

ESTIMATING AND MAPPING TORRENTIALITY RISK IN SMALL FORESTED WATERSHEDS

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Abstract: *The torrentiality degree is a useful indicator in classifying the priority of the proposed torrent control activities in torrential watershed management. The paper analyses and proposes a method for estimation of torrentiality degree of a small torrential watershed, which is improved by using geospatial referenced data incorporated in a geographic informational system. The materials used in estimating the torrentiality degree are all geospatially referenced data extracted from a digital elevation model and from the forest management database of the area, reducing the necessary processing time. For calculation of the peak discharge the standard morphometric diagram's analytic formula was used.*

Key words: *torrentiality, forested watershed, peak discharge.*

1. Introduction

Torrentiality degree is a useful indicator in classifying the priority of the proposed torrent control activities in torrential watershed management. It can be calculated using the procedure proposed by R. Gaspar. It quantifies the torrentiality on a scale of 0 to 1, where 0 characterizes the best retention conditions, and 1 characterizes the opposite.

Thus the torrentiality degree is ranking the watershed between the 2 extreme conditions presented above. For liquid flow of a small watershed, the torrentiality degree is calculated using 3 data input, as mentioned in formula 1 [2]:

$$K_{tor} = \frac{q - q_1}{q_{10} - q_1} \leq 1.0, \quad (1)$$

where: q is the peak discharge for actual

conditions of the watershed; q_1 is the minimum specific peak discharge characterized by the best retention conditions in the same watershed; q_{10} is the maximum specific peak discharge characterized by the worst retention conditions in the same watershed.

The aim of the paper is to propose and analyze an improved method (by using geospatial referenced data) for estimation of torrentiality degree of a small torrential watershed. Another goal is to emphasize the importance of knowing the torrentiality degree and the geographical distribution in basins for managing Torrent Control activities

2. Material and Method

An easy usage of geospatial referenced data into a GIS is the grid format. Having different information stocked in matrixes,

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with the same roughness, facilitates the data manipulation, offering the possibility of producing the result at cell level [4].

The structure of the method itself contains several steps:

1. Entering the primary data input (land cover, soil texture, slope);
2. Extracting the primary data output - the runoff coefficient in grid format;
3. Extracting the secondary data output - the peak discharge (calculated on small watershed level);
4. Realise the steps 1-3 for best and worst retention conditions;
5. Computing the torrentiality degree.

The proposed method uses three data input in order to estimate and map the torrentiality degree:

- The grid information about **Land cover** extracted from Forest Management Database (in areas without an available Forest Management Database, Corine Land Cover can be used);
- The grid information about **Soil texture**

extracted from Forest Management Database (or from Geologic Atlas);

- The grid information about **slope** extracted from DEM (DEM source: 30 m resolution ASTER DEM).

The calculation of torrentiality degree, with classical technique, required a lot of computational time, because of the iterations that had to be made in order to simulate the 3 conditions mentioned above. The obtained result was on watershed level.

Using the GIS techniques applied on proper data for input and adopting a faster formula for the peak discharge, the new method allows an accurate calculation of the runoff coefficient, by estimating it on cell level, and a faster calculation of the peak discharge using Standard Morphometric Diagram - the analytic formula (Figure 1).

In order to calculate the peak discharge for the 3 scenarios, runoff coefficient needed to be calculated. The Frevert method was used, by overlaying the raster data input for soil texture, land cover and slope.

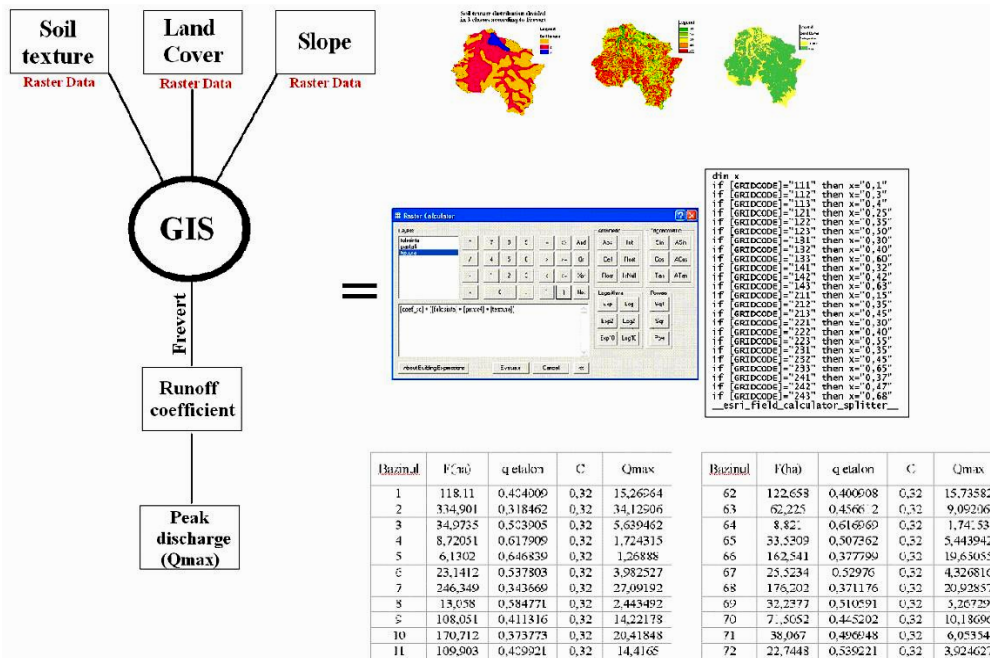


Fig. 1. Logical schema of the method for steps 1-3

For a better adjustment into a computational algorithm the raster data were coded in several categories:

1. *Soil texture data* - for every grid cell an index was attributed according to Frevert classes (1 for sandy-loam, 2 for loamy-sand, 3 for loamy-clay).

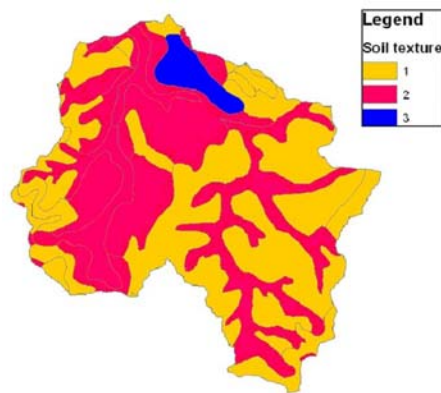


Fig. 2. *Distribution of soil texture classes in Tărlung Upper Basin*

2. *Slope data* - for every grid cell an index was attributed according to modified Frevert classes [3] (10 for slopes between 0 and 5%, 20 for slopes between 5% and 10%, 30 for slopes between 10% and 30%, 40 for slopes over 30%) [6].

3. *Land cover data* - for every grid cell an index was attributed according to Frevert classes (100 for forest, 200 for pasture, 300 for agricultural lands) [5].

After extracting the coded grids and summarising the primary data input, several codes appeared in the resulting matrix. The codes were automatically interpreted, having as a result the value of the runoff coefficient on cell level (Figure 2).

Dealing with small watersheds, the computation of the peak discharge can use different formulas for the presented situation (ex. Rational formula, SCS-CN formula etc.). The method used in estimating the torrentiality degree is the analytic formula of the Standard Morphometric Diagram [1].

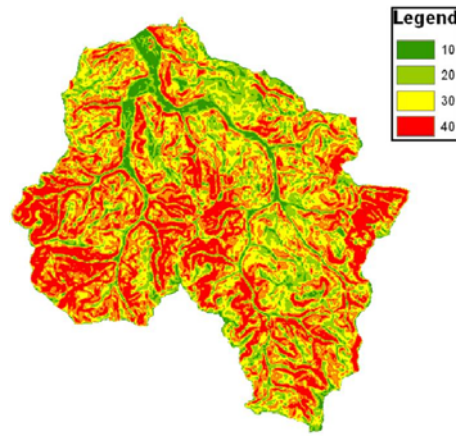


Fig. 3. *Distribution of slope classes in Tărlung Upper Basin*

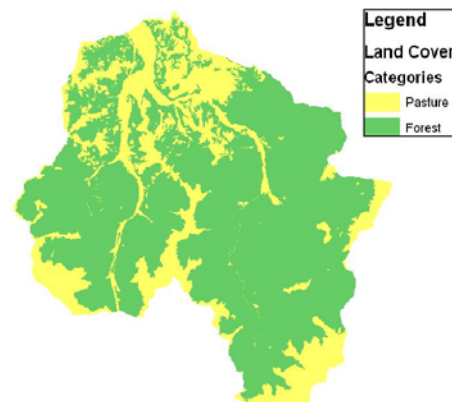


Fig. 4. *Distribution of Land Cover classes in Tărlung Upper Basin*

The Standard Morphometric Diagram is statistically derived from the rational formula, entering in equation the runoff coefficient and the watershed area. Having this data input, the integration into a GIS system is facilitated, offering the chance of reducing the computational time used in estimating the torrentiality degree. The analytic formula uses standard morphometric specific peak discharge, which is the peak discharge for a standard morphometric watershed (a theoretical watershed with the same morphometric characteristics of the examined watershed,

but the soil and vegetation cover are not taken into consideration and the geologic under layer is impermeable). The transition

from the theoretical situation to real situation is realised by multiplying with the runoff coefficient.

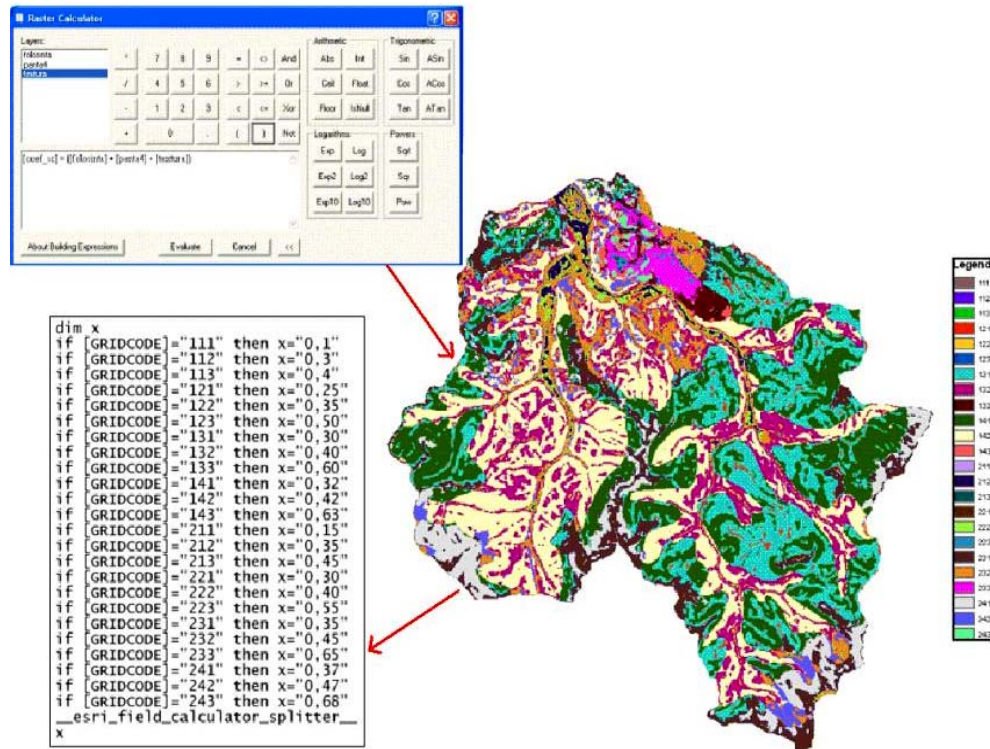


Fig. 5. Automatic extraction of the runoff coefficient

The analytic formula is represented by number (2) formula:

$$q_{\max} = \frac{6.247}{\log F^{0.189}}, \quad (2)$$

where: q_{\max} is the standard morphometric specific peak discharge; F is the watershed area.

From which results the peak discharge using number (3) formula:

$$Q_{\max} = c \cdot q_{\max} \quad (3)$$

where: c is the runoff coefficient; Q_{\max} is the peak discharge.

Using this methodology for calculating the specific peak discharges and the torrentiality coefficient (K_{tor}) was highly facilitative, giving the possibility to apply it, in short time to many watersheds situated in Tărlung Upper Basin.

4. Results and Discussion

The proposed method is applicable in small watersheds, and in the study case it has been used on 148 small watersheds, situated in Tărlung Upper Basin.

For the entire basin, the number of watersheds situated in minimum and medium classes was represented by 135 watersheds, which represents 91% from

the entire studied population (Figure 6).

The torrentiality degree calculated for small watersheds, using the new method, gives another perspective of result interpretation. Taking into discussion the Tărlung Upper Basin, divided into 148 small watersheds, and knowing the geographical distribution of them, new interpretations can be made.

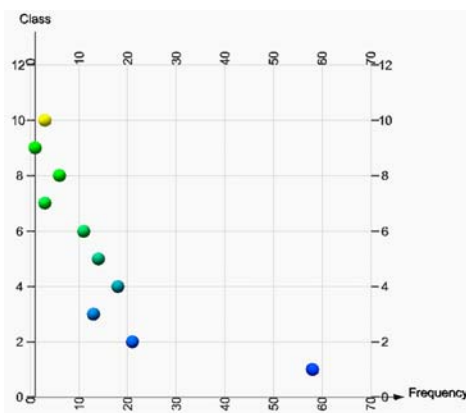


Fig. 6. *The watershed frequency distribution on torrentiality classes*

As it is presented in Figure 7, despite the fact that more than 90% of the delineated watersheds component of the basin have low and medium torrentiality degree, more than 70% of the 10% with high torrentiality degree are located near the “Acumularea Săcele” lake.

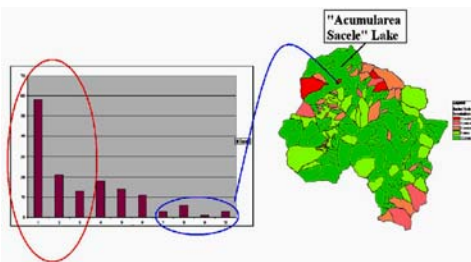


Fig. 7. *The geographical distribution of the watersheds grouped in torrentiality classes*

The extra information on torrential risk geographic distribution gives the opportunity

of concentrating the torrent control hydrotechnical works in those areas.

In the Tărlung Upper Basin, the highest concentration of constructed torrent control hydrotechnical works is located around the “Acumularea Săcele” lake. This area overlaps with the area emphasized by the applied method as having a moderate-high torrentiality degree. This fact shows that the actions made in the past to control the torrential activity of that valleys, justifies the results of the independent GIS method presented in this article.

5. Conclusions

The GIS algorithm reduces the computational time used, the consumed time for computing the torrentiality degree of 148 watersheds being lower than the one used for 1 watershed in the classic way.

The proposed method gives the opportunity to **calculate the torrentiality degree without having a Forest Management Database**, giving independence to method application. Many solutions are provided nowadays, and with ground checking they can facilitate extracting information about torrentiality degree both on small watershed level and on larger basins as presented in the study case. For example for land cover input the Corine Land Cover product can successfully be used, for texture the geologic atlas, for Slope ASTER 30 m DEM free product (on condition of checking it with other products if possible).

Mapping torrentiality degree with the new method, which uses geospatially referenced data, not only reduces the time used, but identifies the zones where to concentrate the studies for Torrent Control activities.

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