Geomorphometrical Mapping of Relief-Dissection Using GIS

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Abstract. In this project we have made an attempt to find out the limits of GIS in morphometrical analysis. The aim is not only to produce and analyse a vertical relief-dissection map, but we wish to point out the regional differences in erosion and its translocation in a geological scale. According to our idea, the vertical relief-dissection map (i.e. negative relict surface) can be constructed for each stream order by subtracting the real surface from the summit planes fitting on the watersheds. Such maps can give information about long-term translocations of erosion and about the changes of its rate. The mapping of vertical relief-dissection is based on morphometrical analyses of the 70's, but as there where no suitable methods it was carried out only under limited conditions. The surface modelling of GIS has opened a new way in this direction.

Introduction

Studying the erosion development of a given surface is a traditional subject in geomorphology. In the latest 20 years geomorphology has moved away from the investigation of the denudation chronology towards the study of processes. The traditional problem of geomorphology is the connection between shapes and processes. The explanation of land surface and the calculation of the characteristics of surface need quantitative description of the relief. In the 70’s, morphometry gave a solution for the problem by quantification of the relief. From the middle of the 80’s, GIS has proved to be a very powerful and useful method and offered advantages for spatial distribution of geomorphological processes.

The landscape by its work often leaves measurable marks behind. From the point of view of the destroying effect, of the intensity of erosion, it is a good estimate to measure the amount of material that has been transported away. Starting from the flat surface the rate of relief transformation can be deduced from the dissected river network, or from the amount of material that has been carved out from the flat terrain and taken away by the rivers. This volume can be calculated by morphometric analyses step by step according to the dissection rate of the river network’s. The degradation is negligible on the edges of the catchment area. If we set a plane on these catchment-edges, we can call this surface the “summit plane” compared to the present situation.
Method

We have analysed an approximately 100 km$^2$ catchment area. It is situated on the NE edge of the 15 million-year-old Mátra volcano (in Northern-Hungary), which produced mostly andesite and riolith. Therefore, since our test area was more or less geologically homogeneous, we cannot take into account the possibility of translocation of stream directions. In addition, the precipitation conditions are very similar all over the area, thus we do not suppose significant change in the rate of erosion.

We have supposed that a currently six-ordered stream (Strahler-order) was five-ordered earlier, four-ordered even before, and so on. This works only as a model, because in spite of the homogeneity geological, climatological and orographical differences could occur. The usability of the order system for statistical/GIS investigation was also supposed. The aim of the research is to highlight these disturbances which can be investigated in the drainage-network.

First of all, we have classified the stream network of the area according to Strahler's system (Fig. 1). The stream network was defined by using the Multiple Flow Direction (MFD) (Freeman 1991) and the Deterministic 8 (D8) (Tarboton et al. 1991) models. Both models calculate the orographically definable catchment area for each pixel in the area. While the D8 model allows water to flow only toward one of the neighbouring pixels, MFD tolerates multiple flow directions as well, i. e. toward more than one pixel.

When calculating the entire catchment area, we have used the real surface, since this is larger than that of the area shown in the map's projection. The real pixel area was calculated with the following formula:

$$T_f = \frac{T_c}{\cos(S)}$$

where $T_f$ stands for actual (absolute) surface area, $T_c$ for the area of a pixel and $S$ indicates slope.

In case of low accumulation values, we have used the MFD model, providing a correct result with non-convergent territorial flows. Where the accumulation value exceeded a threshold of 25000 m$^2$ (set by experience) we used D8, which is more suitable for modelling linear erosion processes. By extracting high values from this map (over 75000 m$^2$ in this case) we can produce the stream network, based on which we can define the individual partial catchment areas. We have counted more than 1000 stream segments. The large number of streams confirmed the statistical results of the drainage analysis.

Secondly, we have subtracted the real surface heights from the summit planes fitting on the watersheds of first-, second-, etc. order. In this way we got different vertical relief dissection-map for each order using ArcInfo 7.0.3. GIS. In order to prepare the n-order vertical variance map, we have created a surface using the intersections of the contour lines and the n-order catchment area boundaries (height values are derived from the values of the intersecting contour lines). The original method considered this as the summit plane (Kertész 1974). Based on GIS analyses, we have concluded that this method is only valid for ideal catchment basins. In most cases the development of the catchment area is far from ideal which makes the real surface to come above the calculated summit plane, thus negative values can appear.