European Commission

Geo-statistical model of Rainfall erosivity by using high temporal resolution precipitation data in Europe

Panagos Panos[1], Cristiano Ballabio[1], Pasqualle Borrelli[1], Katrin Meusburger[2], Christine Alewell[2]

[1]European Commision – Joint Research Centre

[2]University of Basel, Environmental Geosciences

Joint Research Centre

Policy: Soil Thematic Strategy

Sealing

Soil Biodiversity loss

Erosion

Decline of
Soil Organic Matter

Soil Threats

Salinization

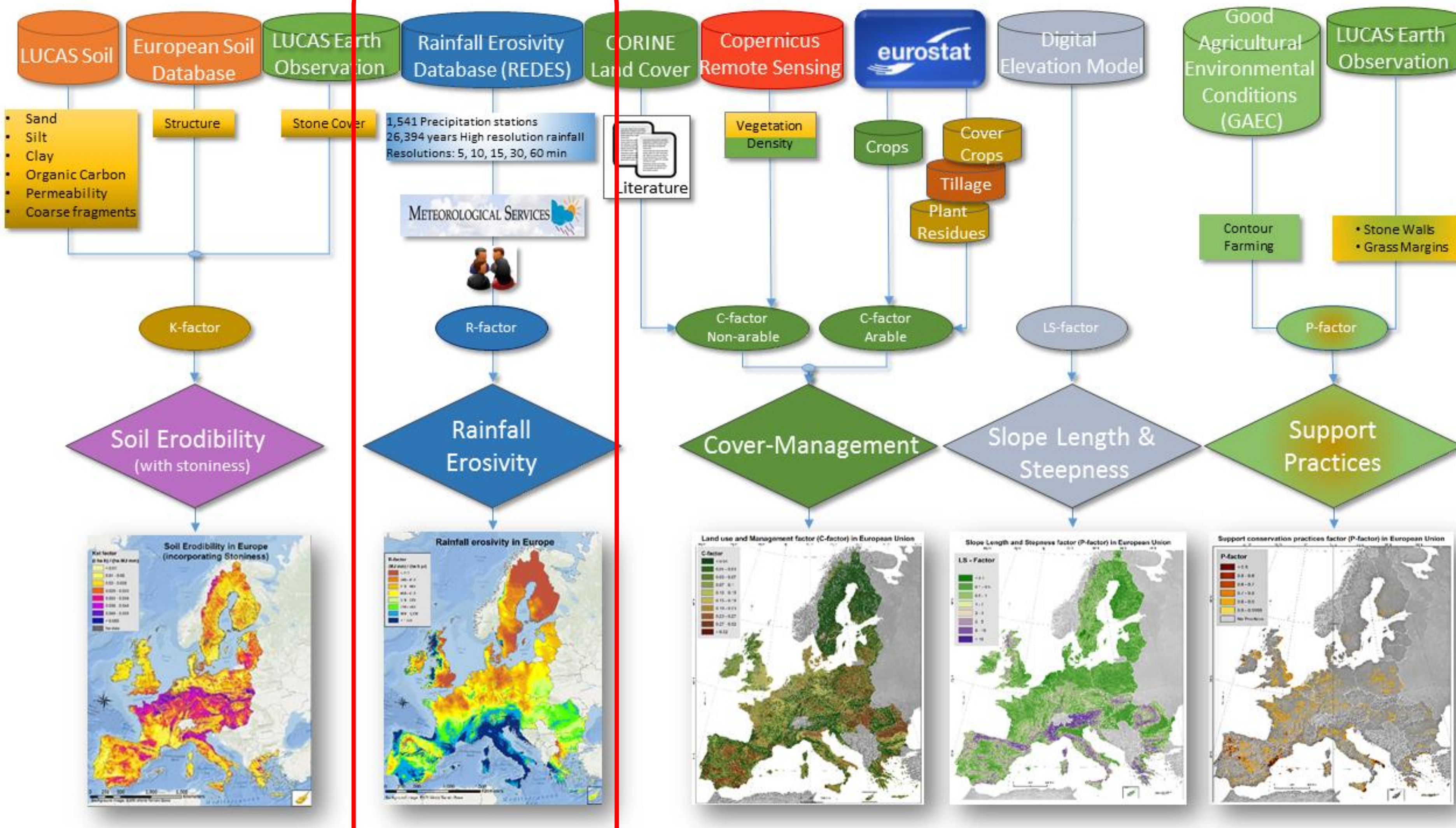
Compaction

Contamination

Landslides

RUSLE2015: New soil erosion model

European Commission



Joint Research Centre

Panagos et al (2015) – In Review

Objective: Why a European Rainfall Erosivity dataset?

European Commission

- **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)
- **Application in**: a) Landslide risk assessment; b) flood risk forecasting; c) Post-fire conservation measures; d) agricultural management and design of crop rotation scenarios and e) Trends and threats of climate change ………………

R-factor and data collection

European Commission

- **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** and **intensity**

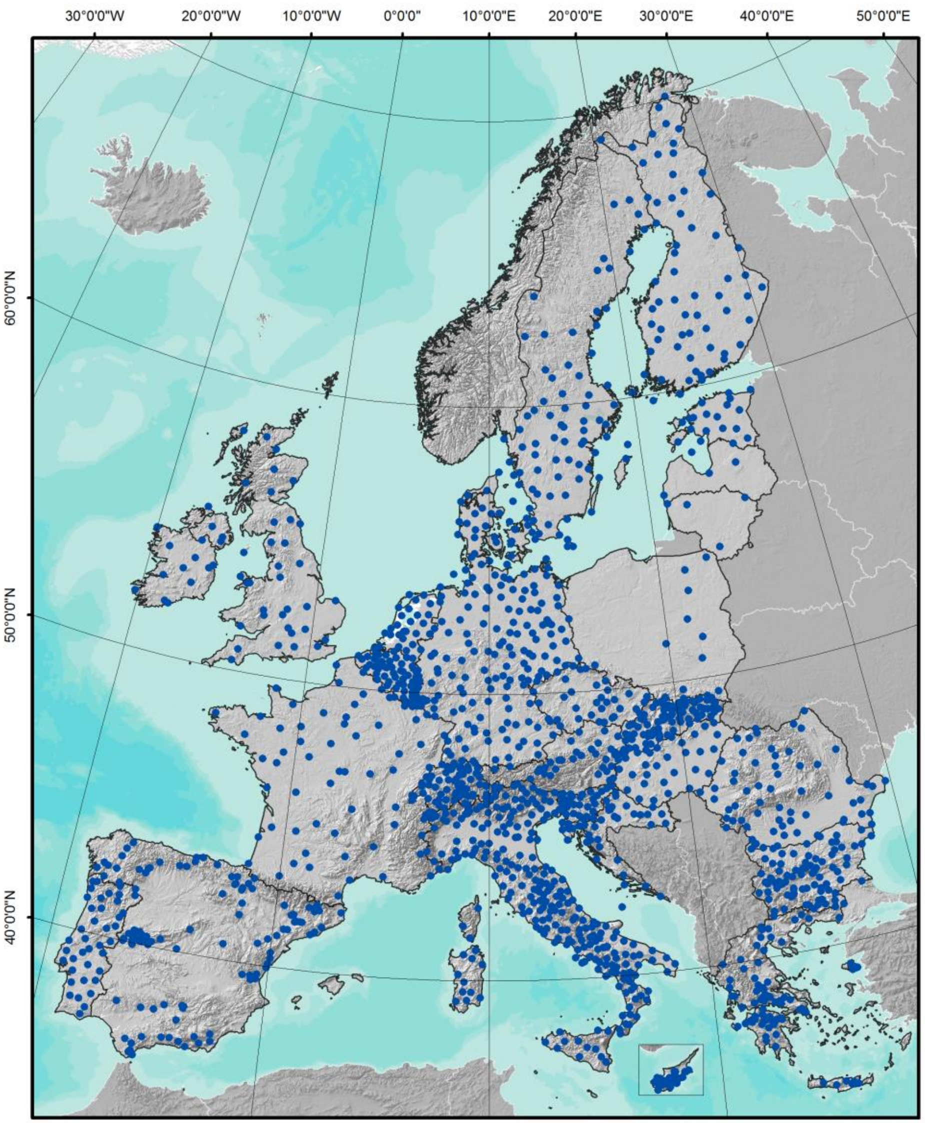
- **Data Collection: Time-consuming and requested laborious pre-processing** (Mar 2013 – May 2014)
- **Participatory approach** (involving countries). High temporal resolution data from:
  - **Meteorological Services (or environmental institutes)**: Royal Netherlands Meteorological Institute, Meteo France, 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 Atmospheric Data Centre(BADC)
  - **'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

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

Country		No. of stations	(Main) period covered	Years per station (average)	(Main) temporal resolution: 5 min, 10 min, 15 min, 30 min, 60 min	Source of data
AT	Austria	31	1995–2010	21	12 stations: 10 min 19 stations: 15 min	Hydrographic offices of Upper Austria, Lower Austria, Burgenland, Styria, Salzburg
BE	Belgium	20	2004–2013	10	Flanders (20 stations): 30 min	Flemish Environmental Agency (VMM),
		29	2004–2013	10	Wallonia (29 stations): 60 min	Service Public de Wallonie
BG	Bulgaria	84	1951–1976	26	30 min	Rousseva et al. (2010)
CY	Cyprus	35	1974–2013	39	30 min	Cyprus Department of Meteorology
CZ	Czech Republic	32	1961–1999	35	30 min	Research Institute for Soil and Water Conservation (Czech Republic)
CH	Switzerland	71	1988–2010	22	10 min	Meusburger et al. (2012)
DE	Germany	148	1996–2013	18	60 min	Deutscher Wetterdienst (DWD)
DK	Denmark	30	1988–2012 2004–2012	15	60 min	Danish Meteorological Institute (DMI), Aarhus University
EE	Estonia	20	2007–2013	7	60 min	Estonian Environment Agency
ES	Spain	113	2002–2013	12	14 stations: 10 min, 81 stations: 15 min 18 stations: 30 min	Regional water agencies
FI	Finland	64	2007–2013	7	60 min	Finnish Climate Service Centre (FMI)
FR	France	60	2004–2013	10	60 min	Météo-France DP/SERV/FDP
GR	Greece	80	1974–1997	30	30 min	Hydroskopio
HR	Croatia	42	1961–2012	40	10 min	Croatian Meteo & Hydrological Service
HU	Hungary	30	1998–2013	16	10 min	Hungarian Meteorological Service
IE	Ireland	13	1950–2010	56	60 min	Met Éireann — The Irish National Meteorological Service
IT	Italy	251	2002–2011	10	30 min	Regional meteorological services, Regional agencies for environmental protection (ARPA)
LT	Lithuania	3	1992–2007	16	30 min	Mazvila et al. (2010)
LU	Luxembourg	16	2000–2013	11	60 min	Agrarmeteorologisches Messnetz
LV	Latvia	4	2007–2013	7	60 min	Latvian Environment, Geology and Meteorology Centre
NL	Netherlands	32	1981–2010	24	60 min	Royal Netherlands Meteorological Institute
PL	Poland	9	1961–1988	27	30 min	Banasik et al. (2001)
PT	Portugal	41	2001–2012	11	60 min	Agência Portuguesa do Ambiente
RO	Romania	60	2006–2013	8	10 min	Meteorological Administration
SE	Sweden	73	1996–2013	18	60 min	Swedish Meteorological and Hydrological Institute (SMHI)
SI	Slovenia	31	1999–2008	10	5 min	Slovenian Environment Agency, Petan et al. (2010)
SK	Slovakia	81	1971–1990	20	60 min	Malíšek (1992)
UK	United Kingdom	11	1993–2012	20	60 min	NERC & UK Environ. Change Network (ECN)
		27	2001–2013	11	60 min	British Atmospheric Data Centre (BADC)

REDES: Rainfall Erosivity Database at European Scale



- **1,541 Rainfall stations** with detailed rainfall intensity (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**: 26,394 years of High Temporal resolution rainfall records (GB of data)
- **Average density:** 1 station per 53km x 53km
- **Stations distribution**: 6.5% of the REDES stations in > 1,000m a.s.l

European Commission

Joint Research Centre

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)*
- **Main advantages of GPR** are:
  - it can model complex non-linear relations between covariates and the target variable
  - directly model both average and variance estimation, thus providing information about prediction uncertainty.

Covariates

European Commission

- ***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*

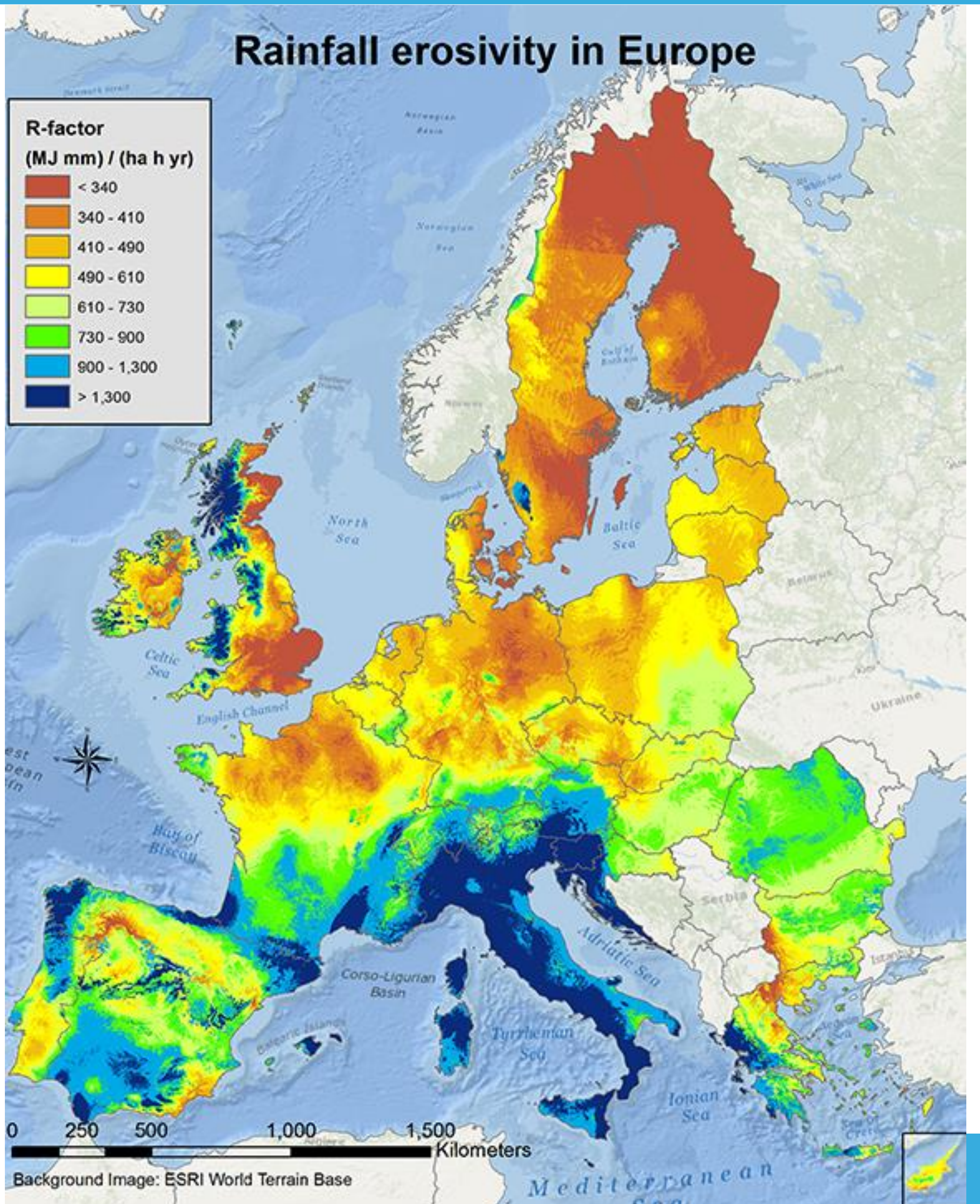
Why Gaussian Process Regression (GPR)?

European Commission

- **Best performing model** in terms of cross validation among a series of candidate models
  - Ordinary Least Squares (OLS), Generalized Linear Model (GLM), Generalized Additive Model (GAM)
  - Regression Kriging
- **Criteria** chosen for the selection of **best model:**
  - the minimization of the **root-mean squared error** and
  - the maximization of the $\mathbf{R^2}$ (coefficient of determination).
- **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)**

Joint Research Centre

Rainfall Erosivity (R-factor)

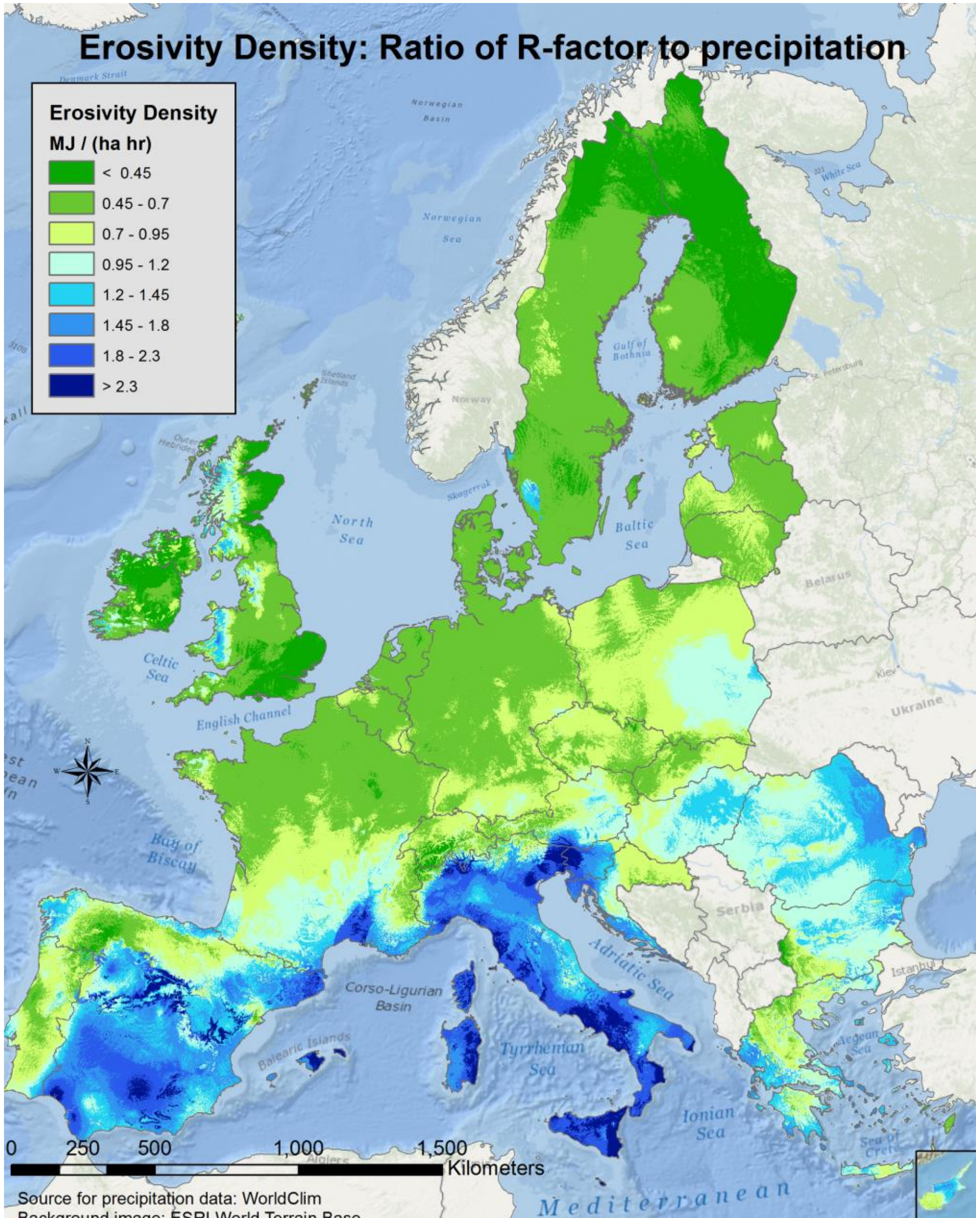


European Commission

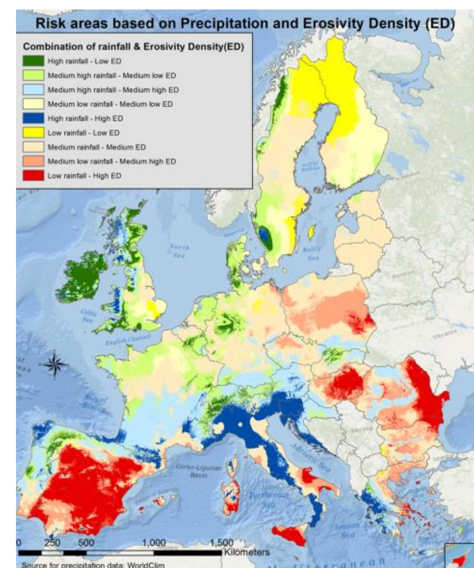
- **Resolution: 500**m
- **Spatial coverage**: European Union (EU-28) plus Switzerland
- **Robust Geo-statistical** model
- Mean: **722 MJ mm ha^{-1} h^{-1} yr^{-1}**
- Highest R-factor in Mediterranean & Alpine regions and lowest in Scandinavia
- **Highest R-factor** levels are in line with the 3 major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

Panagos et al.(2015)

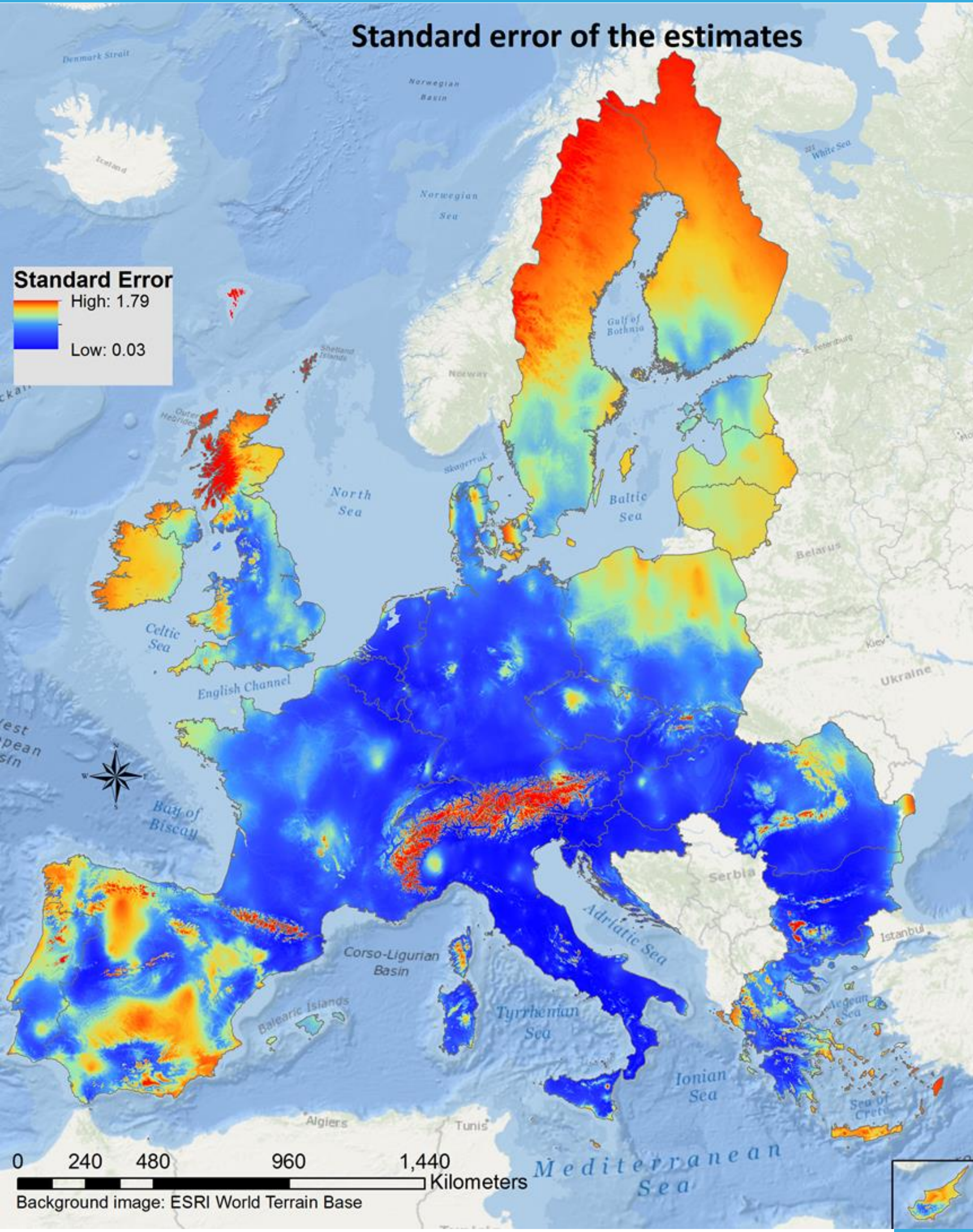
Erosivity density



- **Post-assessment** of rainfall erosivity patterns and type of rainfall
- 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 rainfall)
- Rain distribution is **much smoother** in northern parts of Europe (northern Germany, France, Netherlands)

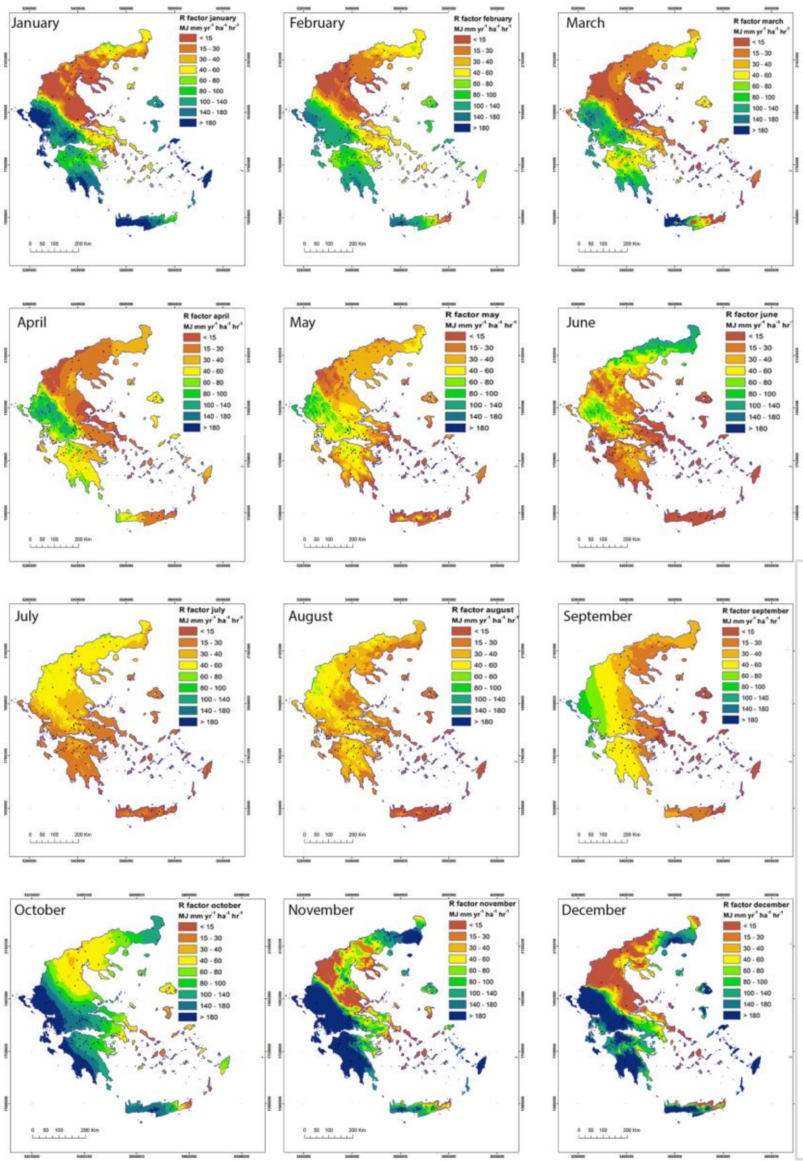


Uncertainty of the prediction model

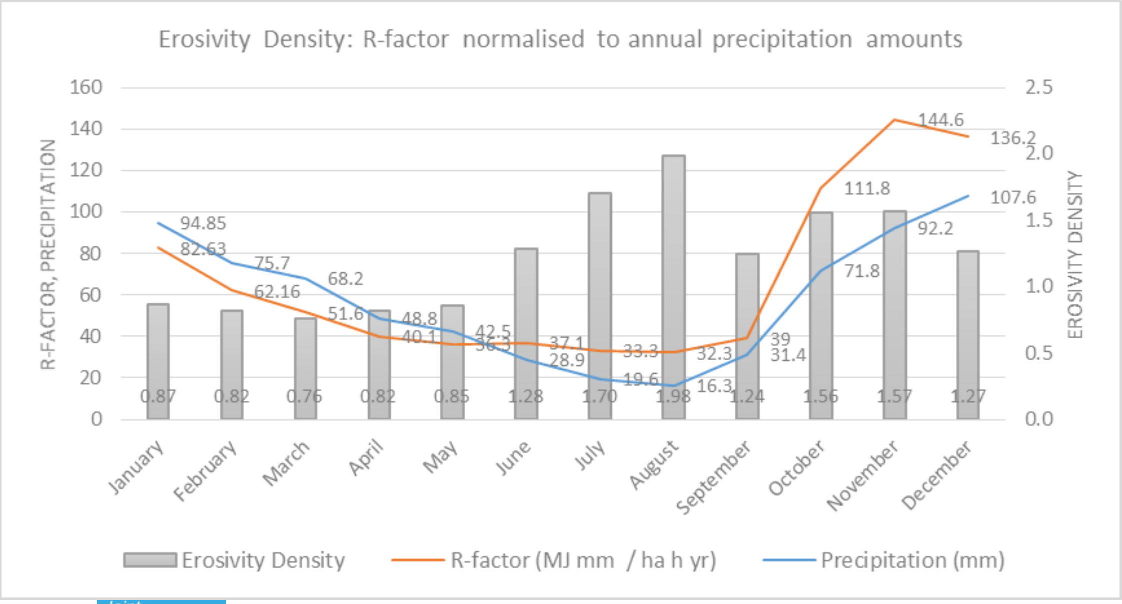


- The model had a **good prediction rate** with low standard errors in the majority of the study area
- **High variability of climatic** and **terrain conditions** in an area of > **4.4 Million km²** resulted in a broad spectrum of rainfall erosivity
- Scotland, north-western Sweden and northern Finland: Relatively **small number of precipitation stations**
- Southern Alps and the Pyrenees**: high diversity of environmental features**

R-factor seasonality

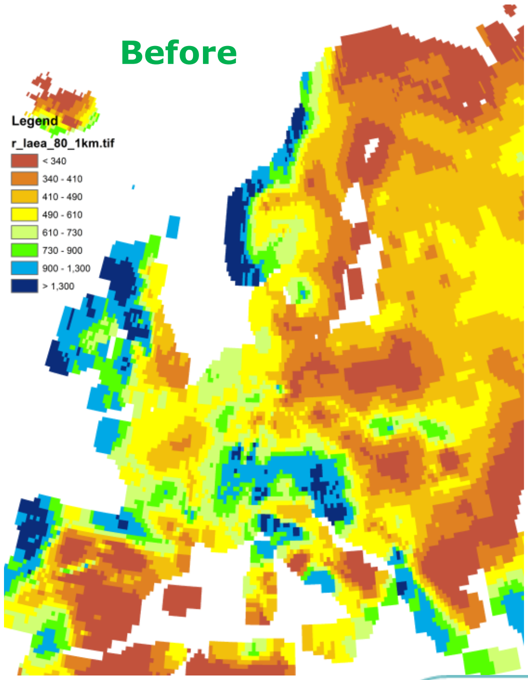


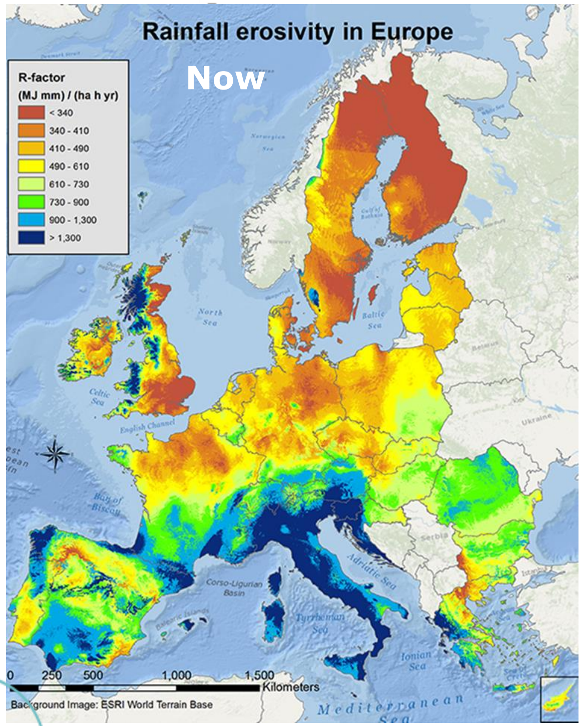
- **60% of the annual rainfall** erosivity in Greece is accounted in **4 months** period (October – January)
- **High Spatial variability: High R** in Western part and Peloponnesus, **Low R** in Eastern coast, Macedonia region, Thessaly and Cyclades
- **High Uncertainty** prediction in May-August



Panagos et al. CATENA. Revised (2015)

R-factor improvements





R-factor improvements:

- 50kmx50km vs 1kmx1km (2500 times finer Scale)
- Based on high temporal resolution measured data
- R-factor is not dependent only on precipitation
- Erosivity density trends in Europe
- Seasonal (and monthly) maps of R-factor
- Calibration rules in different temporal resolutions

Future developments

European Commission

- **Enlarge REDES including more stations** (Especially in countries with low density of stations: Poland, etc)
- **Apply this model to all Europe** including Norway, Balkan states, etc
- **Seasonal variability of the R-factor** → Seasonal variability of soil loss (combined with Land cover & management)
- **Climate change scenarios**: IPCC HadGEM2 predicts 8.2% decrease of precipitation in Europe. Erosivity density & future precipitations → R-factor decrease (*unknown the trends in precipitation intensity?*)
- Development of future **precipitation intensity model** (based on trends)

Information and data:

Science of the Total Environment 511 (2015) 801–814

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Rainfall erosivity in Europe

Panos Panagos [a,*], Cristiano Ballabio [a], Pasquale Borrelli [a], Katrin Meusburger [b], Andreas Klik [c], Svetla Rousseva [d], Melita Perčec Tadić [e], Silas Michaelides [f], Michaela Hrabalíková [g], Preben Olsen [h], Juha Aalto [i], Mónika Lakatos [j], Anna Rymszewicz [k], Alexandru Dumitrescu [l], Santiago Beguería [m], Christine Alewell [b]

[a] *European Commission, Joint Research Centre, Institute for Environment and Sustainability, Via E. Fermi 2749, I-21027 Ispra, VA, Italy*
[b] *Environmental Geosciences, University of Basel, Switzerland*
[c] *Institute of Hydraulics and Rural Water Management, University of Natural Resources and Life Sciences, Vienna, Austria*
[d] *Institute of Soil Science, Agrotechnology and Plant Protection Sofia, Bulgaria*
[e] *Meteorological and Hydrological Service, Zagreb, Croatia*
[f] *Department of Meteorology, Nicosia, Cyprus*
[g] *Faculty of Environmental Sciences, Czech University of Life Sciences Prague, Czech Republic*
[h] *Department of Agroecology, Aarhus University, Denmark*
[i] *Finnish Meteorological Institute, Finland*
[j] *Hungarian Meteorological Service, Budapest, Hungary*
[k] *UCD Dooge Centre for Water Resources Research, University College Dublin, Ireland*
[l] *National Meteorological Administration, Bucharest, Romania*
[m] *Estación Experimental de Aula Dei-Consejo Superior de Investigaciones Científicas (EEAD-CSIC), Zaragoza, Spain*

European Soil Data Centre:
http://eusoils.jrc.ec.europa.eu/library/themes/erosion/RainfallErosivity/

Panos.panagos@jrc.ec.europa.eu

Joint Research Centre