EVALUATION OF CLIMATE CHANGE IMPACT ON SOIL EROSION IN ROMANIA

Cristian Valeriu PATRICHE [1] , Bogdan ROȘCA [1] , Radu Gabriel PIRNAU [1] , Liviu Mihai IRIMIA [2]
[1] Romanian Academy, Iasi Branch, Geography Research Center (patriche.cristian@acadiasi.ro; rosca.bogdan@acadiasi.ro; radu.pirnau@acadiasi.ro)
[2] Iași University of Life Sciences, Faculty of Horticulture (liviuirimia2005@yahoo.fr)

Abstract : Rainfall is a key factor in soil erosion models, determining the detachment of soil particles and their transport downslope. Our study aims to reveal whether or not climate change will significantly affect rainfall erosivity in Romania, and implicitly soil erosion. For this purpose, we computed the statistical relationship between rainfall erosivity and the modified Fournier index and applied it to future precipitation evolution scenarios. The precipitation predictions were extracted from CHESLA database for the Romanian territory for two climate change scenarios (RCP 4.5 and 8.5). We used average predictions from 5 selected climate models in order to minimize prediction uncertainty. The results show that rainfall erosivity is likely to enhance during the 2041-2060 period, especially in the western, south-western and eastern part of the country, causing a corresponding increase in soil erosion rates with 1-2 t ha^{-1} yr^{-1} on average. During the 2061-2080 period, rainfall erosivity is likely to decrease in the central and eastern Romania.

Keywords: rainfall erosivity ; climate change ; Romania.

Introduction

Climate change affects all climate parameters, including rainfall. 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.

Our study investigates the possible evolution of RUSLE rainfall erosivity (R) factor under climate change scenarios and seeks identify the areas which are likely to experience an increase in soil erosion rates during the next decades.

Materials and methods

RUSLE (Revised Universal Soil Loss Equation) is a wide-spread method used to estimate annual soil erosion rates (Renard, 1997) and it is based on earlier USLE (Universal Soil Loss Equation) method proposed by Wischmeyer and Smith (1978). The method in integrates 6 variables into the following equation:

$$E = R \times K \times L \times S \times C \times P$$

where:

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

Rainfall erosivity factor, together with C factor, is a temporally dynamic factor, subject to changes according to climate evolution. Rainfall erosivity is defined as the capacity of rainfalls to produce soil erosion and it depends on rain intensity and duration. This factor was well computed and mapped at EU level by Panagos et al (2015) at 500 m resolution starting from a large database of erosive rainfalls recorded at meteorological stations throughout Europe. We extracted this factor for the Romanian territory and used it to estimate current and future R factors, based on statistical relationship with the modified Fournier index. This index was proposed by Arnoldus (1980) to estimate rainfall erosivity based on monthly precipitation data:

$$\begin{gathered} F \\ ¿ \\ \frac{\sum_{i=1}^{12} p_i^2}{P} \end{gathered}$$

where:

- p_i – mean monthly precipitations (mm);
- P – mean annual precipitation (mm).

Some statistical regression equations were proposed by Renard et al. (1994) for the continental United States for the estimation of R factor based on F index. Their application to the Romanian territory led however to values larger than expected, probably because the continental climate of eastern US is more excessive than the one of Romania. The solution was to adopt the spatial model computed by Panagos et al (2015) and to link it statistically to the modified Fournier index in order to estimate the R factor for future climate scenarios.

Figure 1 shows the computation of this statistical relationship. We tested both linear and non-linear regression models and achieved the best results by applying the non-parametric regression method in XLSTAT software (Addins) using the natural logarithm of F index and X, Y coordinates as predictors. This model ($R^2 = 0.714$, RMSE = 50.9) was then applied to predict future R factor values based on future F index values and the X,Y coordinates at a spatial resolution of 5 x 5 km. The predicted R factor values were compared with the predicted current R factor values in order to estimate the R factor temporal dynamics.

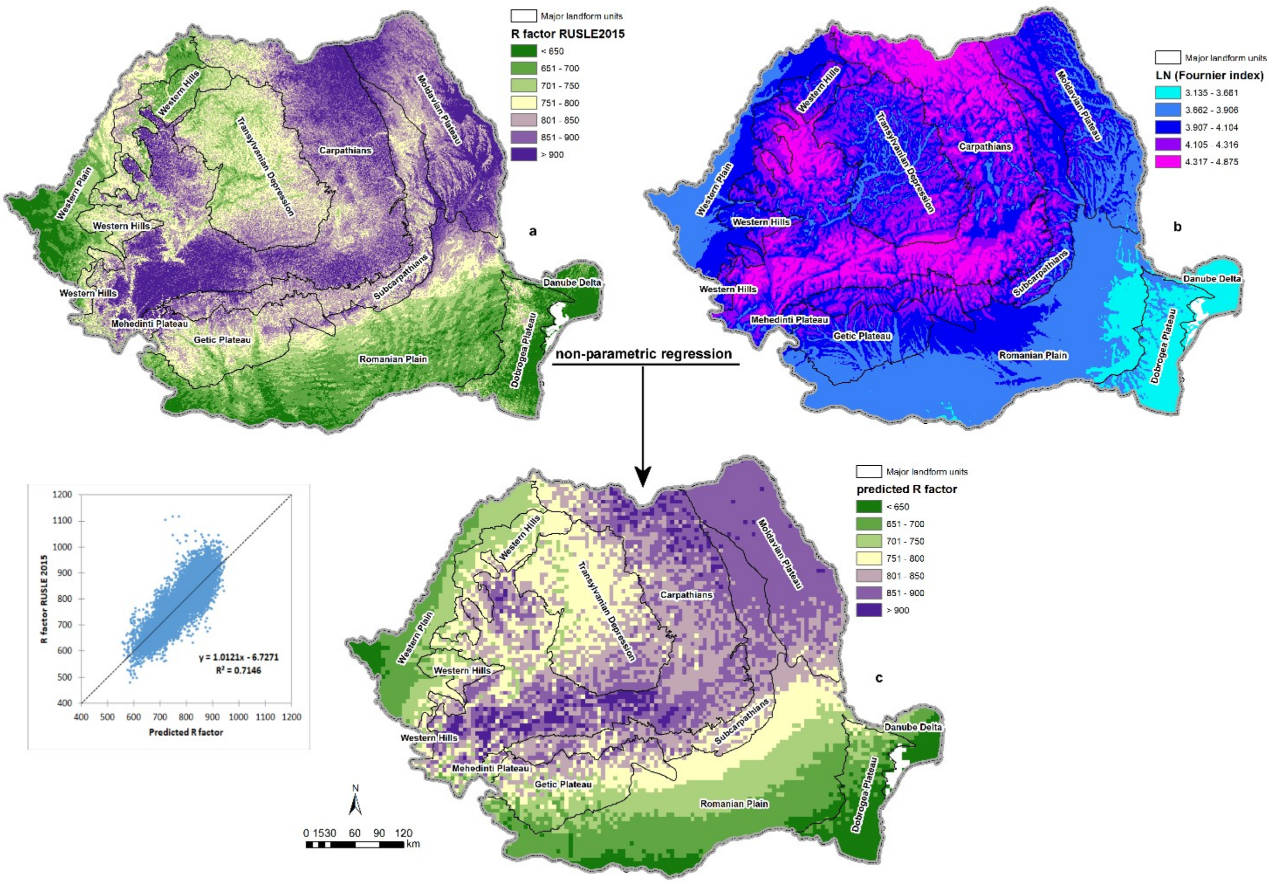

figure 1. Prediction of current R factor (c) through non-parametric regression, based in RUSLE 2015 R factor (a) and the natural logarithm of Fournier index (b).

For the estimation of future R factor evolution, we used the precipitation data from CHESLA database version 1.2 (https://chelsa-climate.org/) for 5 climate models and 2 representative concentration pathways (RCP) extreme scenarios (4.5 and 8.5) and 2 time periods (2041-2060 and 2061-2080). CHELSA is a global raster database at ~ 1km resolution including temperature and precipitation monthly data for current, future and past climates (Karger et al., 2017). 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 as specified by Sanderson et al. (2015). The average predictions of these models were further used to compute the F indexes for the 2 RCP scenarios and the 2 time periods.

Results

Table 1 shows some statistical indices for the predictions of current and future rainfall erosivity. We notice that there is an increase in rainfall erosivity mean, minimum and maximum values form present to 2041-2060 period. For the next time period (2061-2080), we notice a decrease of these values compared to the previous period, but which still remain higher than the current ones.

Table 1. Statistics of predicted current and future R factor for Romania (MJ mm ha^{-1} h^{-1} $year^{-1}$).

Statistics	**Current**	**2041-2060**		**2061-2080**	
		45 scenario	85 scenario	45 scenario	85 scenario
Average	782.8	801.4	803.0	790	785.2
Minimum	558	580	587	566	573
Maximum	955	974	976	960	950
Standard deviation	79.6	74.3	73.9	75.2	74.4

The differences between the predicted future and current R factor values (figure 2) shows the same trend of rainfall erosivity increasing during the 2041-2060 time period and then decreasing during the 2061-2080 period.

During the 2041-2060 period, our analysis shows that the rainfall erosivity trend is positive throughout the country. The areas most affected by an increase in rainfall erosivity (> 40 MJ mm ha^{-1} h^{-1} $year^{-1}$) are in the South West (Western Getic Plateau, Mehedinți Plateau), West (Western Hills and Plain, part of the Western Carpathians) and East (Danube Delta) of Romania. These areas cumulate 6.9% (about 16500 km^2) of the country in the RCP 4.5 scenario and 9.8% (about 23000 km^2) in the RCP 8.5 scenario (Table 2). An increase with > 40 MJ mm ha^{-1} h^{-1} $year^{-1}$ of rainfall erosivity will induce a corresponding increase in soil erosion rate with > 1-2 t ha^{-1} yr^{-1}. Locally, the soil erosion rates may grow with as much as 10-20 t ha^{-1} yr^{-1}.

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 scenario and 58.5% under RCP 8.5 scenario – Table 2) is likely to have R factor values slightly lower than at present (Figure 2c, d). However, the regions previously mentioned from western, south-western and eastern Romania, which are likely to have increased rainfall erosivity during the 2041-2060 period, will continue to have R factor values higher than present.

At European scale, Panagos et al. (2017) found a similar positive trend of rainfall erosivity for most of the continent based on HadGEM2 climate model. However, the differences between 2050 and current R factor values estimated for Romania under the RCP 4.5 scenario are higher than the values we found in our study. On the other hand, a more recent study (Panagos et al., 2021) on future possible changes of soil erosion rates under different climate change scenarios (RCP 2.6, 4.5 and 8.5) on agricultural land in Europe and using average predictions of 19 climate models, shows similar estimates on erosion rate growth of 1-2.5 1-2 t ha^{-1} yr^{-1} for most of the agricultural land of Romania.

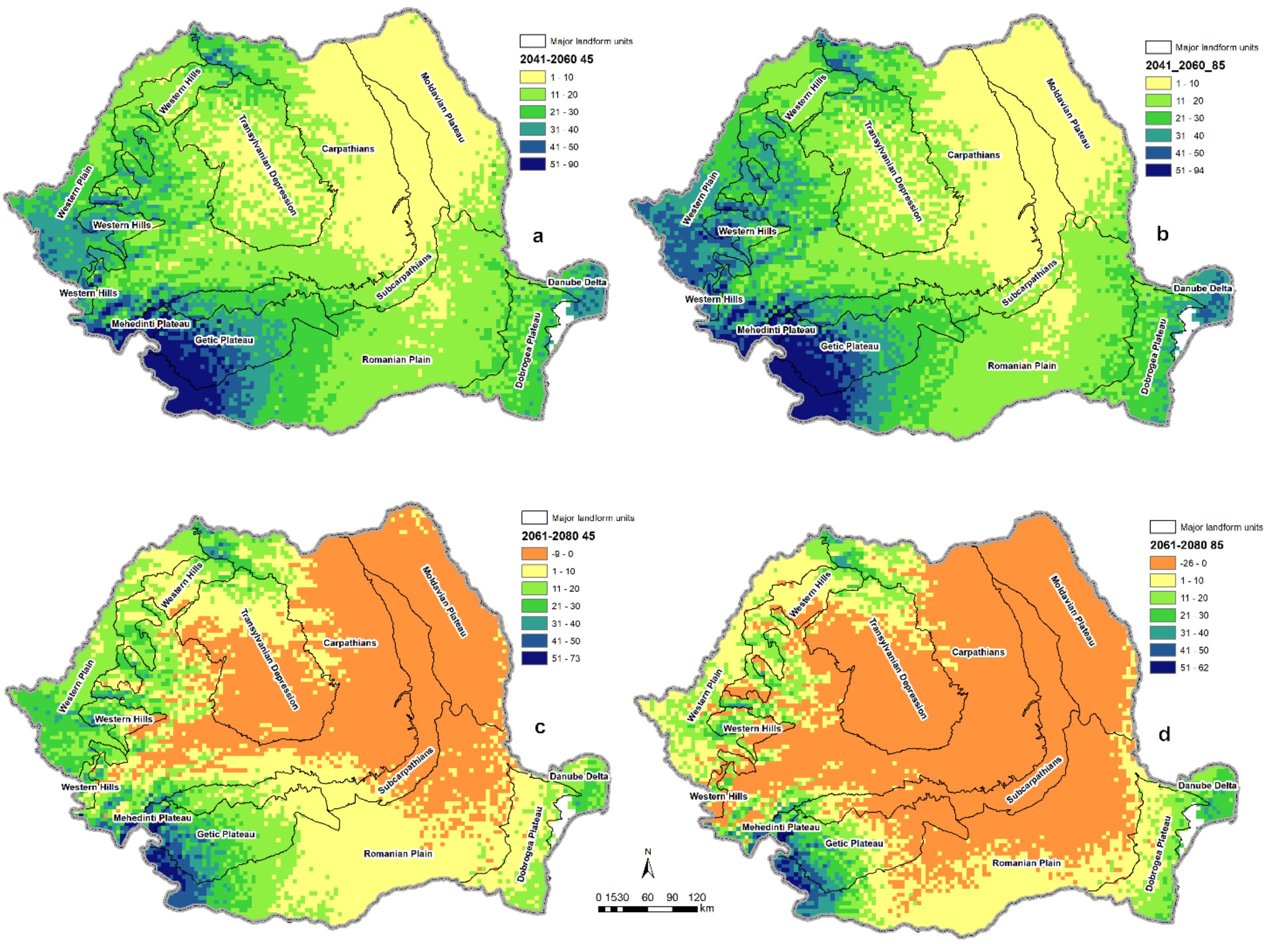

figure 2. Differences between future and current R factor values: a - 2041-2060 period and 45 scenario; b - 2041-2060 period and 85 scenario; c - 2061-2080 period and 45 scenario; d - 2061-2080 period and 85 scenario

Table 2. Percentages of classes showing the differences between future and current R factor values.

Differences	**2041-2060**		**2061-2080**	
(MJ mm ha^{-1} h^{-1} year$^{-1)}$	*4.5 scenario*	*8.5 scenario*	*4.5 scenario*	*8.5 scenario*
< 0	0.0	0.0	39.4	58.5
0 - 10	27.8	26.3	30.6	23.6
11 - 20	37.0	34.2	18.0	10.7
21 - 30	19.4	19.1	7.6	4.0
31 – 40	8.8	10.7	2.2	1.8
41 – 50	3.2	5.4	1.7	1.0
> 50	3.7	4.4	0.6	0.3

Studies attempting to predict the effects of climate change on various environmental processes are subject to uncertainty. There are various sources of possible errors, including the uncertainty of models' predictions, which can be minimized by considering an average prediction of multiple models. Also, our predictions are based on the modified Fournier index – rainfall erosivity statistical relationship and therefore the predicted R factor values are in a narrower range compared to the current R factor values. Nevertheless, though the computed changes in R factor values and the estimated soil erosion rates may be debatable, we consider that the increasing rainfall erosivity trend we identified for the next time period (2041-2060) and that the spatial patterns showing higher R factor values in the western part of the country have a high confidence degree.

Conclusion

Our study attempts to predict rainfall erosivity factor for the Romanian territory for the next decades using the relationship between this factor and the modified Fournier index computed from average monthly precipitations. 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.

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