horizontal dissection is determined by the development of the erosion network. An additional step is also to determine the order of streams by the thalweg lines of streams. It is based on

the Horton-Strahler method (Horton 1945, Strahler 1957), according to which a stream of a larger order is formed after the merger of single-order streams. The average value of the steepness of this study area is 3.5°, and its maximum values are recorded along the entire valley of the Dnister and its tributaries. The slope of the northern aspect opposite the Horoshova village has the highest value (38°). The slopes of the western and eastern aspects on the Zbruch River are extremely steep and close to the maximum values. We may conclude that tectonic movements in this area are also very active now, and the nature of the relief clearly demonstrates this. The most widespread in the study area are slightly inclined slopes, which predominate in its northern part and have a general incline to the south, to the area of the largest tectonic deformation – Khotyn Upland.

Analysing the slope aspect map (fig. 3), it can be concluded that in this part of the study area the slopes have mostly eastern, south-eastern and southern exposures. Of particular interest are the symmetrical slopes that formed along probable tectonic uplifts. Such slopes are common along the rivers Seret, Zbruch, Smotrych, between the valleys of which may be tectonic faults. The symmetry of the eastern and western slopes is very clear. Along of the Dnister River, the slopes of the northern exposure are very common. They are extremely steep, and due to their canyon-like shape occupy a small area of the river valley. Slopes aspects of this area clearly demonstrate the full range of complex tectonic and geological interactions within the study area, which ultimately led to the emergence of a variety of landforms, especially polygenetic incised meanders.

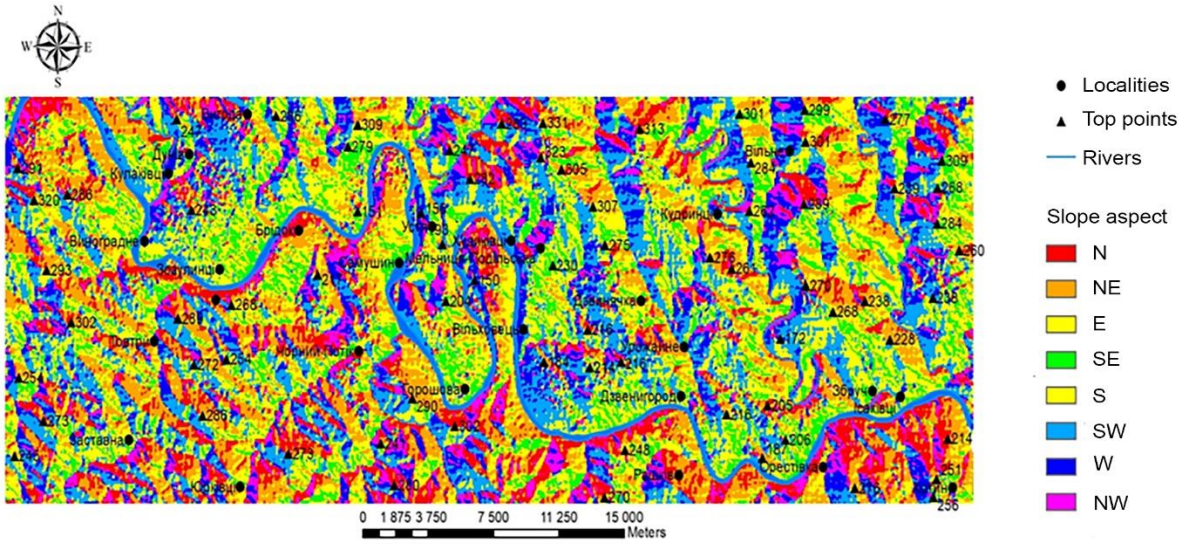

Figure 3 *Slope aspect map of the Horoshovetsky meander of the Dnister River*

Conclusions

GIS modelling of a number of basic morphometric indicators makes it possible to assess the relief, ravine and gully network of the Podillia Upland and the preconditions for the development of erosion processes. During the study, the main morphometric maps were constructed for a more detailed relief assessment: vertical (interfluvial dimension) dissection, horizontal (amplitude altimetry) dissection, slope steepness, slope aspect. Morphometric indicators are unevenly distributed throughout the territory. The main feature of this relief is its significant vertical and horizontal dissection in the Dnister River valley and its tributaries. It can be concluded that most of the territory has elevations over 200 m and only within the river valley they reach smaller values. The regularity of the distribution of channel processes and the scale of the river's incision into rocks are clearly visible. A characteristic feature is the spread of linear landforms here, which are very clearly cut by tributaries of the Dnister. Elevations here reach more than 350 m a.s.l., and the depth of the Dnister cut is about 200 m, which can be seen from the analysis of the hypsometric map. Slopes of this territory mainly have eastern, south-eastern and southern aspects. Morphometric indicators of the study area clearly demonstrate the full range of complex tectonic and geological interaction of geological and

geomorphological processes, which ultimately led to the emergence of various landforms, especially polygenetic incised meanders.

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