Applying RUSLE for soil erosion estimation in Romania under current climate and future climate change scenarios

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INTRODUCTION

• Our study investigates the possible evolution of RUSLE rainfall erosivity (R) factor under climate change scenarios in Romania and seeks identify the areas which are likely to experience an increase in soil erosion rates during the next decades.
• In contrast to temperature, which generally increases in most regions, rainfall manifests different evolution patterns, decreasing in some areas and increasing in others.
• A general finding for regions under temperate continental climate is the trend for rainfall to concentrate and become more aggressive.
INPUT DATA AND METHODS

• RUSLE (Revised Universal Soil Loss Equation) model was used to estimate current and future erosion rates:

\[ E = R \times K \times L \times S \times C \times P \]

- E – annual estimated soil erosion rate (t ha\(^{-1}\) yr\(^{-1}\));
- R – rainfall erosivity factor (MJ mm ha\(^{-1}\) h\(^{-1}\) year\(^{-1}\));
- K – soil erodibility (t ha h h\(^{-1}\) MJ\(^{-1}\) mm\(^{-1}\))
- L – slope length factor;
- S – slope factor;
- C – crop and crop management factor;
- P – soil conservation practice factor.
INPUT DATA AND METHODS

Input data

- EUDEM (25 x 25 m resolution) was used to derive LS factor
- Soil map of Romania in vector format (1:200,000), spatial models of particle-size fractions and organic matter, point soil profile database, European soil database (ESDB) were used to derive soil erodibility in 4 manners
- The annual crops for the year 2021 and CLC 2018 were used for computing crop and crop management factor
- European rainfall erosivity factor from RUSLE 2015 model (Panagos et al., 2015)
- Precipitation raster data for current and future climate extracted from CHELSA database.
SOIL EROSION FACTORS

Rainfall erosivity factor for current climate
• We extracted the model achieved by Panagos et al (2015) at EU level (500 m resolution)
• We also tested statistical regression equations proposed by Renard et al. (1994) for the continental United States for the estimation of R factor based on Fournier index. Their application to the Romanian territory led to values larger than expected, probably because the continental climate of eastern US is more excessive than the one of Romania.
SOIL EROSION FACTORS

Soil erodibility factor
• We tested 4 manners of quantification

- Torri et al. (1997) formula based on particle-size fractions and organic matter content
- Mathematical expression of USLE erodibility nomograph and soil structure inferred from soil map of Romania (1:200,000)
SOIL EROSION FACTORS

Soil erodibility factor
• We tested 4 manners of quantification

Mathematical expression of USLE erodibility nomograph and soil structure inferred from soil profiles

Mathematical expression of USLE erodibility nomograph and soil structure inferred from ESDB
SOIL EROSION FACTORS

Slope and slope length factor

- We tested several algorithms, but achieved realistic results only with Desmet & Govers (1996) method using SAGA GIS software (LS Factor, Field Based module)
- The other tested methods produced higher values leading to high erosion rates
SOIL EROSION FACTORS

Crop and crop management factor

- We used the annual crops for the year 2021 (given in parcels centroids) for arable land and CLC 2018 for the other land use categories
- Most of the C factor values were taken from Panagos et al., 2015)
SOIL EROSION RATES

- 4 models were achieved according to the different manners of quantifying soil erodibility

Soil erodibility - Torri et al. (1997)

Soil erodibility - soil map of Romania
SOIL EROSION RATES

• The best model will be selected based on validation with measured erosion rates – NOT YET PERFORMED

Soil erodibility – profile database

Soil erodibility - ESDB
## Average estimated erosion rates (t / ha\(^{-1}\) yr\(^{-1}\)) for Romania

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>RUSLE 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>2.23</td>
<td>2.94</td>
<td>3.13</td>
<td>2.75</td>
<td>2.84</td>
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<tr>
<td><strong>Arable land</strong></td>
<td>2.80</td>
<td>3.25</td>
<td>3.63</td>
<td>3.12</td>
<td>3.39</td>
</tr>
</tbody>
</table>
PREDICTIONS OF RAINFALL EROSION EVOLUTION

• We used the precipitation data for 5 climate models and 2 representative concentration pathways (RCP) extreme scenarios (4.5, the more mild scenario and 8.5, the more extreme scenario) and 2 time periods (2041-2060 and 2061-2080). The selection of the 5 climate models (CESM1-BGC, CESM1-CAM5, CMCC-CM, MIROC5, MPI-ESM-MR) was based on the lowest amount of models’ interdependence and the average predictions of these models were further used to estimate future rainfall erosivity.

• The modified Fournier index was computed for both current and future climate, based on monthly precipitation data:

$$MFI = \frac{\sum_{i=1}^{12} p_i^2}{P}$$

✓ $p_i$ – mean monthly precipitations (mm);
✓ $P$ – mean annual precipitation (mm).
PREDICTIONS OF RAINFALL EROSIvITY EVOLUTION

- Statistical relationships between current rainfall erosivity (dependent variable) and MFI (predictor) were investigated
- Both linear and non-linear parametric and non-parametric regression models were tested
- The best model was the non-parametric regression model using the natural logarithm of MFI, X and Y coordinates as predictors

<table>
<thead>
<tr>
<th>Statistical model</th>
<th>Predictors</th>
<th>R²</th>
<th>RMSE</th>
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</thead>
<tbody>
<tr>
<td>Linear regression</td>
<td>F index</td>
<td>0.477</td>
<td>68.880</td>
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<tr>
<td></td>
<td>X coordinates</td>
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<td></td>
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<tr>
<td></td>
<td>Y coordinates</td>
<td></td>
<td></td>
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<tr>
<td>Linear regression</td>
<td>LN(F index)</td>
<td>0.522</td>
<td>65.872</td>
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<td>X coordinates</td>
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<tr>
<td></td>
<td>Y coordinates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-parametric regression</td>
<td>F index</td>
<td>0.705</td>
<td>51.694</td>
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<tr>
<td></td>
<td>X coordinates</td>
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<tr>
<td></td>
<td>Y coordinates</td>
<td></td>
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</tr>
<tr>
<td>Non-parametric regression</td>
<td>LN(F index)</td>
<td><strong>0.714</strong></td>
<td><strong>50.965</strong></td>
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<tr>
<td></td>
<td>X coordinates</td>
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<tr>
<td></td>
<td>Y coordinates</td>
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</tr>
</tbody>
</table>
• This model was applied to estimate future R factor values, which were then compared to the current estimated R factor values to infer trends in rainfall erosivity evolution.
PREDICTIONS OF RAINFALL EROSIVITY EVOLUTION

Predicted rainfall erosivity

Current estimated rainfall erosivity

2041-2060 RCP 4.5

2041-2060 RCP 8.5

2061-2080 RCP 4.5

2061-2080 RCP 8.5
Predicted differences between future and current in rainfall erosivity values

- During the 2041-2060 period, our analysis shows that the rainfall erosivity trend is positive throughout the country.
- An increase in rainfall erosivity > 40 MJ mm ha\(^{-1}\) h\(^{-1}\) year\(^{-1}\) is found for 6.9% (16500 km\(^2\)) of the country in RCP 4.5 and 9.8% (about 23000 km\(^2\)) in the RCP 8.5.
Predicted differences between future and current in rainfall erosivity values

- During the 2041-2060 period, our analysis shows that the rainfall erosivity trend is positive throughout the country.
- This will induce a corresponding increase in soil erosion rate with $>1-2 \text{ t ha}^{-1} \text{ yr}^{-1}$. Locally, the soil erosion rates may grow with as much as 10-20 t ha$^{-1}$ yr$^{-1}$. 
Predicted differences between future and current in rainfall erosivity values

- *During the 2061-2080 period, it is expected for the rainfall erosivity to decrease*, because of precipitation decline as a consequence of global warming.

- Most of the country (39.4% under RCP 4.5 and 58.5% under RCP 8.5) is likely to have R factor values slightly lower than at present.
Predicted differences between future and current in rainfall erosivity values

- During the 2061-2080 period, it is expected for the rainfall erosivity to decrease, because of precipitation decline as a consequence of global warming.
- However, the regions in W, SW and E Romania, showing increased rainfall erosivity during 2041-2060, will continue to have R factor values higher than present.
PREDICTIONS OF RAINFALL EROSIVITY EVOLUTION

Sources of uncertainty

• Uncertainty in the estimated future precipitation data
• Statistical errors of the non-parametric regression model
• Types / number of predictors used for R factor prediction
• Our study compares the trends induced by MFI. Deviations from this trend may be important
CONCLUSIONS

• The results clearly show an increasing trend of rainfall erosivity for 2041-2060 period, especially in the western, south-western and eastern part of the country, which is likely to enhance soil erosion, on average by 1-2 t ha\(^{-1}\) yr\(^{-1}\).

• After this increase, our analysis shows that it is likely for the rainfall erosivity values to decrease in the central and eastern part of the country, due to precipitations decrease during 2061-2080 period.

• Still, areas previously identified as more affected by increased erosivity will continue to have R factor values higher that at present.