Spatial distribution of hypsometric curves within the Parsęta River drainage basin (Poland) as a geoindicator of geomorphological hazards

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Abstract—**The article presents the changeability of hypsometric parameters calculated for hypsographic curves in 235 catchments of the Parsęta River drainage basin. Catchments with convex curves are more susceptible to the destructive effects of extreme denudational processes, whereas catchments with concave curves are better prepared for the affecting of a wide range of denudational processes of various magnitude.**

I. INTRODUCTION

Clarke and Orrell [1], as well as Baulig [2], reproached geomorphometry for the fact that the analysis results of a small study area cannot be translated into a bigger area, as the occurrence of landforms is irregular, non-continuous and unpredictable. Hettner [3] claimed that morphometric methods do not have any meaning in the explanation of origin. Dorywalski [4] thought that the transition from qualitative to quantitative studies shows the development of a science, allows to determine precise terms, and eliminates the researcher's subjectivism. Geomorphometry is a science of determining and analysing relief elements in quantitative terms (Hengl, Reuter 2008). Measurements are most frequently taken in topographic maps, digital elevation and terrain models, satellite images or air-photos, and not on the basis of field study. Measurements and statistical methods constitute the basis to create coefficients and indexes, making it possible to describe landform in a quantitative way, which is more precise and explicit that general verbal description. This direction was initiated by Humboldt [5] and Ritter [6], and developed by American geomorphologists in mid-20th century. Strahler [7] was one of them; he initiated the analysis of river drainage basins by hypsographic curves.

The study objective is to determine the morphological and evolutionary diversification of catchments in the Parsęta River drainage basin through their hypsographic curves in the context of secular and extreme processes. According to Strahler [7], the shape and course of the hypsographic curve should render the drainage basin's relief age diversification and evolution extent. The objectives of this study, which uses the concept of hypsographic curves, are the following: to obtain hypsographic curves of catchments of the Parsęta River drainage basin and to attempt to find a relationship between the shape of the hypsographic curves and the spatial position of the catchments, as well as to interpret the role of curves in the course of denudational processes.

Strahler [7] compared hypsographic curves with three river catchments which differed in the development of relief. He noticed that the shape of the curves depends on the relief development phase. The bigger sediment loss resulting from erosion in a given area, the older the relief. Therefore, a hypsographic curve with a convex shape corresponds to the early development phase, an S-shaped curve shows the mature phase, and a concave curve indicates the old-age phase.

II. STUDY AREA

Calculations of hypsometric curves was conducted for the Parsęta River drainage basin (Western Pomerania). The Parsęta River drainage basin includes the 131.6 km long Parsęta River

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valley, and its area is 3145 km^2 [9]. The relief of the Parsęta River drainage basin is of postglacial nature.

III. Methods

A digital elevation model DTED2 with grid cells of 35 m × 35 m constitutes source data for the Parsęta River drainage basin. Hypsometric curves were described with the following parameters: hypsographic curve integral, hypsometric skewness, hypsometric kurtosis, probability density function skewness, probability density function kurtosis, catchment size, circularity. Catchment limits in *.SHP format come from the Computer Map of Polish Hydrographic Division [8]. The Parsęta River drainage basin was divided into 235 catchments.

IV. Results

A. Hypsographic curve integral

Curve integral is the surface area determined by the hypsographic curve and the graph axes. The higher the value, the more convex the curve; the lower the value, the more concave the curve. However, the value of the curve integral does not explicitly determine its shape. Curve integral values fall in the range between 0.17 and 0.77, with the mean value equal to 0.43 (Fig. 1). The lowest values occur in the middle part of the drainage basin. These are catchments located very close to the Parsęta River or constituting the River's catchments of the first order. The highest values are characteristic for catchments located at the outskirts of the drainage basin, in the vicinity of a drainage divide of the first order. These areas have the biggest absolute altitude. Hypsographic curve integral serves well to distinguish between catchments, i.e. for young catchments the curves are concave, and for mature catchments they are convex (Fig. 2).

B. Skewness

Values of the hypsometric skewness parameter for the Parsęta River drainage basin catchments fall in the range between 0.037 and 1.24, with the mean value equal to 0.48 (Fig. 3). All hypsographic curves have positive skewness. It is difficult to confirm the correctness in the spatial distribution of hypsometric skewness. Catchments with the lowest skewness values border catchments with the highest value of this parameter. However, there are more catchments with the lowest value of the parameter in the north-west part of the drainage basin.

C. Kurtosis

For the Parsęta River drainage basin catchments the kurtosis values fall in the range between 1.33 and 4.41, with the mean value equal to 2.2 (Fig. 4). The highest kurtosis values occur in the north-east part of the drainage basin, next to the Radew River catchments, whereas the lowest values — in the north and central part of the drainage basin.

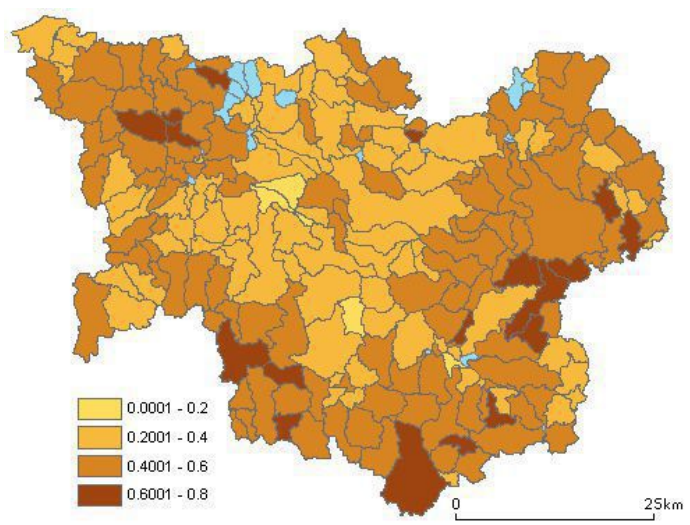

Figure 1. Map of the Parsęta River drainage basin showing spatial diversification of hypsographic curve integral. Blue colour means that no data are available

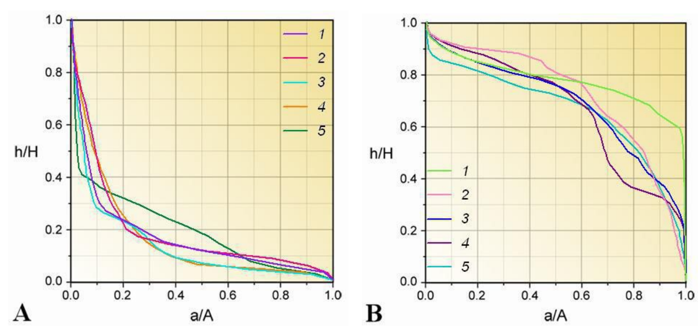

Figura 2. Hypsographic curves of the Parsęta River drainage basin catchments with the lowest (A) and the highest (B) value of hypsographic curve integral
A: 1- the Parsęta River from the Mogilica River to the Liśnica River (R), 2- the Parsęta River from the tributary from near Sadkowo to Dębnica (L), 3- the Liśnica River from the tributary below Żytelkowo to the mouth, 4- the Parsęta River from Gęsia to Perznica (R), 5- the Pokrzywnica River from the tributary from near Zwartowo to Młynówka (L)
B: 1- Tributary from Kłopotowo, 2- Tributary from near Zajączkowo, 3- Rosnowski Channel, 4- Tributary from Górowino, 5 – from Debrzyca to Łęczna (R)

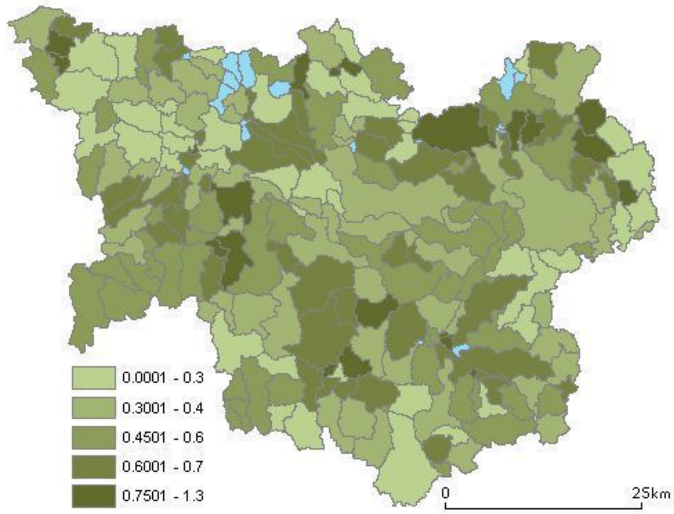

Figure 3. Map of the Parsęta River drainage basin showing spatial diversification of hypsometric skewness. Blue colour means that no data are available

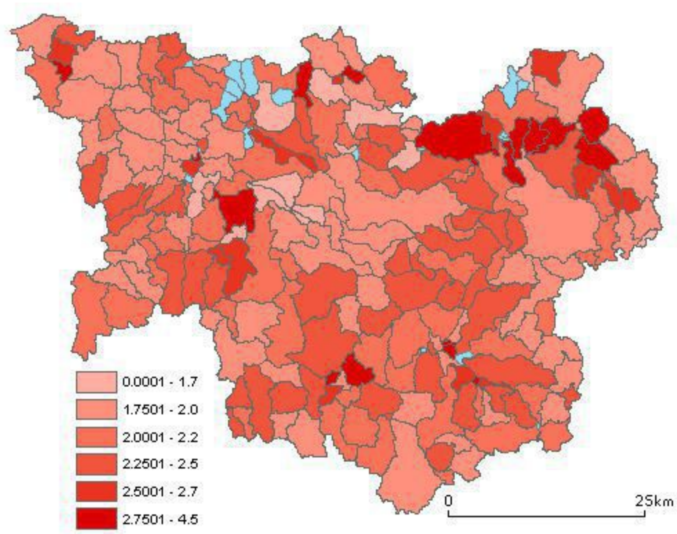

Figure 4. Map of the Parsęta River drainage basin showing spatial diversification of hypsometric kurtosis. Blue colour means that no data are available

D. Probability density function skewness

Probability density function skewness for the Parsęta River drainage basin catchments takes values in the range from -13.3 to 1.9 (Fig. 5). The highest values of probability density function skewness are visible in the central part of the drainage basin. The lowest values are characteristic for catchments in the south edge of the drainage basin, as well as its east and south-east part.

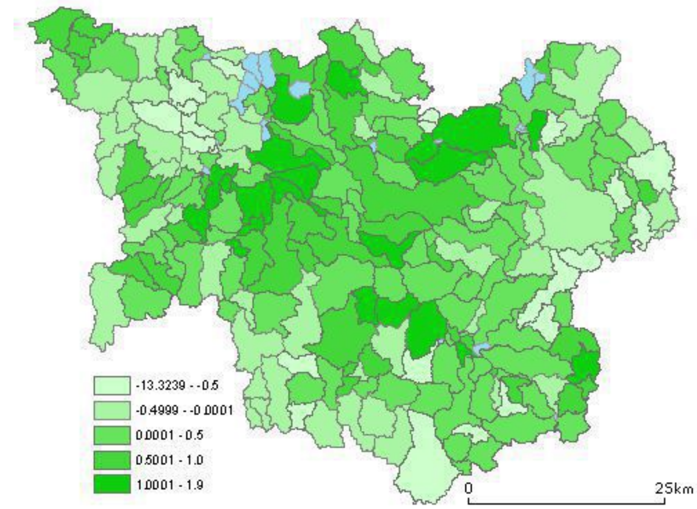

Figure 5. Map of the Parsęta River drainage basin showing spatial diversification of probability density function skewness. Blue colour means that no data are available

E. Probability density function kurtosis

The values of the probability density function kurtosis fall in the range between -119.9 and 4.62, with the mean value equal to 1.27 (Fig. 6). The definite majority of the Parsęta River drainage basin hypsographic curves have kurtosis values lower than 3, which means that their distribution is flatter than normal distribution. The lowest values of probability density function kurtosis can be found in the north-west part of the drainage basin; catchments with the highest values are evenly distributed on the whole drainage basin, no regularity can be found in their distribution.

F. Catchment size

The size of the Parsęta River drainage basin catchments is very diversified. The smallest catchment has only 0.17 km², whereas the biggest - over 89 km². The average size is 14 km². The smallest catchments are usually direct catchments of the Parsęta or the Radew Rivers, i.e. riverside catchments. The biggest catchments are located farther from the biggest rivers. They can be found in the central and west part of the region (Fig. 7).

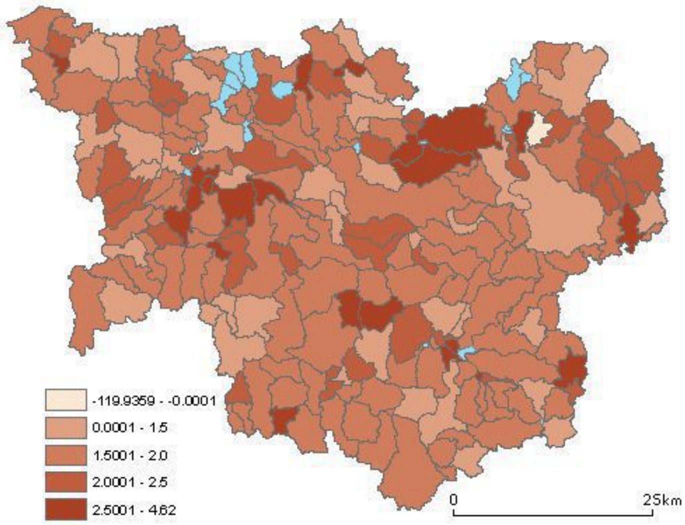

Figure 6. Map of the Parsęta River drainage basin showing spatial diversification of probability density function kurtosis. Blue colour means that no data are available

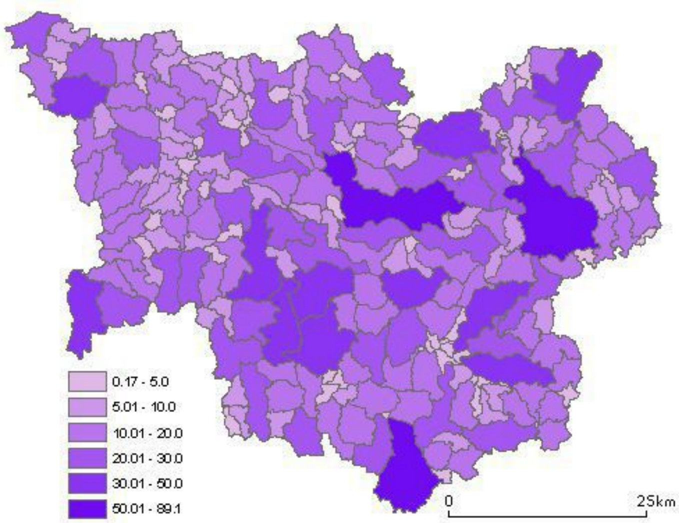

Figure 7. Map of the Parsęta River drainage basin showing spatial diversification of catchment size

G. Catchment circularity

The circularity of the Parsęta River drainage basin catchments falls between 0.22 and 0.81, with the mean value equal to 0.45 (Fig. 8). The biggest number of catchments with the smallest circularity are located in the central part of the drainage basin; they have the characteristic elongated shape. Most circular catchments are evenly distributed across the entire drainage basin.

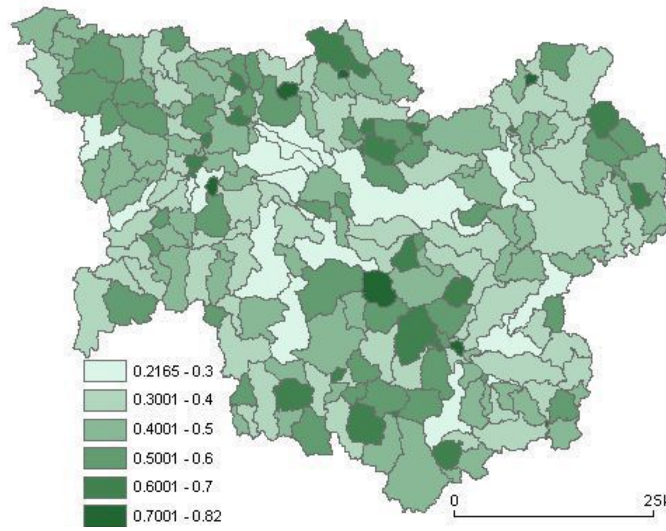

Figure 8. Map of the Parsęta River drainage basin showing spatial diversification of catchment circularity

V. CONCLUSIONS

The hypsographic curves of the Parsęta River drainage basin catchments are very diversified. They represent all landform development types distinguished by Strahler (1952). This proves high geodiversity of the study area. Parameters of the hypsographic curves distinguished by Strahler (1952) and Harlin (1978) are suitable for describing curve shape with numbers.

The Parsęta River drainage basin catchments can be divided into two groups. The first includes catchments located in the central part of the drainage basin. The shape of their hypsographic curves is concave, which is confirmed by the curve integral, as well as the low values of kurtosis and probability density function skewness. Whereas catchments located on the outskirts of the drainage basin have hypsographic curves with a more convex shape. Observing the denudational processes, both secular and extreme, which take place in the Parsęta River drainage basin, it is appropriate to conclude that catchments with convex curves are more susceptible to the destructive effects of extreme denudational processes, whereas catchments with concave curves are better prepared for the affecting of a wide range of denudational processes of various magnitude.

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