Rainfall Erosivity Database on the European Scale (REDES): A product of a high temporal resolution rainfall data collection in Europe

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Soil Threats

- Sealing
- Decline of Soil Organic Matter
- Soil Biodiversity loss
- Erosion
- Salinization
- Compaction
- Contamination
- Landslides

Policy: Soil Thematic Strategy
RUSLE2015: New soil erosion model

- LUCAS Soil
- European Soil Database
- LUCAS Earth Observation
- Rainfall Erosivity Database (REDES)
- CORINE Land Cover
- Copernicus Remote Sensing
- Digital Elevation Model
- Good Agricultural Environmental Conditions (GAEC)
- LUCAS Earth Observation

Structures
- Sand
- Silt
- Clay
- Organic Carbon
- Permeability
- Coarse Fragments

K-factor

R-factor

Rainfall Erosivity

Soil Erodibility (with stoniness)

Cover-Management

Slope Length & Steepness

Support Practices

C-factor
- Non-arable
- Arable

LS-factor

Contour Farming
- Stone Walls
- Grass Margins

Objective: Why a European Rainfall Erosivity dataset?

- **Important factor for Soil erosion modelling:** Rainfall erosivity (R-factor) is one of the 5 factors for estimating soil erosion using (R)USLE model.

- Previous attempts of Rainfall Erosivity maps (at European scale) were not convincing neither the scientific community nor policy makers.

- Many local/regional studies based on functions plus low temporal resolution rainfall data.

- **Few studies estimate** rainfall erosivity based on high temporal resolution rainfall data (5-min, 10-min, 15-min, 30-min, 60-min)

- **Other applications:** a) Landslide risk assessment; b) flood risk forecasting; c) Post-fire conservation measures; d) agricultural management and design of crop rotation scenarios and e) Ecosystem services f) Trends and threats of climate change
Rainfall erosivity (R-factor) is the kinetic energy of rainfall (MJ mm ha\(^{-1}\) h\(^{-1}\) y\(^{-1}\))

- Combines the influence of rainfall duration, magnitude, frequency and intensity

- Time-consuming and requested laborious pre-processing (Mar 2013 – May 2014)

- Participatory approach (with countries). High temporal resolution data from:
  - Meteorological Services (or environmental institutes): Royal Netherlands Meteorological Institute, Meteo France, Deutscher Wetterdienst – DWD (Germany), Flemish Environmental Agency and the Service Public de Wallonie (Belgium), Estonian Environment Agency, Swedish Meteorological Service (SMHI), …
  - Meteorologists from Cyprus, Finland, Croatia, Hungary and Romania
  - Scientists who have developed research activities (in Rainfall erosivity) in their countries
  - Research project databases: Hydroskopio (Greece), Sistema National de Recursos Hidricos (Portugal), NERC, British
  - ‘Grey’ literature and searches with national language terms: Slovakia, Poland, Lithuania

- Conditions set for the data collection exercise
  - Continuous records for at least 10 years
  - Preference was given to datasets that cover the last decade.
  - Data of up to 60 minutes resolution were included
# Data collection 2013-2014

Overview of the precipitation data collected to estimate the R-factor.

<table>
<thead>
<tr>
<th>Country</th>
<th>No. of stations</th>
<th>(Main) period covered</th>
<th>Years per station (average)</th>
<th>(Main) temporal resolution: 5 min, 10 min, 15 min, 30 min, 60 min</th>
<th>Source of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT</td>
<td>Austria</td>
<td>31</td>
<td>1995–2010</td>
<td>12 stations: 10 min, 19 stations: 15 min</td>
<td>Hydrographic offices of Upper Austria, Lower Austria, Burgenland, Styria, Salzburg</td>
</tr>
<tr>
<td>BE</td>
<td>Belgium</td>
<td>20</td>
<td>2004–2013</td>
<td>Flanders (20 stations): 30 min, Wallonia (29 stations): 60 min</td>
<td>Flemish Environmental Agency (VMM), Service Public de Wallonie</td>
</tr>
<tr>
<td>BG</td>
<td>Bulgaria</td>
<td>84</td>
<td>1951–1976</td>
<td>30 min</td>
<td>Rousseva et al. (2010)</td>
</tr>
<tr>
<td>CY</td>
<td>Cyprus</td>
<td>35</td>
<td>1974–2013</td>
<td>30 min</td>
<td>Cyprus Department of Meteorology</td>
</tr>
<tr>
<td>CZ</td>
<td>Czech Republic</td>
<td>32</td>
<td>1961–1999</td>
<td>30 min</td>
<td>Research Institute for Soil and Water Conservation (Czech Republic)</td>
</tr>
<tr>
<td>CH</td>
<td>Switzerland</td>
<td>71</td>
<td>1988–2010</td>
<td>10 min</td>
<td>Meusburger et al. (2012)</td>
</tr>
<tr>
<td>DE</td>
<td>Germany</td>
<td>148</td>
<td>1996–2013</td>
<td>60 min</td>
<td>Deutscher Wetterdienst (DWD)</td>
</tr>
<tr>
<td>DK</td>
<td>Denmark</td>
<td>30</td>
<td>1988–2012</td>
<td>60 min</td>
<td>Danish Meteorological Institute (DMI), Aarhus University</td>
</tr>
<tr>
<td>EE</td>
<td>Estonia</td>
<td>20</td>
<td>2007–2013</td>
<td>60 min</td>
<td>Estonian Environment Agency</td>
</tr>
<tr>
<td>ES</td>
<td>Spain</td>
<td>113</td>
<td>2002–2013</td>
<td>14 stations: 10 min, 81 stations: 15 min, 18 stations: 30 min</td>
<td>Regional water agencies</td>
</tr>
<tr>
<td>FI</td>
<td>Finland</td>
<td>64</td>
<td>2007–2013</td>
<td>60 min</td>
<td>Finnish Climate Service Centre (FMI)</td>
</tr>
<tr>
<td>FR</td>
<td>France</td>
<td>60</td>
<td>2004–2013</td>
<td>60 min</td>
<td>Météo-France DP/SERV/FDP</td>
</tr>
<tr>
<td>GR</td>
<td>Greece</td>
<td>80</td>
<td>1974–1997</td>
<td>30 min</td>
<td>Hydroskopio</td>
</tr>
<tr>
<td>HR</td>
<td>Croatia</td>
<td>42</td>
<td>1961–2012</td>
<td>10 min</td>
<td>Croatian Meteo &amp; Hydrological Service</td>
</tr>
<tr>
<td>HU</td>
<td>Hungary</td>
<td>30</td>
<td>1998–2013</td>
<td>10 min</td>
<td>Hungarian Meteorological Service</td>
</tr>
<tr>
<td>IE</td>
<td>Ireland</td>
<td>13</td>
<td>1950–2010</td>
<td>60 min</td>
<td>Met Éireann — The Irish National Meteorological Service</td>
</tr>
<tr>
<td>IT</td>
<td>Italy</td>
<td>251</td>
<td>2002–2011</td>
<td>30 min</td>
<td>Regional meteorological services, Regional agencies for environmental protection (ARPA)</td>
</tr>
<tr>
<td>LU</td>
<td>Luxembourg</td>
<td>16</td>
<td>2000–2013</td>
<td>60 min</td>
<td>Agrarmeteorologisches Messnetz</td>
</tr>
<tr>
<td>LV</td>
<td>Latvia</td>
<td>4</td>
<td>2007–2013</td>
<td>60 min</td>
<td>Latvian Environment, Geology and Meteorology Centre</td>
</tr>
<tr>
<td>NL</td>
<td>Netherlands</td>
<td>32</td>
<td>1981–2010</td>
<td>60 min</td>
<td>Royal Netherlands Meteorological Institute</td>
</tr>
<tr>
<td>PL</td>
<td>Poland</td>
<td>9</td>
<td>1961–1988</td>
<td>30 min</td>
<td>Banasik et al. (2001)</td>
</tr>
<tr>
<td>PT</td>
<td>Portugal</td>
<td>41</td>
<td>2001–2012</td>
<td>60 min</td>
<td>Agência Portuguesa do Ambiente</td>
</tr>
<tr>
<td>RO</td>
<td>Romania</td>
<td>60</td>
<td>2006–2013</td>
<td>10 min</td>
<td>Meteorological Administration</td>
</tr>
<tr>
<td>SE</td>
<td>Sweden</td>
<td>73</td>
<td>1996–2013</td>
<td>60 min</td>
<td>Swedish Meteorological and Hydrological Institute (SMHI)</td>
</tr>
<tr>
<td>SK</td>
<td>Slovakia</td>
<td>81</td>
<td>1971–1990</td>
<td>60 min</td>
<td>Mališek (1992)</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
<td>11</td>
<td>1993–2012</td>
<td>60 min</td>
<td>NERC &amp; UK Environ. Change Network (ECN)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27</td>
<td>2001–2013</td>
<td>60 min</td>
<td>British Atmospheric Data Centre (BADC)</td>
</tr>
</tbody>
</table>
REDES: Rainfall Erosivity Database at European Scale

- **1,541** Precipitation stations with detailed rainfall intensity; **1675 Precipitation Stations** in 2015 update (all countries)
- **Calibration requested:** 5 min, 10-min, 15 min, 60 min.
- **Temporal Resolution:** 30-Minutes
- **Time series:** 7 – 56 Years (Mean: 17.1yr; 75% of time series in 2000-2010)
- **Data:** 29,000 years of High Temporal resolution rainfall records (GB of data)
- **Average density:** 1 station per 50km x 50km
- **Stations distribution:** 6.5% of the REDES stations in > 1,000m a.s.l
Geo-statistical Model

- **Regression approach**: R-factor correlates mostly with climatic data but not only...

- **Gaussian Process Regression (GPR)**: A non-linear regression approach

- **GPR can be performed over an arbitrary number of covariates, including terrain features and geographical coordinates** (while kriging is usually performed on two- or three-dimension geographical space)

**Covariates**:

- **Climatic data** (*Worldclim Database 1km, 1950-2000*):
  - Average monthly precipitation, average minimum & maximum monthly precipitation, average monthly temperature, precipitation of the wettest month, precipitation of the driest month precipitation seasonality (variation of precipitation over seasons).

- **Elevation**: *SRTM 90m*

- **Spatial position**: Latitude, Longitude
Why Gaussian Process Regression (GPR)?

• **Best performing model** in terms of cross validation among a series of candidate models
  - OLS, GLM, GAM....
  - Regression Kriging

• **Criteria** chosen for the selection of **best model**:
  - the minimization of the root-mean squared error and
  - the maximization of the $R^2$.

• **GPR model performance** was tested for both a fitting and a cross-validation dataset.

• **The cross-validation** is carried out by random sampling with 10% replacement of the original dataset used for validation.

• **Good performance** for both
  - the cross-validation dataset ($R^2 = 0.63$)
  - and the fitting dataset ($R^2 = 0.72$)
Rainfall Erosivity (R-factor)

- **Resolution:** 500m
- **Spatial coverage:** European Union (EU-28) plus Switzerland
- **Robust Geo-statistical** model
- **Mean:** 722 MJ mm ha\(^{-1}\) h\(^{-1}\) yr\(^{-1}\)
- Highest R-factor in Mediterranean & Alpine regions and lowest in Scandinavia
- Highest R-factor levels are in line with the 3 major regions (van Delden, 2001) with highest frequency of thunderstorms.

Panagos et al. 2015. Science of Total Environment
Erosivity density

- **R-factor not dependent** only from rainfall
- **High erosivity density** is observed in Italy, Slovenia and Spain (R-factor is 2-3 times higher than precipitation).
- Rain distribution is much smoother in northern parts of Europe (northern Germany, France, Netherlands)

![Erosivity Density: Ratio of R-factor to precipitation](image-url)
• The model had a **good prediction rate** with low standard errors in the majority of the study area.

• **High variability of climatic and terrain conditions** in an area of > 4.4 Million km$^2$ resulted in a broad spectrum of rainfall erosivity.

• Scotland, north-western Sweden and northern Finland: Relatively **small number of precipitation stations**.

• Southern Alps and the Pyrenees: **high diversity of environmental features**.

**Standard error of the estimates**
Conversion factors due to different time resolutions

<table>
<thead>
<tr>
<th>Resolution of source data</th>
<th>Target resolution</th>
<th>Conversion factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-min</td>
<td>30-min</td>
<td>0.7496</td>
</tr>
<tr>
<td>5-min</td>
<td>30-min</td>
<td>0.7984</td>
</tr>
<tr>
<td>10-min</td>
<td>30-min</td>
<td>0.8205</td>
</tr>
<tr>
<td>15-min</td>
<td>30-min</td>
<td>0.8716</td>
</tr>
<tr>
<td>60-min</td>
<td>30-min</td>
<td>1.5597</td>
</tr>
</tbody>
</table>

- Source data in different time resolutions: 1-min, 5-min, 10-min, 15-min, 30-min, 60-min
- Harmonization is requested: Common time resolution of 30-min
- Development of Monthly component in REDES: 19,000 Monthly values
- Conversion factors show small variability in winter and much higher in summer

Panagos et al. WATER. (2016)
Rainfall erosivity seasonality

- **Dynamic component** in soil loss by water erosion
- **Different intra-annual** R-factor patterns (July / January)
- **53% of the annual rainfall erosivity in Europe** is accounted in **4 months** period (June – September)
- **Northern and Central European** countries exhibit the largest R-factor values in summer
- **Southern European countries** exhibit the largest R-factor values during October to January

*Panagos et al. WATER. (2016)*
Erosivity & Climate Change

**Fitting**
- REDES, R2010
- 16 significant WorldClim 2010 grids
- Simulated Annealing
- 36 Baseline climate grids + 6 Bioclimatic grids (WorldClim 1950-2000)

**Prediction**
- IPCG General Circulation Models (GCM)
  - Model HadGEM2
  - Scenario RCP 4.5
  - 16 significant grids 2050
- GPR regression model
- R2050

- **Target:** 2050
- **Model:** HadGEM2
- **Scenario:** RCP 4.5
- **18% increase** compared to baseline

*Panagos et al. In Review (2016)*
Regional studies

**Switzerland**
Meusburger et al. 2012 HESS

**Italy**
Borrelli et al. 2016 Journal of Digital Earth

**Greece**
Panagos et al. 2016, CATENA
• Rainfall Erosivity Database at the European Scale (REDES)
• Rainfall Erosivity map of Europe
• Conversion factors between different time resolutions
• Monthly Rainfall Erosivity Database & Seasonal Maps
• National Studies: Switzerland (2012), Greece (2016), Italy (2016)
• 2050 R-factor predictions
• Reduce the intrinsic climate model uncertainty

Future Studies:
  • Larger spectrum of available Global and Regional Circulation Models (GRMs/RCMs) (11 combinations),
  • all three RCP scenarios (RCP2.6, RCP4.5 and RCP8.5) and
  • the latest version of the bias-adjusted EURO-CORDEX simulations

• Global Rainfall Erosivity Database: following the same participatory approach as in Europe, we have on board 15 Contributors (+ REDES) and 10 studies from the literature.
Rainfall erosivity in Europe

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Information and data:
European Soil Data Centre:

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