Modelling event scale rainfall erosivity across European climate regions

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Background

Long-term annual average estimates of soil erosion fundamentally limit our understanding and mitigation capacity of highly variable erosive storm events in Europe. Event-scale rainfall erosivity (raindrop kinetic energy and consequential overland runoff) is a first order driver of soil erosion with distinct timings and magnitudes, statistically best described by the (R)USLE EI_{30} parameter. Using rainfall erosivity from homogenised high resolution rainfall data (5-60 min Δt) in the REDES database (Panagos et al., 2015), we assessed several simple regression model configurations on a monthly basis across European climatic regions. The derived models allow the use of abundant low temporal resolution precipitation products to determine rainfall erosivity for a range of time and spatial scales in Europe.

REDES overview

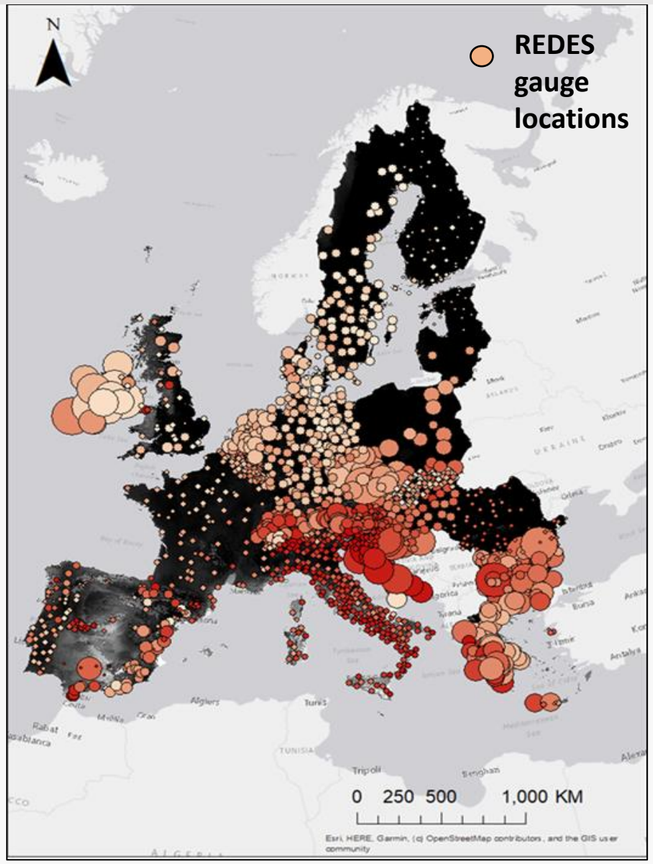

Fig 1: The Rainfall Erosivity Database on the European Scale (REDES) contains the most comprehensive collection of rainfall erosivity (EI_{30}) events from high resolution rain gauge data in Europe. Circles represent the data record length (size) and R-factor (colour).

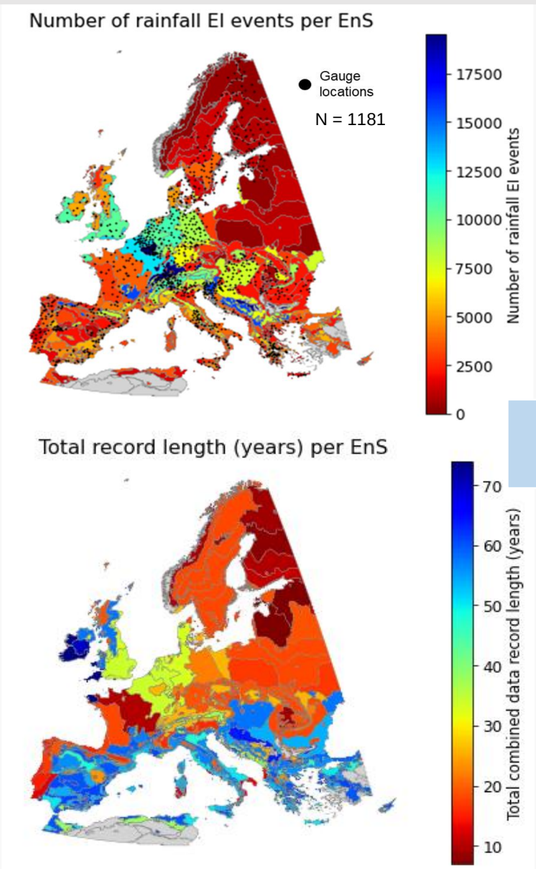

Fig 2: Environmental strata (EnS) allow the spatial upscaling of point scale data records. The total record length and N(events) vary with gauge density and the REDES national data record length.

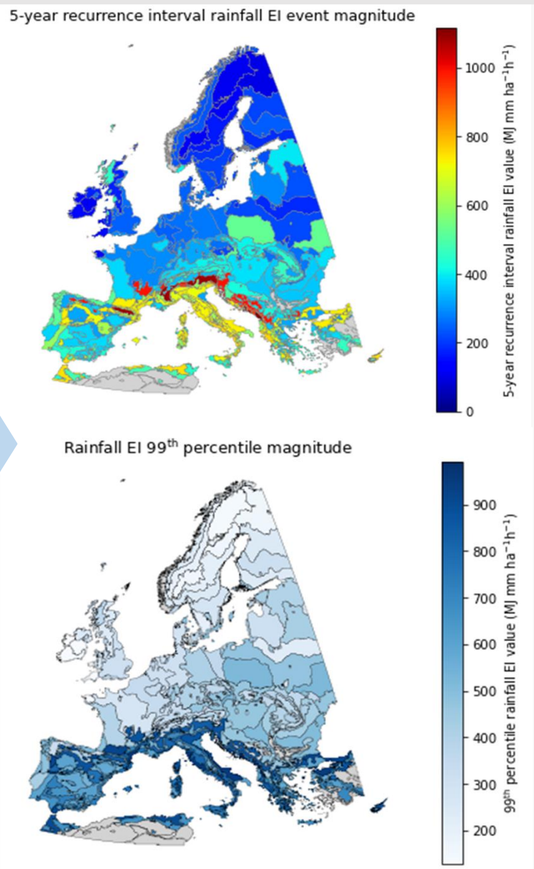

Fig 3: EnS show distinct North-West to South-East spatial trends in extreme event intensity (99th percentile value and 5-year recurrence interval magnitude). Rainfall erosivity shows a characteristic positively-skewed distribution in each EnS.

EnZ code	EnZ name	N analysed EnS
ALN	Alpine North	2
ALS	Alpine South	6
ATC	Atlantic Central	5
ATN	Atlantic North	4
BOR	Boreal	8
CON	Continental	11
LUS	Lusitanian	4
MDM	Mediterranean Mountains	9
MDN	Mediterranean North	10
MDS	Mediterranean South	7
NEM	Nemoral	5
PAN	Pannonian	3

The number of analysed environmental strata (EnS) with REDES coverage (total = 74). The EnS database (Metzger et al., 2005) used for upscaling consists in total of 84 EnS in 13 EnZs, statistically delineated from 20 environmental variables. Environmental Zones (EnZs) represents the broad climatic zone encompassing numerous Environmental Strata (EnS).

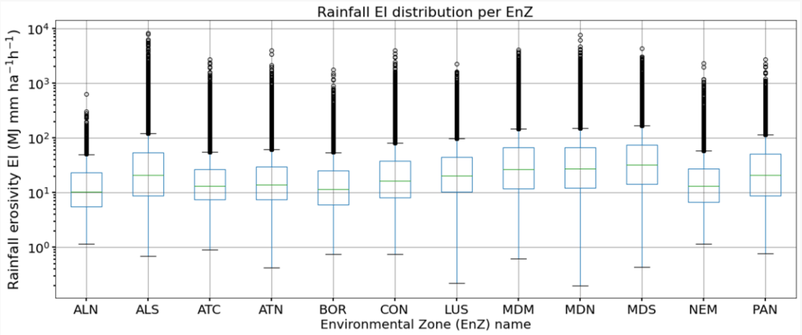

Fig 4: Box-plots of rainfall EI distribution per EnZ.

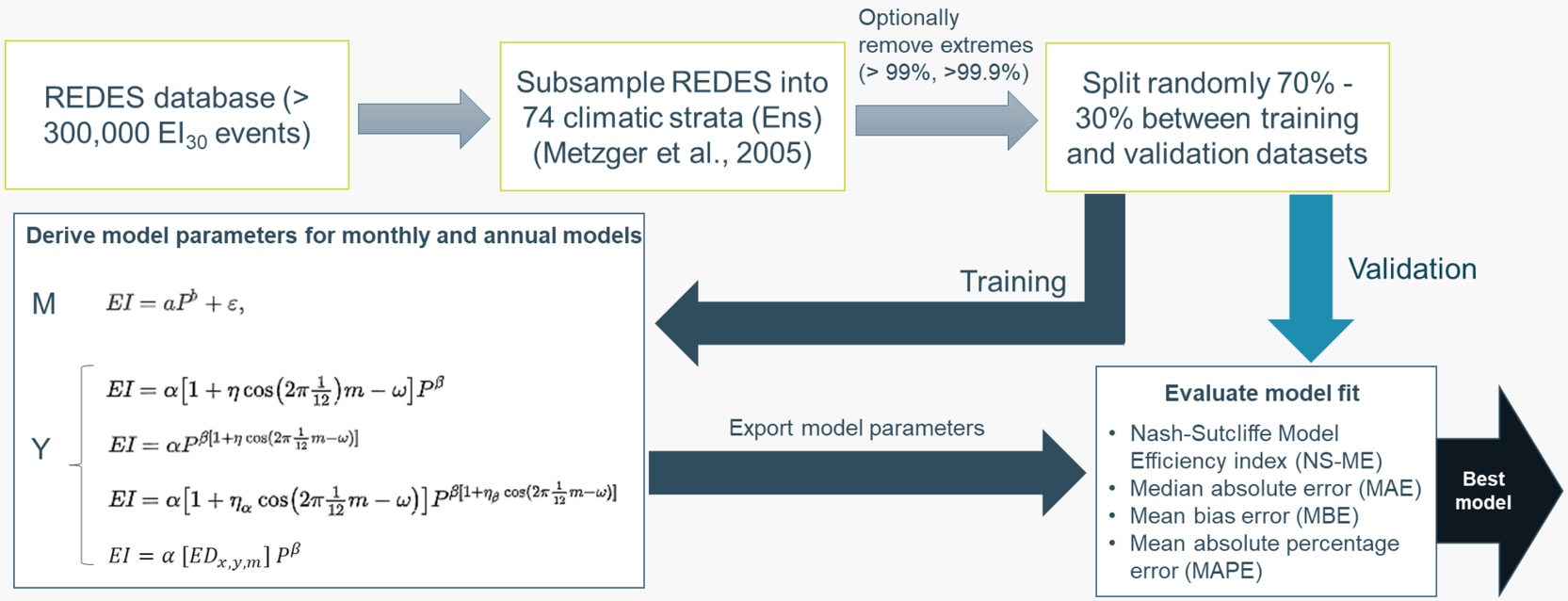

Fig 5: Workflow to stratify and model rainfall erosivity as a function of rainfall depth per month.

- Rainfall EI was calculated from high resolution rain gauge records via:

$$\mathrm{EI30} = \left(\sum_{r=1}^{0} e_r v_r\right) I_{30}$$

- Where I_{30} is the maximum 30-minute intensity (mm h^{-1}) of the storm. For each period (r) contributing to the event, e_r is the empirically calculated unit rainfall energy (MJ ha^{-1} mm^{-1}) and v_r is the rainfall volume (mm).

- Optimized non-linear least squares power-law based fits were used to capture the spatial and temporal relationship between event precipitation depth and rainfall EI. Models were generated and evaluated on a monthly basis using 4 model configurations; 4 with singular annual parameter sets and 1 with 12 monthly parameter sets. The best model configuration was selected and further analysed.

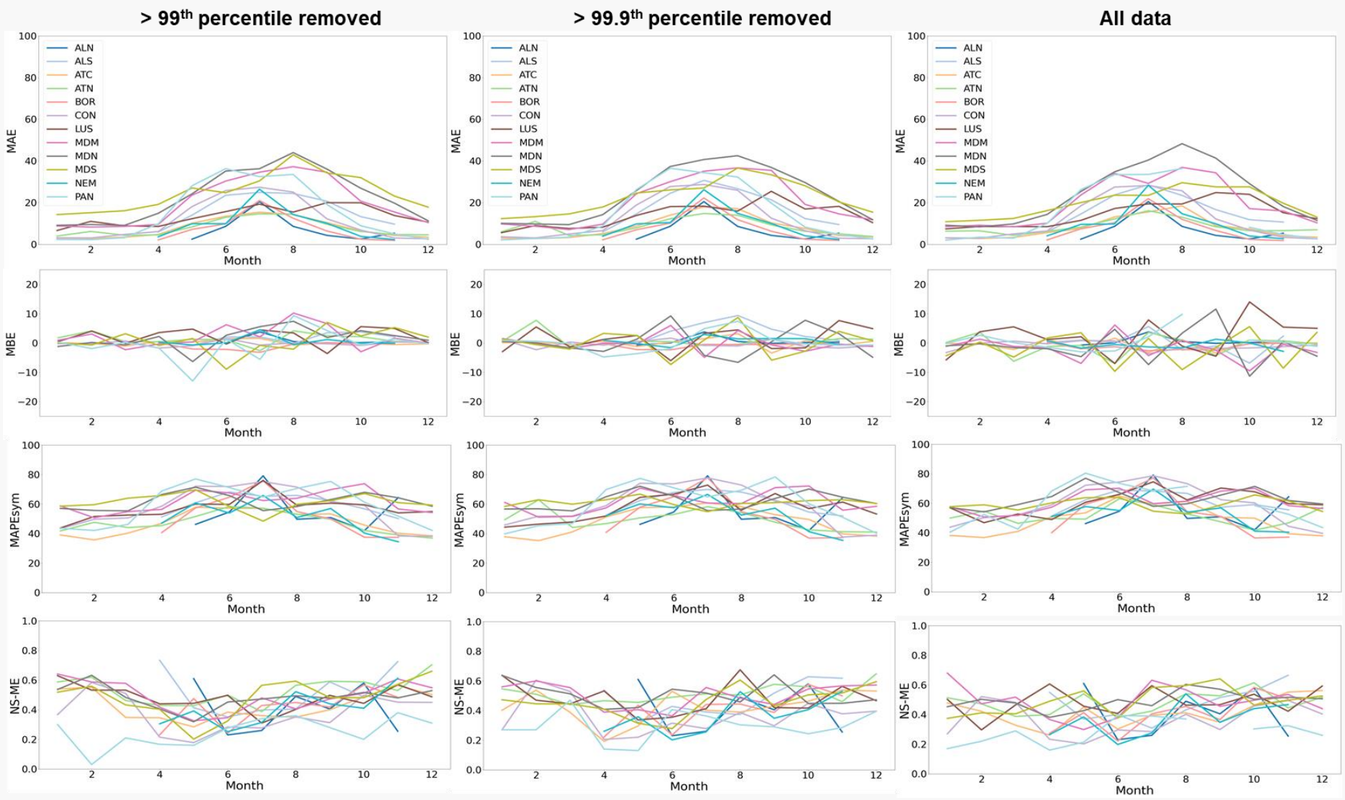

Fig 6: Monthly model performance metrics averaged per EnZ. Models were generated and assessed considering the entire EnS event subsample as well as with the most extreme events removed.

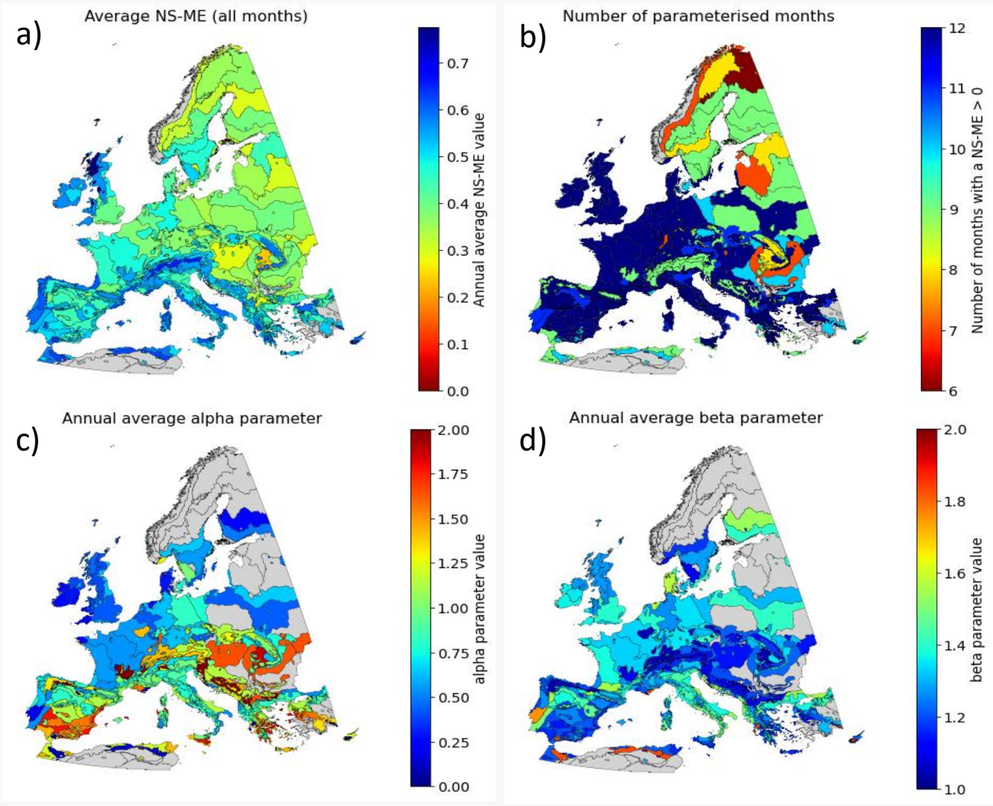

Fig 7: Spatially distributed model output per EnS. Months were not parameterised if snowfall seasonally dominates or if no suitable parameters were found.

Outcomes:

- Established environmental strata (EnS) allow the upscaling and modelling of event rainfall erosivity from heterogeneous national gauge data.
- The model configuration with 12 monthly alpha and beta parameter sets outperformed singular annual parameter sets with associated oscillatory functions.
- Inclusion of the most extreme events reduces model performance: The prediction capacity and number of parameterised months (%months) was higher and more robust against overfitting when 99% of events were used in the model fitting process ($NS\text{-}ME_{mean} = 0.47$, $MAE_{mean} = 15.4$, %months = 82), compared with 99.9% ($NS\text{-}ME_{mean} = 0.46$, $MAE_{mean} = 15.4$, %months = 80) and 100% ($NS\text{-}ME_{mean} = 0.46$, $MAE_{mean} = 15.2$, %months = 76).
- The NS-ME per EnS positively correlated with the data record length ($r = 0.26$, $p < 0.05$) and the magnitude of the 5-year recurrence interval event ($r = 0.42$, $p < 0.01$).
- Model efficiency varies both spatially (according to the rainfall stochasticity) and temporally (according to the seasonal predictability of events).
- Further work will explore the application of these parameter surfaces alongside a variety of open-access precipitation products (hourly to daily) across a range of spatial and temporal scales.