Soil erosion in Europe: Current status, challenges and future developments

Asia – EC Joint Conference 2017: All that Soil Erosion: Global task to Conserve Our Soil Resources

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JRC: Who we are? facts & figures
The Joint Research Centre (JRC) is the European Commission’s science and knowledge service which employs scientists to carry out research in order to provide independent scientific advice and support to EU policy.

- €386 million Budget annually, plus €62 million earned income
- Independent of private, commercial or national interests
- Policy neutral: has no policy agenda of its own
- 42 large scale research facilities, more than 110 online databases
- 125 instances of support to the EU policy-maker annually
- 83% of core research staff with PhD’s
- Over 1,400 scientific publications per year

More than 100 economic, bio-physical and nuclear models
Soil erosion. What is? What are the main effects?

On site effects
- losses in production
- yields and nutrients
- damage to plantations
- reduction of the available planting area

Off site effects
- sedimentation,
- flooding,
- landslides
- water eutrophication
- siltation of reservoirs
- the loss of biodiversity
- land abandonment
- destruction of infrastructure such as roads, railways and other public assets

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

Soil erosion indicators & policy support

European Parliament - Greens
SDGs
UNEP
ENV-ESTAT: EUROPE 2020
EEA
ESTAT: Agro-Environmental
DG AGRI

15 GET 15 LAND

OECD
ipbes GLOBAL SOIL RESOURCES ASSESSMENT 2015
United Nations Convention to Combat Desertification
 Soil Erosion after EIONET data collection (2009-2010)

RUSLE2015: New soil erosion model
A = K * R * C * LS * P

Panagos et al. (2014), Soil Science & Plant Nutrition

Soil Erodibility (K-factor)

- Combines the influence of Texture, Organic carbon, soil structure, Permeability, coarse fragments and Stone cover
- **20,000** Land use/cover survey (LUCAS) samples with measured data
- **Regression interpolation** using Terrain features, Lat/Long, vegetation covariates
- **Spatial Resolution**: 500m
- **Verified** against 21 local, regional and national datasets from 13 countries


Soil Erodibility (K-Factor) incorporating Stone cover

- Improved version taking into account **Stoniness**: 20,000 LUCAS surveyed points
- **Stone cover effect**: 15%
- Important effect in **Mediterranean**
Rainfall erosivity and data collection

- **Rainfall erosivity** is the kinetic energy of rainfall (MJ mm ha\(^{-1}\) h\(^{-1}\) yr\(^{-1}\))
- Combines the influence of **precipitation duration, magnitude and intensity**
- **Participatory approach**: Environmental & Meteorological Services from all Member States (Mar 2013 – Jun 2014).
- **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 precipitation records
- **REDES**: Rainfall Erosivity Database on the European Scale


Rainfall Erosivity (R-factor)

- **Resolution**: 500m; **Robust Geostatistical model**
- Highest R-factor in Mediterranean & Alpine regions and lowest in Scandinavia
- R-factor **not dependent** only from precipitation

Panagos et al. STOTEN (2015)
**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 erosivity in summer
- **Southern European countries** exhibit the largest erosivity values during October to January

*Ballabio et al. STOTEN (2017)*

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**Topography (LS-factor)**

**Slope Length and Steepness factor (LS-factor) in European Union**

- **25m DEM → resolution 25m LS-factor** (capture geomorphological features compared to 100m DEM)
- Desmet & Govers algorithm (1996)
- Fast process with SAGA software
- **50GB of dataset available in European Soil Data Centre (ESDAC)**
- No arbitrary limitations in slope length

*Panagos et al.(2015), Geosciences, MDPI*
Good Agricultural practices against Erosion

- Reduced Tillage
- Stone Walls
- Plant residues
- Grass margins
- Cover crops
- Contour farming


Cover – Management (C-factor)

- Differentiate between Arable lands & Non-Arable lands
- Non arable: Forest – Shrub – sparse vegetation – Heterogeneous – Permanent crops - pastures/grasslands
- CORINE Land Cover & Vegetation Density
  - Calibrate the C-factor from literature: 20 major published studies
  - with Remote Sensing (RS) images from Copernicus Programme: Vegetation Density layer: RS every 10 days

Example: Pastures C-factor
- Range from literature: 0.05 – 0.15
- Each pixel gets a value in this range depending on its Vegetation Density (0-100%)
- Pastures (mean) C-factor in Ireland: 0.077
- Pastures (mean) C-factor in Cyprus: 0.125

C-factor in arable lands: \( C_{\text{crop}} \)

\[ C_{\text{arable}} = C_{\text{crop}} \times C_{\text{management}} \]

- **NUTS2** (regional) level
- Based on **crop composition** over 5 years (2008-2012)
- Weighted average of crop composition & their C-factor
- Future: NUTS3 or farm level (LPIS)


Management factor: \( C_{\text{management}} \)

\[ C_{\text{arable}} = C_{\text{crop}} \times C_{\text{management}} \]

Plant residues applied in 10.6% of EU-28 arable lands

Support Practices (P-factor)

Data input from:
- Good Agricultural Environmental Conditions (GAEC) database plus
- LUCAS 270,000 earth observations

Support practices Impact:
- Contour farming (5%)
- Stone Walls (38%)
- Grass Buffers (57%)

P-factor in EU-28: 0.97
P-factor in arable: 0.95

Panagos et al. (2015). Environmental Science and Policy

Soil loss by water erosion (RUSLE2015)

- Average EU-28: 2.46 t ha\(^{-1}\) yr\(^{-1}\) (in the erosive prone areas: 91% of EU)
- Total Soil loss: 970 Mt annually
- Spatial resolution: 100m
- Reference year: 2010

- 24% of EU lands have rates > 2 t/ha
- 11% of total area contributes to almost 70% of total Soil Loss

"Between 2000 and 2010, intervention measures through the European policies (Common Agricultural Policy, Soil Thematic Strategy) have reduced the rate of soil erosion by an average of 9% in total (20% in arable lands)"

**Sediments distribution**

- WaTEM/SEDEM model
- Calibration with 25 catchments in EU
- Soil loss in the riverine systems is about 15% of RUSLE2015 estimates (SDR: 015)
- Spatial resolution: 25m
- Estimated sediment yield in Europe totals 0.164 ± 0.013 Pg yr⁻¹
- 93% of gross soil loss to rivers occurs in agricultural lands (surplus of sediments in forests and semi-natural areas)
- SOC displacement by water erosion in Europe of 14.5 Tg yr⁻¹

_Borrelli et al. (2018) – Environmental Research_

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**RUSLE2015 & Soil Loss Map: Concluding remarks**

- **Trend**: Decrease of 9% (20% in arable lands) due to impact of Common Agriculture Policy (CAP) and Soil protection measures: reduced tillage, plant residues, cover crop, contour farming, maintenance of stone walls, increase of Buffer strips.

- Very good correspondence with EIONET (7 out of 9 Member States): The European model is as robust as national ones.

- **High resolution & best available** input data in EU

- **Transparent way & easily parameterization**

- **Peer-reviewed following literature**

- **Replicable & comparable** with national estimates

- **Participatory**: involvement of countries [National meteorological services (Erosivity), LUCAS-topsoil (erodibility), CORINE/Copernicus (vegetation), Statistics – Eurostat (management)]

- Incorporates **Scenario analysis**

Climate change scenarios and Rainfall Erosivity in 2050

- **Climate change scenarios (2050):** Taking into account IPCC HadGEM2 and REDES we predict 18% increase of R-factor in 2050.

- **Highest R-factor increase** is projected in Northern & Central Europe.

- **Rainfall erosivity will increase in 81% of the study area and decrease in the rest 19%**

- **R-factor projections include the uncertainty of climatic models**


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Land use Scenarios & policy developments

- **Land use scenarios:** Projections of land use change for the year 2050 based on the pan-European Land Use Modelling Platform (LUISA)

- According to LUISA:
  - All agricultural land uses will be reduced by 2050 (croplands will decrease by 1.2%, permanent crops by 0.2% and pastures by 0.8%)
  - Semi-natural areas will also decrease by 1%
  - Urban areas will increase by 0.7% and forest areas by 2.2%.

- Forest lands, which are the least erosion prone (with mean annual soil loss of 0.065 t/ha), will replace erosion-sensitive land uses (permanent crops, arable, pastures and semi-natural).

- In aggregated soil loss terms, the future land use changes projected by LUISA will result in a **5.8% reduction in soil loss**

- **Policy developments:**
  - Biofuels directive pushes for replacing cereals with energy crops: sugar beet, sunflowers (more erosive). i.e. scenario of 10% conversion to energy crops → increase 3.8% of soil loss in arable lands
  - Hypothetical scenario: Duplicate the grass margins and apply contour farming in arable lands > 5% slope → Reduce soil erosion by 5%
Joint Research Centre (JRC)

A pan-European quantitative assessment of soil loss by wind

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Towards first qualitative estimation of wind erosion

In 2013, the European Commission requested to the JRC a new wind erosion assessment

LUCAS topsoil sampling
Wind-erodible fraction of soil
Index of Land Susceptibility to Wind Erosion

Borrelli et al., 2014. Geoderma, 232
Borrelli et al., 2016. Land Degradation & Development, 27
Borrelli et al., 2015. Sustainability, 7
GIS-RWEQ model

The first quantitative assessment at European level.

Main Factors influencing wind erosion (included in the model):

Climate: wind velocity & direction, Rainfall and evapotranspiration

Soil characteristics: sand, silt, clay, Calcium Carbonate(CaCO3), organic matter, water-retention capacity and soil moisture

Land use (vegetation cover): land use type, percent of vegetation cover and landscape roughness

Model used: RWEQ

The model scheme is designed to describe the daily soil loss potential at regional or larger scale

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Soil loss by wind modelled for the European arable land

The average annual soil loss predicted by GIS-RWEQ in the EU arable land totalled 0.53 Mg ha$^{-1}$ yr$^{-1}$

- $2^{nd}$ quantile equal to 0.3 Mg ha$^{-1}$ yr$^{-1}$
- $4^{th}$ quantile equal to 1.9 Mg ha$^{-1}$ yr$^{-1}$

- Highest wind erosion rates in arable lands: Denmark, Netherlands and Bulgaria

- Peak in winter period (December-February): 57% of total

- Noticeable rates in Eastern UK, North France, Belgium, Czech Republic, Slovakia and Hungary

- In Mediterranean, higher soil loss rates were located in the Spanish regions of Aragón, Castilla y Leon, the Italian regions of Apulia, Tuscany and Sardinia, in the Provence in France and the Greek regions of Central and Eastern Macedonia and Thrace and Aegean islands.

Data available:

Borrrelli et al., 2017. Land Degradation & Development, 28: 335-344
Integration of soil erosion with soil organic carbon Modelling framework

Emanuele Lugato,
P. Borrelli, A. Jones, K. Van Oost, L. Montanarella, P. Panagos
Baseline

Top-soil (0-30 cm) organic carbon content (t C ha⁻¹) in 2010

17.63 Gt SOC stock

Lugato et al. 2014, Global Change Biology

SOC sequestration scenarios

1) Conversion from arable to grassland (LUC_AR_GR)
2) Crop residue management (AR_RES): 100% incorporation of cereal straw compared to 50% of BAU scenario;
3) Reduced tillage scenario (AR_RT): substitution of the mouldboard plough with a more superficial tillage;
4) Combined residue incorporation + reduced tillage (AR_RET);
5) Ley in rotation (AR_LEY): inclusion of two consecutive years of a fodder crop (alfalfa) in the BAU rotation;
6) Cover crop (AR_CC): the insertion of cover crops in the rotation schemes, which biomass was entirely incorporated (green manure).


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Modelling carbon under agricultural management practices

Modelling tools predicting quantitative effect of different mitigation measures on soil organic carbon in agricultural soils

Lugato et al., 2014. Global Change Biology

Erosion & SOC modelling (Integration)

- Coupling RUSLE2015 with CENTURY biogeochemical model
- SOC balance and C fluxes at grid cell (1.87 M grid cells of 1Km)
- Part of the C eroded was assumed to move out from grid cell generating CO₂ flux

Average eroded soil organic carbon

- 76% of agricultural lands < 0.05 t C ha\(^{-1}\) yr\(^{-1}\)
- Hotspots with eroded SOC > 0.45 t C ha\(^{-1}\) yr\(^{-1}\)
- Erosion across EU agricultural lands contributes to 2.28 Mt CO\(_{2eq}\)
- Policy oriented scenario estimate to sequester 12.6-42 Mt CO\(_{2eq}\)

“
Agricultural practices are needed to prevent or reduce erosion and maintain soil productivity”

Global Rainfall Erosivity Database

Development of the first ever Global Rainfall Erosivity Database
63 countries; >50 scientists; 100 organizations; 3,625 stations; 60,000 yrs HR data

Panagos et al. (2017). Scientific Reports
Rainfall Erosivity Map

Panagos et al. (2017). Scientific Reports

Global Soil Erosion

High resolution: 250 x 250 grid

35.9 Pg yr\(^{-1}\) of soil erosion (2012)

Coverage: 202 countries ≈ 125 10\(^6\) Km\(^2\)
A study which is more than a map or a model ....

**New insights in Earth systems dynamics**

- 4 Million Km² change land use between 2000-2012
- Increase of total erosion by 2.5% due to decrease in forestlands
- Africa has the highest increase (8%) followed by South America and South East Asia

- Focus in croplands: 17 Pg yr⁻¹
- Croplands are 11.2% of study and are responsible for 50.5% of soil erosion

*Borrelli et al. (2017). Nature Comm. in press*

**Reflections & way forward**

- Previous global over-estimated dated in 1980’s-1990’s global soil erosion (73.5 Pg yr⁻¹) compared to current one: 35.9 Pg yr⁻¹
- Deforestation is the main threat for soil erosion increase
- Conservation practices can reduce considerably soil erosion
- Integrate the climate change effects (increased rainfall intensity and erosivity)
- Integrate the current soil erosion assessment with carbon dynamics
- Increased use of fertilizers (and high cost) of fertilizers to mitigate loss of agricultural productivity
- Land Degradation neutrality by 2030? How to achieve it?

*Borrelli et al. (2017). Nature Comm. in press*
Soil erosion modelling workshop

Erosion modelling workshop

This workshop will mainly discuss issues regarding how the local/regional modelling results can be upscaled to (or applied at) the European scale. The workshop also serves as a follow-up to recent JRC modelling developments and published maps of soil erosion by water and wind. The workshop will try to focus on how various project or local/regional modelling applications can improve ‘know-how’ at the European scale. Emphasis will also be given to management practices that can reduce soil erosion.

Joint Research Centre
Ispra (VA), Italy
20 March 2017
Auditorium, Bldg 58
21-22 March 2017
Amphitheatre, Bldg 36


#SOILER17

2nd Soil erosion modelling workshop

Seoul, 5-7 December 2017
Invited to submit your paper in WATER journal
Plans: 3rd workshop in South America (Rio, Brazil (21st WCSS)

Soil Erosion by Water

Guest Editor
Dr. Panos Panagos

Deadline
31 March 2018