ASSESSING RAINFALL EROSIVITY FROM MONTHLY PRECIPITATION DATA

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ABSTRACT. Assessing Rainfall Erosivity from Monthly Precipitation Data. Human induced soil degradation and erosion are between the biggest environmental challenges of the XXI century. It is estimated that the world's top soil could be eroded within the next 60 years. Here we estimated the soil erosion by water in the Transylvanian Plain by applying the RUSLE equation in combination with the modified version of Fournier index, which takes into account the monthly and yearly precipitations for estimating the rainfall erosivity. Using GIS we generated an erosivity map for The Transylvanian Plain and used it in further spatial analyses to evaluate soil erosion.

Keywords: rainfall erosivity, RUSLE, Modified Fournier Index, Transylvanian Plain

1. INTRODUCTION

There are different types of models available to estimate soil erosion, including the EUROSEM (European Soil Erosion Model), LISEM (Limburg Soil Erosion Model), PESERA (Pan-European Soil Erosion Risk Assessment) and WEPP (Water Erosion Prediction Project) models. The most commonly used remains the classic Universal Soil Loss Equation (USLE), developed by Wischmeier & Smith (1965) and revised by Renard et al. (1991) who proposed for the first time the name „RUSLE" for the updated framework. Originally the equation was developed for the continental USA to evaluate and select between various soil conservation practices for different crop types and land-use/management systems.

RUSLE estimates the water induced soil erosion on the basis of six key factors: rainfall erosivity (R), soil erodibility (K), slope length (L), slope steepness (S), landcover and management practices (C) and conservation practices (P). The equation is:

$$A = R \times K \times L \times S \times C \times P \qquad (1)$$

where, A is the estimated spatial and temporal average soil loss per unit of area. As we know RUSLE uses the same basic equation as USLE but it also incorporates the new research results regarding their factors. Both equations reflect

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empirical associations and so they are valid only if their factors can be transposed from the experimental field to the wider reality.

In the USA one can simply estimate the above mentioned six factors from the RUSLE database; however in Europe the factors should be computed and contextualized according to the local and regional geographical and bioclimatical characteristics. In the European literature (Moțoc, et. al 1983; Renard, et al. 1997; Bilasco et al. 2009; Panagos, 2015) there are several definitions for the factors corresponding to different geographic regions and experimental fields.

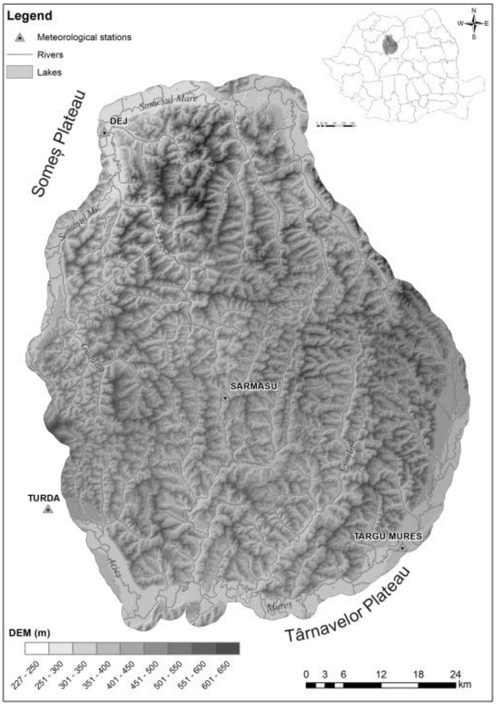

Fig. 1. ***Study area: Transylvanian Plain***

One of the most problematic component of the equation (1) is the rainfall erosivity factor due to the scarcely available data. In the original equation Wischmeier and Smith (1965) determined that the energy available to move sediment during a rainstorm is the product of the total amount of kinetic energy (E) of the storm, and the intensity (I) of the storm, named the EI parameter. Therefore the R-factor can be defined as the average annual sum of the EI parameters for all storms during a given year. Also they determined that the maximum thirty minute intensity of the storm yielded the best results.

One major problem for applying this formula will remain the scarcity of detailed rainfall intensity data. Because of this, several authors attempted to find correlations between the R-factor and some straightforward measurable characteristics of rainfall. In the paper we implement one of these equations for our study area (Yu & Rosewell, 1996), for assessing its usability in estimating erosion quantities with only monthly and yearly precipitation data.

2. DATA AND METHODS

2.1 Study area

The Transylvanian Plain (Fig. 1) represents the smallest unit of the three major divisions of Transylvania Plateau. Located in the north-central part of the Transylvanian Basin, between the mountain peaks of Călimani Mountains in the east and the Apuseni in the southwest, the Transylvania Plain appears as a low hilly region, used predominantly agriculturally. Compared to the other units of the

Transylvanian Plateau (Târnavelor Plateau and Somes Plateau), the Transylvania Plain presents distinct geographical features derived in part from its relative position regarding the adjacent mountain areas. Its orographic characteristics and crop management makes it perfect for comparing results, regarding the quantitative erosion estimated through the USLE equation.

Also, Moțoc, M (1963) experimented here for the data necessary for the USLE type ROMSEM model, with which he computed for Romania several of the USLE factors, from the experimental soil plots of Câmpia Turzii (Cluj County).

2.2. Methods

In 1960 Fournier developed an index using monthly and yearly precipitations to estimate rainfall aggressiveness, later research showed that the index it was correlated to other climatic variables, which are also contributing factors in the triggering or reactivation of erosive phenomena. The Fournier index formula is:

$$F = \frac{P_{\max}^2}{P} \qquad (2)$$

where, F is the Fournier Index, P_{max} is the monthly average amount of precipitation of the rainiest month (mm), and P is the average annual quantity of precipitation.

Later Arnoldus, in 1980 modified the original index so the formula transformed to:

$$F_M = \sum_{i=1}^{12} \frac{P_i^2}{P} \qquad (3)$$

where, F_M – Modified Fournier Index, Pi is the monthly average amount of precipitation for month *i* (mm), and P is the average annual quantity of precipitation (mm). He also showed, that the F_M index is a good approximation of R (rainfall erosivity) to which it is linearly correlated. F_M takes into account the seasonal variation in the precipitation, analyzing data on F_M, for different European regions (Bergsma, 1980; Bolinne et al., 1980; Gabriels et al., 1986), showed that the F_M index is strongly linearly correlated to the mean annual rainfall. This new modified formula also considered the yearly variation of the precipitation and also it showed a good correlation with altitude.

With the development of the new GIS technology it has became obvious that a spatial form of the USLE equation should be implemented. This is possible because all modern GIS programs have a layer based computation (Raster Calculator) method, which allows a relatively simple computation of the erosion if the USLE equation factors maps are accessible.

As we mentioned above, Yu & Rosewell (1996) found a strong correlation between the modified Fournier index and the R-factor:

$$R = 3.82 F_M^{1.41} \ [\text{MJ mm ha}^{-1}\ \text{h}^{-1}\ \text{yr}^{-1}] \qquad (4)$$

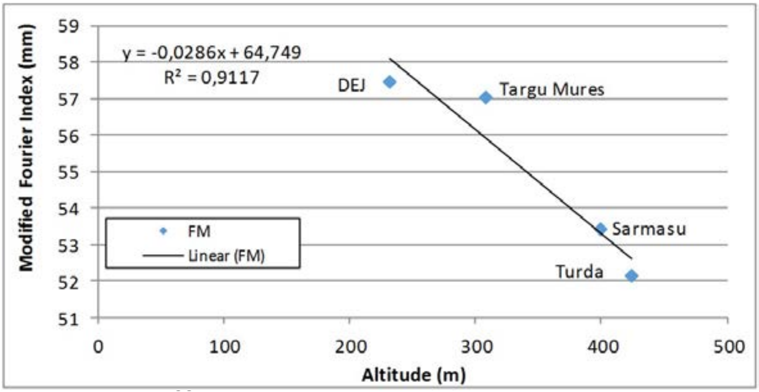

Fig. 2. ***Station altitude and the Modified Fourier index correlation***

For the assessment of the R-factor we chose four nearby meteorological stations, to the Transylvanian Plain, with long term monthly and yearly data available (1961-2000). We found a strong correlation between the modified Fourier index and the altitude of the stations (Fig. 2.) which made it possible to spatially represent the data through GIS (Fig. 3.).

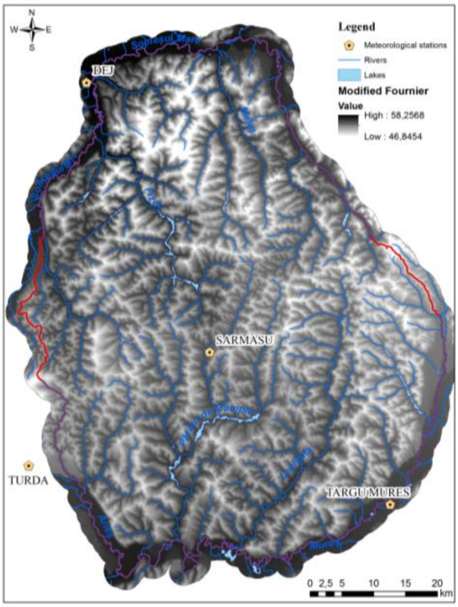

Fig. 3. ***Modified Fourier Index Map***

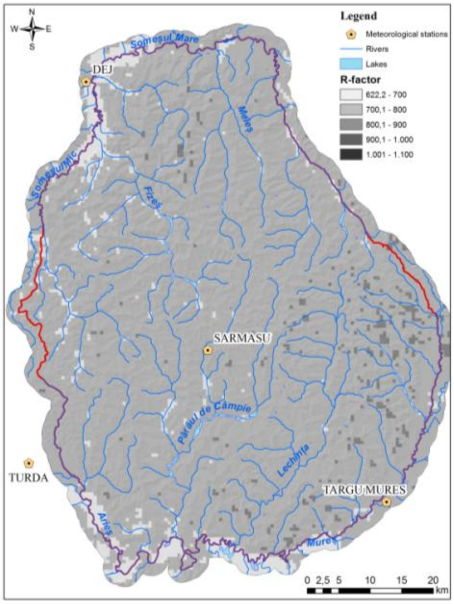

Fig. 4. ***R-factor, computed from rainfall intensity values RUSLE2015***

With the help of Esri"s ArcGIS/ArcMap Raster Calculator we implemented the correlation equation in GIS, using the DEM through spatial analysis (replacing "x" with the DEM in the equation y = -0,0286x + 64,749) we created the Modified Fourier Index Map (Fig. 3).

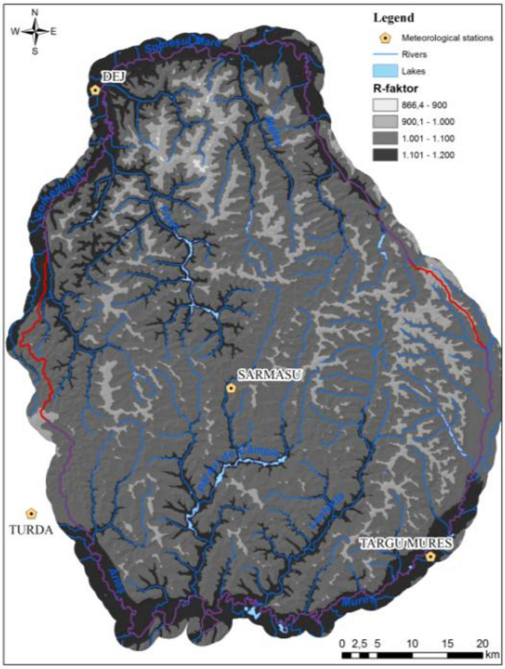

Fig. 5. ***R-factor modeled from F_M***

3. RESULTS AND DISCUSSION

In 2015 the European Commission, Joint Research Centre, Institute for Environment and Sustainability assessed the soil erosion by water for the entire European Union. The rainfall erosivity for our study region for 15 and 30 minute rainfall intensities is presented by Fig. 4 (Panagos, 2015). To evaluate the correctness of our computed values we compared our results with the above mentioned Europe wide study.

RUSLE factors such as soil erodibility (K), slope length (L), slope steepness (S), landcover and management practices (C) and the conservation practices (P) were used from the European Soil Data Centre (ESDAC), evaluated with 2015 state of art research (Panagos, 2015).

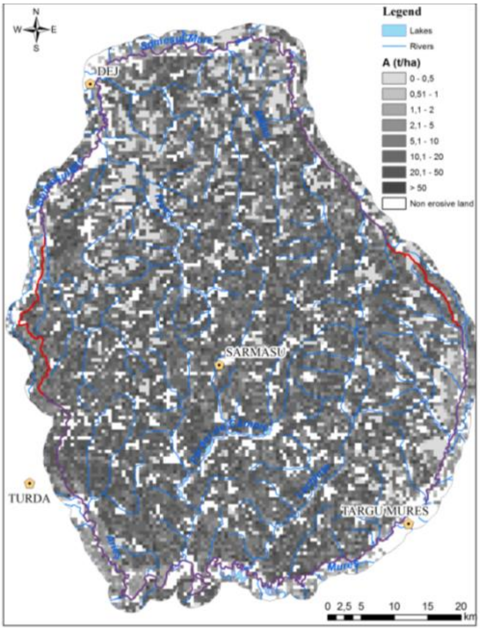

Fig. 6. ***Soil erosion map created based on the Modified Fournier Index***

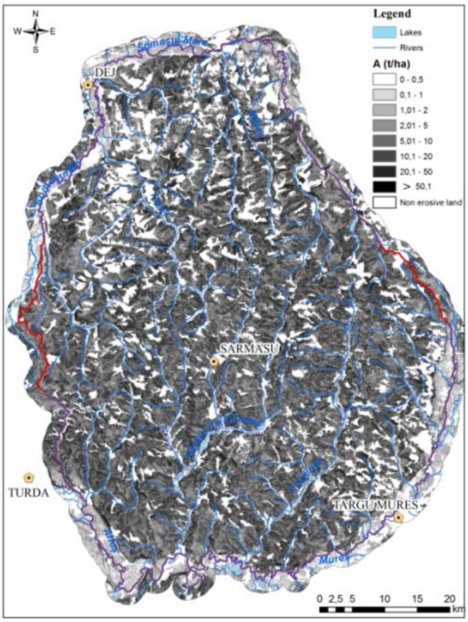

Fig. 7. ***RUSLE2015 Soil erosion map (Panagos, 2015)***

The chosen scale for the RUSLE2015 analysis is the 100 m pixel, this being the most appropriate because the C-factor (at 100 m resolution) can be altered as a result of policy interventions that affect land use (Fig. 7). The 100 m resolution also falls between the coarse resolution values of the K-factor (500 m), the R-factor (500 m), the P-factor (1 km), and the very high resolution of the LS-factor (25 m) (Panagos, 2015).

The RUSLE equation can simply be implemented in a spatial form because all factors can be interpreted as maps. If all factors are spatialized with a simple mathematical function one can compute the average erosion for the analyzed area, in our case the Transylvanian Plain. We used here the Esri‟s ArcGIS/ArcMap Spatial Analyst tools/ Map Algebra / Raster Calculator toolbox to implement the equation (Fig. 6).

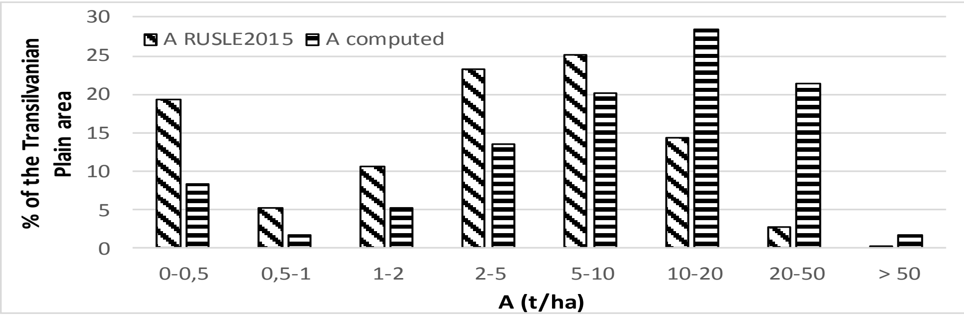

Fig. 8. ***Comparing the two resulting soil erosion map values***

4. CONCLUSIONS

We summarize our conclusions in the following main points:

- the modified Fournier index overestimates at high values and underestimates the RUSLE2015 at the small values (as indicated by Fig. 8).
- the amplitude of the erosion values are the same between 0 and a small percentage above 50 t/ha/year.
- based on the significant values of the erosion (Fig. 6, 7) we conclude that spatially both methods give maximum values on the same areas, the differences appears mostly because the resolution differences.

Finally we conclude that the application of the Modified Fourier Index for assessing the R factor in the RUSLE/USLE equation needs further research, however, the similar values from literature and the good correlation with altitude make it a good candidate to use it for estimate the R-factor from monthly precipitation values.

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