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TOOLBOX FOR DETERMINING THE VOLUME OF ERODED MATERIAL FROM THE CATCHMENTS

HERISANU, G[heorghe] A[ntonel]; ZAVOIANU, I[on] & CRUCERU, N[icolae]

Abstract: *The article presents a software application developed for ArcGIS version 9.x, which can be used to calculate the volume of material eroded from a river basin. Here are presented the principles of calculation, the algorithm and the application itself, specifying the steps of analysis and the results. The application may present a particular interest to realize catchments management plans and to determine dynamics of the relief.*
Key words: *GIS, erosion, basin, denudation rate*

1. INTRODUCTION

Knowing the volume of material eroded by river systems over time is a very useful to achieve a good management plan of water resources and river basins and to determine the optimal position of dams and reservoirs with different utilities. Also, knowing the value of volume of eroded material and the age of the initial basin surface, the average rate of denudation relief is determined, with particular importance in hydraulic studies and to determine long-term landscape dynamics.

The method has been proposed in the first half of the twentieth century by W.B. Langbein, 1947; it was later picked up and refined by A. N. Strahler, 1952; R. J. Chorley, 1957; L.B. Leopold et al. 1964; I. Zăvoianu, 1985, and others. More recently, we can note the methodological contributions of the Italian school: S. Ciccacci et al. (1981), Della Seta, M.et al. (2006, 2009).

2. PAPER DATA

The need to determine the average rate of denudation, as part of river basin management plan, also required data processing by modern computer technologies.

Starting from the numerical model of the terrain and using a Geographical Information Systems (GIS), the volume and quantity of eroded material can automatically be determined, quickly and with minimal effort.

The toolbox is an application for ESRI ArcGIS 9.x. and is dedicated to automatic analysis of the land. The toolbox integrates earlier achievements of other specialists, being also adapted some algorithms and software sequences specific for both 9.x and 3.x versions.

The toolbox has several interrelated parts so that to analyze an area (preferably well-defined catchments) on the basis of the digital terrain model and, using the difference between the volume corresponding to the initial surface of the basin and the current one, to calculate the volume dislodged by erosion process.

Restoring the original surface of the catchments is based on correlation and interpolation of current altitude values existing on relatively flat surfaces of interfluves, as remnants of previous drainage areas.

To use the toolbox, two elements are needed, namely: the Digital Terrain Model (the better the digital terrain model resolution, the more accurate the results) - called *theme 1*, and a line-type vector representing the network of interfluves (primary and secondary orders) for the basin, here after called *theme 2*. Analysis is performed through application to provide the user interface.

To determine the initial volume of the basin area, first we proceed to reconstruct the original surface on which erosion has installed, starting from the existing remains of the old surface, situated on interfluves.

This part of our application includes the principles and some parts of the toolbox realized by J. Jenness (2006) and T. Dilts (2010), on the basis of analysis of the altitude difference of a cell of the numerical model and average altitudes neighboring cells (A. Weiss, 2001), the neighborhood analysis of slopes and TPI (Topographic Position Index) by Small Neighborhood algorithms (for small area analysis - small ray neighborhood analysis) and Large Neighborhood (for large areas analysis - greater ray neighborhood analysis).

Out off the numerical model of land (theme 1), 10 simple forms of relief are extracted, according to this algorithm (J. Jenness 2006; T. Dilts 2010) and taking into account the neighborhood analysis and the type of relief on which the basin is located: 1-canyons, deeply incised streams; 2-midslope drainages, shallow valleys; 3-upland drainages, headwaters; 4-U-shape valleys; 5-plains; 6-open slopes; 7-upper slopes, mesas; 8-local ridges/hills in valleys; 9-midslope ridges, small hills in plains and 10-mountain tops, high ridges

The operator has control over the entire process by introducing a range of neighborhood analysis, a prior knowledge of the topographical map for that area being indicated. After using this algorithm for automated classification of landforms, the identified peaks are of interest (types 8, 9 and 10) and will be selected and translated into a new theme (Theme 3) - figure 1a).

Also starting from the digital terrain model (theme 1) an analysis of basin slopes is performed and, at the end, there are retained only those perimeters with slopes values that satisfy the condition imposed by the user, usually with slopes less than 4˚ (theme 4) - figure 1b). The line-type vector (theme 2), representing the interfluves, will be converted into a point-type vector (for each digitized vertex); this vector table will contain the associated attribute information of the slope value and the type of relief (interfluve or not - theme 5) - figure 1c). By combining the three aforementioned analyzed and selected themes (themes 3, 4 and 5) will result a point-type vector corresponding to those parts and points of interfluve that match the specific relief form and slope of that basin (theme 6) - figure 1d). By interpolating these points will result the initial surface of the river basin (theme 7) - figure 1e).

Any software dedicated to Geographic Information Systems presents a number of vector and raster functions - the Cut/Fill function will be applied between the volume of the derived initial surface and the volume corresponding to the current surface calculated on the of theme 1. The difference is just the volume of the eroded material, figure 1f).

The presented application allows knowledge, in a very short time and with minimal costs, of the amount of the volume of material eroded from a basin. Knowing the age of the initial surface and the volume of eroded material, we can estimate the average denudation rate of relief for very long periods of time.

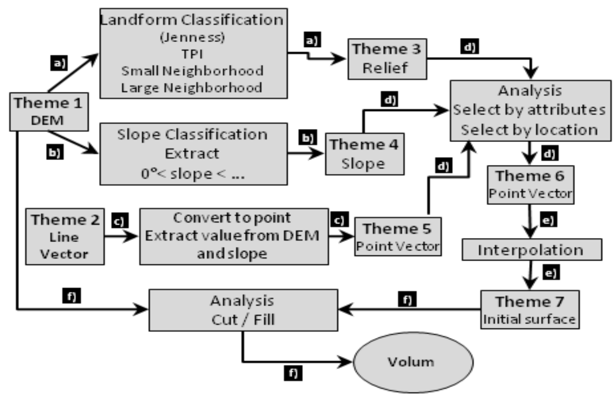

Fig. 2. Schematic diagram of the application: a) identifying watersheds, b) slope analysis, c) vector conversion of line and in point and award values to altitude and slope, d) points corresponding selection criteria imposed by slope and type of relief (interfluves), e) selected interpolation points, f) the volume difference between the initial surface (Theme 7) and the current (Theme 1)

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This application can be used on any computer having an operating system that supports ArcGIS 9.x; any type of numerical model of terrain (DEM) can be used as input (free types as SRTM, ASTER GDEM, etc, or commercial versions) and the vector for interfluves must be ArcView specific (**.shp type).

For example, we present the Bârlad river basin area controlled at Vaslui hydrometric station that has order 7 in Horton-Strahler system, with an area of 1537 km^2. A series of tests has been made to verify the application, starting from the numerical model of land corresponding to the current surface and vectors representing peaks of different orders of magnitude in Horton-Strahler system. Applying the above algorithm on these input data, the results were as it follows:

- When using vectors for interfluves of orders 3 and 4, the initial surface of the basin is generated with very good accuracy, but this is not very different from the general configuration of the current surface, and therefore the volume of material considered as eroded is small.
- From the analysis of vectors representing the interfluves of order 5, the generated initial surface is relatively widespread over the basin, thus showing major differences in its volume and the volume corresponding to the current surface (the volume considered as dislodged is twice as compared with the volume corresponding for summits of order 3 analysis).

Starting from the value of the calculated eroded volume, the average denudation rate was determined, for each of the analyzed situations. It was noticed that the value of the average rate of denudation, in all cases, is less than the measured average suspended silt flow for the last 50 years. The fact is explainable if we take into account the fact that, over time, the erosive potential of the network of rivers has increased, both because of growth of altitude intervals at the lower order, and as a result of human intervention in the landscape during the last centuries.

Human intervention, reflected primarily by deforestation, has led to an acceleration of current geomorphological processes, so that we currently observe an increase in activation of gullies and landslides; both are considered as main sources of increasing the amount of eroded material.

For the future, we propose few further lines of research, namely:

-Checking and comparing the results obtained from processing the measurements from gauging stations or experimental stands with values resulting from the use of this GIS application.

-Finding a relationship of trust between the values resulting from the use and application at different resolutions of DEM.

-Translating this application towards open source software.

-Implementation in this toolbox of parts of the Hydrology toolbox and/or the Arc Hydro Tools applications, so that the line-vector representing interfluves not to be required, thus the volume of eroded material being calculated only by the analysis of the numerical model of terrain.

-Implementation in this application of two new specific conditionings: geology (petrography, structure) and land cover.

3. CONCLUSION

The proposed method is the result of a large number of analysis and verification in river basins where could reshape/restore with sufficient precision the initial surface from which relief modelling started. In case the interfluves cannot restore the surface of erosion that began to act, the results are wrong. Denudation rate, determined by this method, is an average period of life during river basin; during this period there were stages with maximum and minimum values, depending on the geological evolution of the basin. Accuracy of calculations depends very much on whether it is possible to consider or determine the correct age of the initial surface at which started relief modelling within the basin and on the reliability of data (DEM and vector) entered into the analysis

4. ACKNOWLEDGEMENTS

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