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C3S Demo Case Soil Erosion

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Copernicus Climate Change Service (C3S) soil erosion demonstration case

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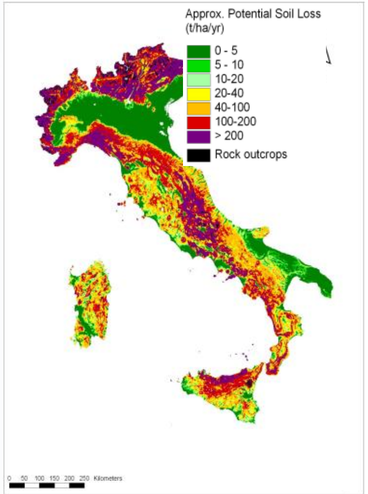
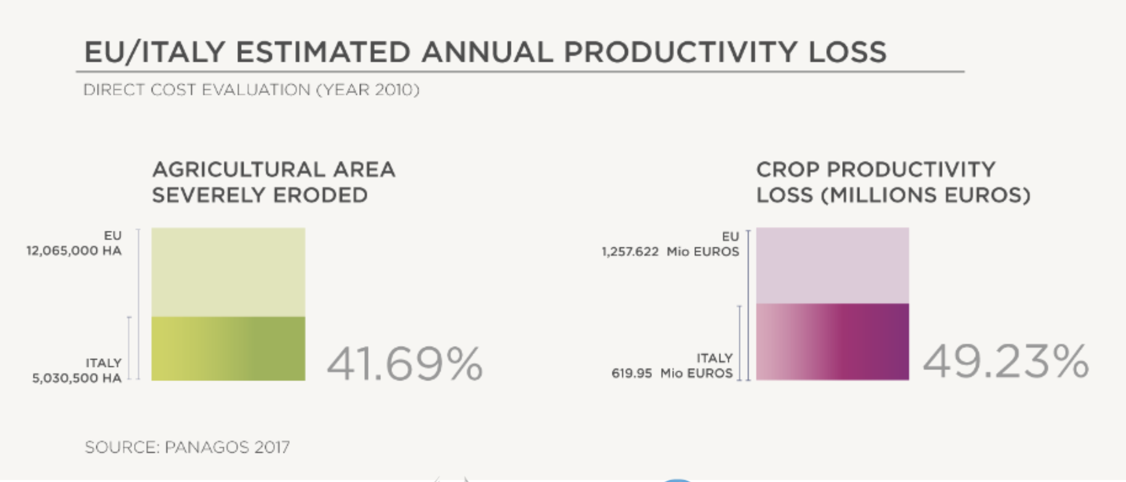
Pilot case: Italy

In Europe, Italy is the country that suffers the highest economic impacts (Panagos et al. 2018 doi:10.1002/ldr.2879) from rainfall-induced soil erosion.

Italy suffers 24% of total soil loss in EU and, due to 33% of agricultural lands exposed, costs are as high as:

- 619 Mil. € crop production
- 251 Mil. € net agricultural production
- 37 Mil. € GDP





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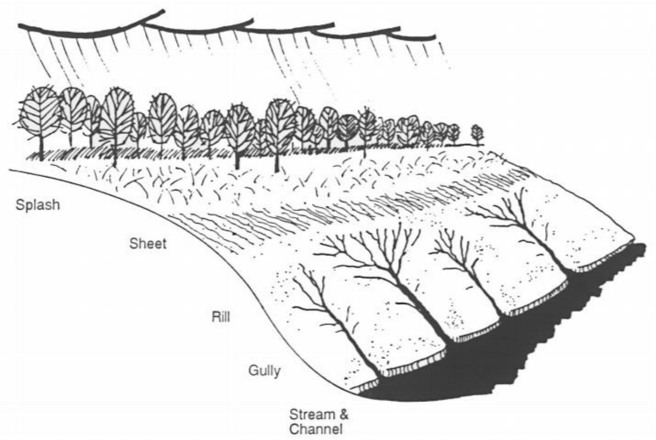
RUSLE equation

The Revised Universal Soil Loss Equation (RUSLE; Renard et al., 1997) is an empirical regression equation widely-adopted to evaluate potential Soil Losses (SL) by rainfall-related rill and sheet (inter-rill) erosion; it is not able to provide event-based assessments but only annual evaluations of soil loss spatially and temporally lumped.

$$SL = LS * K * C * P * R$$

soil susceptibility factors

rainfall erosivity



SL: Annual average soil loss (t ha^{-1} yr^{-1})
K: Soil Erodibility factor (t ha h ha^{-1} MJ^{-1} mm^{-1})
C: Cover-Management factor (unitless),
LS: Slope Length and Steepness factor (unitless)
P: Support practices factor (unitless)
R: Rainfall Erosivity factor (MJ mm ha^{-1} h^{-1} yr^{-1})

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C3S Demo Case "Soil Erosion"

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A proper assessment of rainfall erosivity requires complete rainfall data series on long time spans at adequate spatial and temporal resolution under current and future time horizons. In many cases, it is a prominent issue for researchers and practitioners.

Copernicus Climate Change Service (C3S) contracted CMCC Foundation to develop "Soil Erosion" Demonstration Case.

It has the goal to promote the C3S potentialities for supporting investigations about soil erosion:

- C3S Climate Data Store (CDS) hosts rainfall time series for the historical period and most recent decades from observational and reanalysis datasets, at (sub) daily time step and with horizontal resolution ranging from 31 km to 5.5 km. For the future, the simulations' ensemble within EURO-CORDEX (resolution ~12 km, daily time step) are available for robust evaluations.
- As Demo Case products, datasets and a Web Application will be released providing assessments on soil loss and rainfall erosivity over Italy for current and future time spans by means of RUSLE equation.

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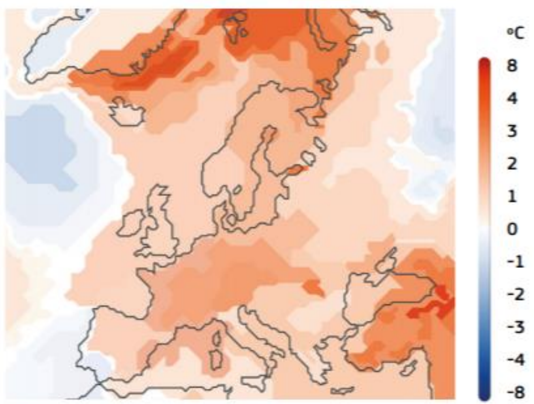
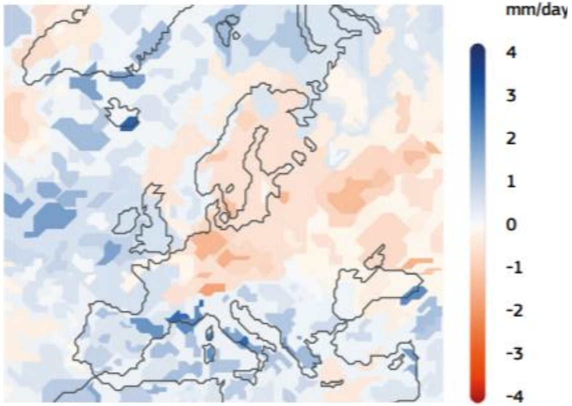
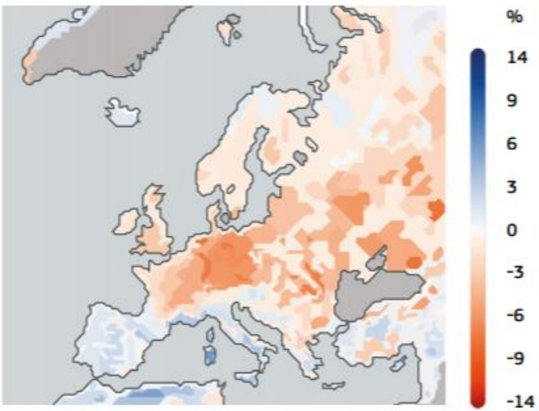
Copernicus Climate Change Service (C3S) provide authoritative information about the past, present and future climate, as well as tools to enable climate change mitigation and adaptation strategies by policy makers and businesses.



Surface air temperature anomaly for 2018 relative to the annual average for the period 1981-2010. **Data source:** ERA5 **Credit:** C3S/ECMWF



ERA5 precipitation anomaly for 2018



ERA5 soil moisture anomaly for 2018

C3S is implemented by the European Centre for Medium-Range Weather Forecasts (ECMWF) on behalf of the European Commission. There is no restriction on data use or reproduction and redistribution, with or without adaptation, for commercial or non-commercial purposes.

CDS Facts

40 818 registered users

Users from **171** different countries

73 M total number of data requests

22 595 TB total data volume delivered

Status as of April 2020

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Collection of User requirements for Demo Case

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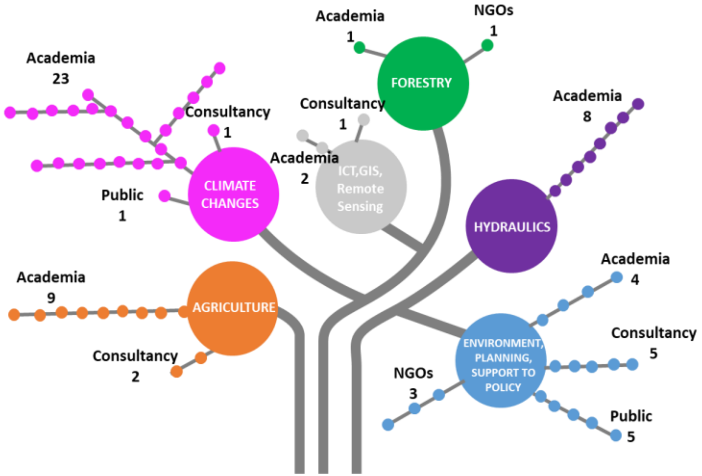
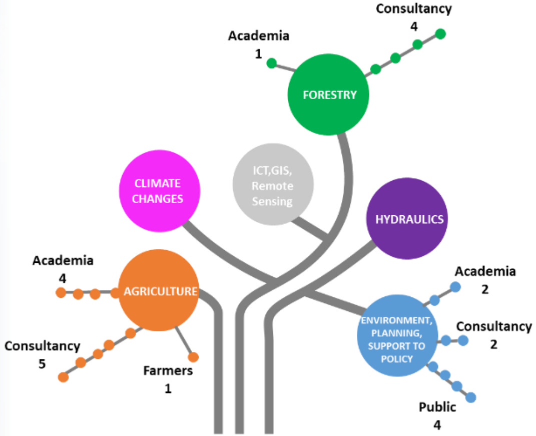
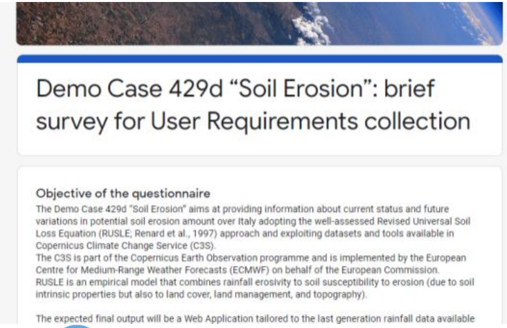
A webinar to increase the awareness about the potentialities of CDS for soil erosion assessments and to collect feedback about the expected outputs was held on December 5 2019
(World Soil Day celebration)

https://youtu.be/BlS_Bwzdb8c





11 telco interviews
2 physical meetings
10 web-survey



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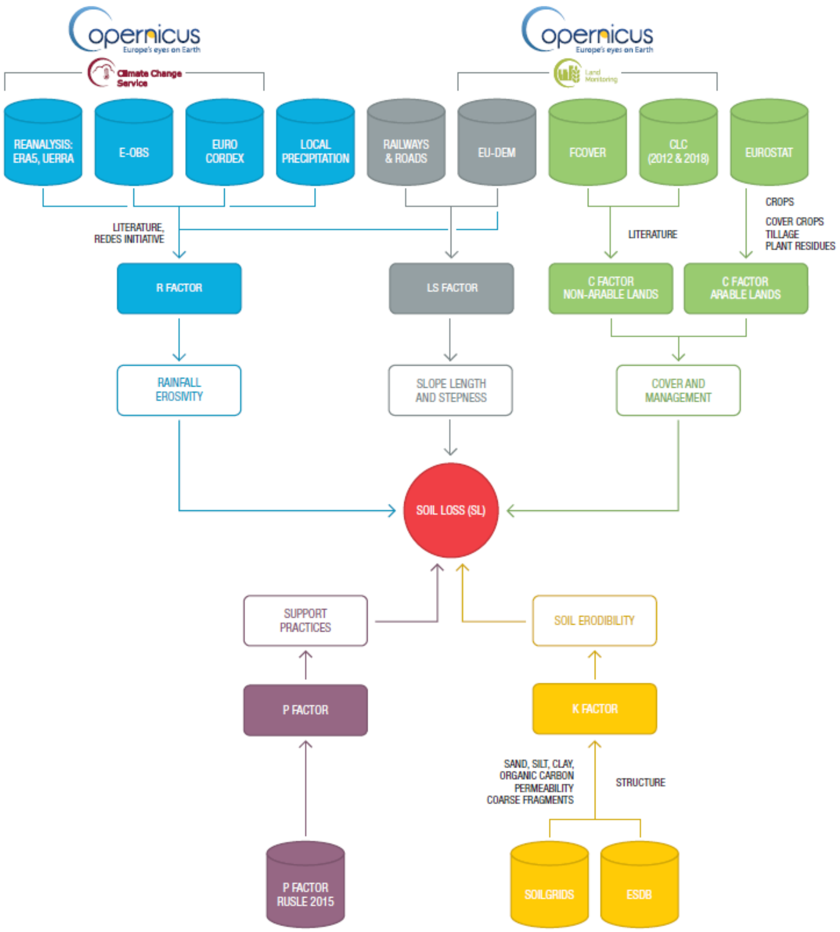
Computing soil losses by RUSLE equation:



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Assessment of R-factor:

Rigorous computation of the R-factor is usually hindered by a general lack of data at the adequate spatial and temporal resolution. Thus, several methodologies have been proposed in literature that relate annual or monthly R-factors to simpler indicators, usually representative of precipitation depths aggregated at a coarser temporal level.

In this case, six methods suggested by Bazzoffi (2007; ISBN: 8850652283) and already tested over Italy will be adopted for current (exploiting ERA5, ERA5land and E-OBS) and future (EURO-CORDEX ensemble) time spans:

#	**reference**	**equation**
1	Arnoldus (1977)	$R = 0.302 \cdot F^{1.93}$
2	Arnoldus (1980)	$R = 17.02 \cdot [(4.17 \cdot F) - 152]$
3	Renard and Freimund (1994)	$R = 0.739 \cdot F^{1.847}$
4	Renard and Freimund (1994)	$R = 0.0483 \cdot P^{1.61}$
5	Lo et al. (1985)	$R = 38.46 + 3.48 \cdot P$
6	Yu e Rosewell (1996)	$R = 3.82 \cdot F^{1.41}$

Modified Fournier Index *F* (mm):

$$F = \frac{1}{P} \cdot \sum_{m=1}^{12} P_m^2$$

where P_m = average monthly precipitation for month “m” over the historical period, and P = average annual precipitation over the historical period.

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Overview of R-factor workflow steps

Project Phase	Needed data	Data sources	Expected output	Further comments
Step 1	Reanalysis and gridded observational datasets for rainfall over Italy	Climate Data Store (CDS)	Gridded R-factor dataset obtained by using a selection of empirical models coupled with rainfall data retrievable in CDS, at the same horizontal resolution of rainfall data	Empirical models will be selected from the Bazzoffi ensemble of methods
Step 2	Sub-hourly rain gauge observations over Italy (to select erosive storm events and to obtain relevant cumulative precipitation aggregations)	JRC database, local repositories, on-line repositories*	R-factor estimation for sparse locations as retrievable from the available data by means of R-factor rigorous approach and by means of the same empirical models as Step 1	Differences with Step 1 provide information about the reliability of gridded rainfall datasets and empirical models to reproduce rainfall erosivity over Italy
Step 3	EURO-CORDEX simulations on current and future period and the most reliable dataset among those in CDS for R-factor estimation (for bias correction purposes)	Climate Data Store (CDS)	Gridded bias-corrected rainfall values at the horizontal resolution of EURO-CORDEX simulations for RCP scenarios and time horizons	Bias correction will be performed by means of Quantile Delta Mapping, using the most reliable CDS gridded rainfall dataset among those evaluated at Step 1. Outputs of Step 3 constitute the input for Step 4
Step 4	EURO-CORDEX bias-corrected simulations on future periods	Climate Data Store (CDS)	Gridded R-factor dataset at the horizontal resolution of EURO-CORDEX simulations for RCP scenarios and future time horizons . Quantification and representation of variability across GCM/RCM chains	Differences with Step 1 provide information about expected changes on soil erosion over Italy as returned by EURO-CORDEX ensemble

*Special thanks to Dr. Panagos from JRC and several Regional Authorities for sharing data and results supporting the research side of the investigation

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Influence of methods

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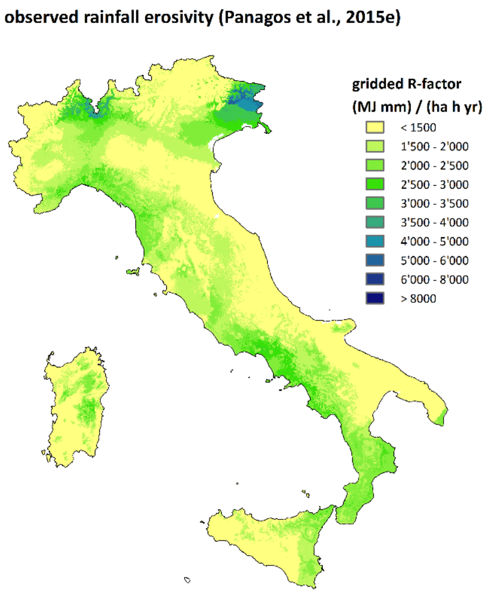

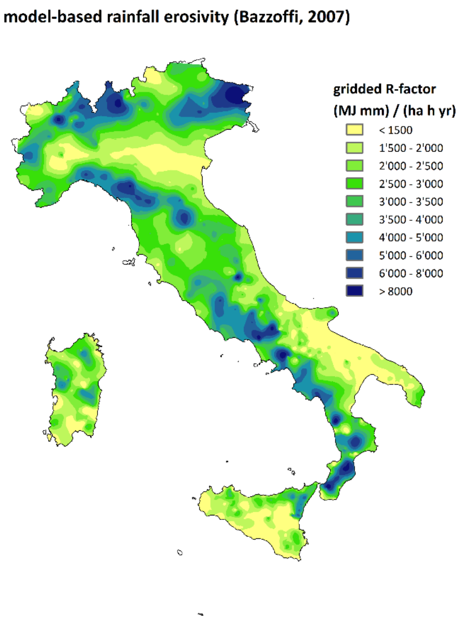

Spatially distributed R-factor estimated by means of rigorous approach relying on sub-hourly rainfall observations.

Spatially distributed R-factor estimated by means of 6 empirical models relying on monthly/annual rainfall observations suggested by Bazzoffi (2007)

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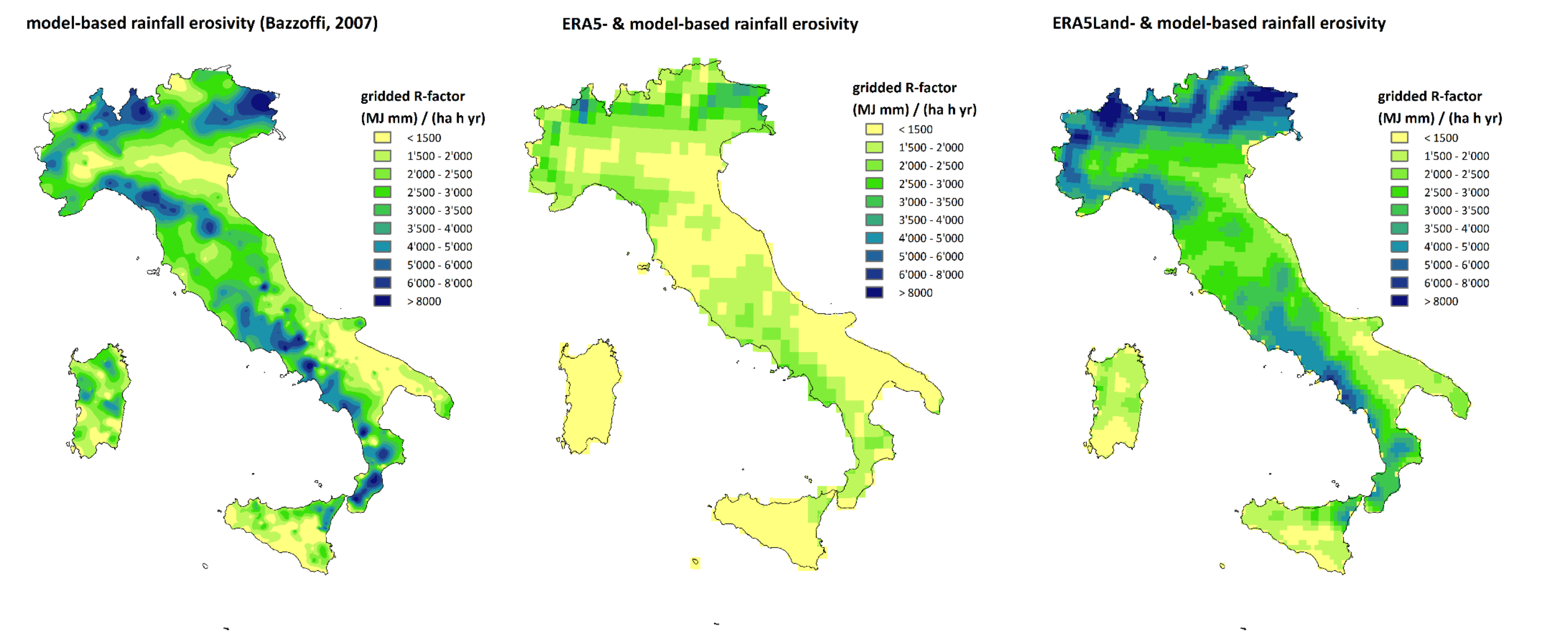
Time period (2002-2011)

Influence of rainfall datasets



Time period (2002-2011)

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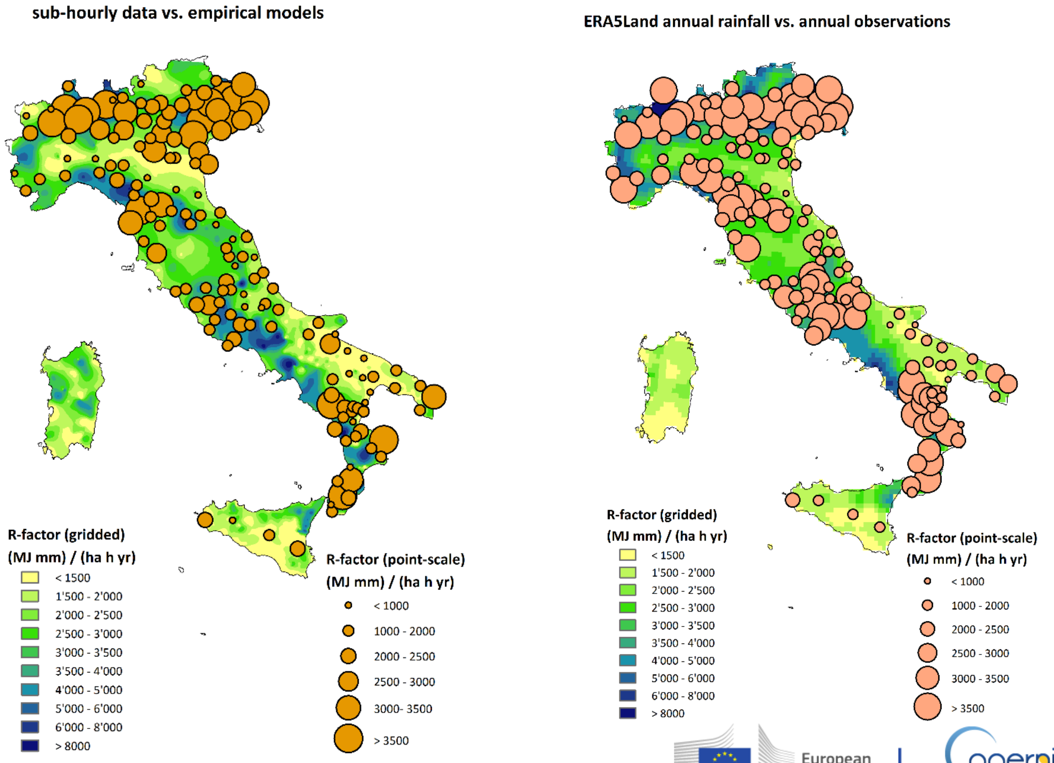
Influence of time resolution and datasets



Time period (2002-2011)

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The future & its uncertainty

Climate projections included in EURO-CORDEX (www.euro-cordex.net) ensemble and already available on CDS will be exploited to provide a clear view about expected variations and associated uncertainties. Two time spans will be considered:
-short term 2021-2050
-medium term 2051-2080

Morevoer, 32 simulation chains between Earth System/General Circulation Models and Regional Climate Models under 3 Representative Concentration Pathways (RCPs) will be considered:

- 6 for RCP2.6
- 13 for RCP4.5
- 13 for RCP8.5

Time period (2002-2011)

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Bias-correction of EURO-CORDEX

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Errors, assumed as systematic in climate projections, usually prevent the adoption of absolute values. They are due to current permitted spatial resolutions and associated physical parametrizations. To overcome such issues, different approaches, usually known as bias correction methods, have been proposed in literature.

In the Demo Case, Quantile Delta Mapping is adopted. It is a parametric technique consisting in adjusting each quantile by means of a climate signal which depends on the probability level:

$$(\Phi^{-1})_{bc} = (\Phi^{-1})_{obs} \cdot \frac{(\Phi^{-1})_{proj}}{(\Phi^{-1})_{curr}}$$

where Φ^{-1} is the inverse of a suitable Cumulative Distribution Function pointing to a specific probability level (or return period T). According to this method, able to particularly preserve climate signal also for the extreme values, for each grid cell the bias correction will rely on a future projection sample of annual/monthly precipitation (1/12 values for each year of the considered 30-year time horizon), a current sample of annual/monthly modeled precipitation (1/12 values for each year of the considered 30-year time window), and an observed sample of annual/monthly precipitation (1/12 values for each year of the reference period of the adopted dataset). Distributions are fitted recurring to a Gamma approach.

Reference dataset is provided by ERA5land.

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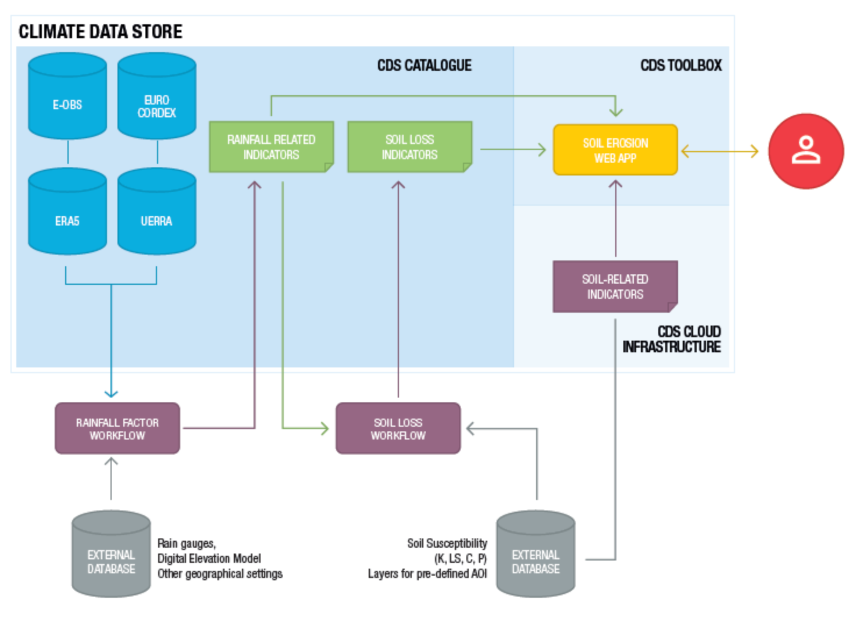
C3S Soil Erosion Web Application:

The App will be implemented as a parametrized CDS python workflow and as CDS interactive web page that will allow the users to access information related to Soil Loss and Rainfall-related (including R-factor) indicators that are available in the datasets produced.
This module can also dynamically re-generate Soil Loss information according to user parameters for pre-defined (e.g. administrative units - NUTS) Areas Of Interest (AOIs).



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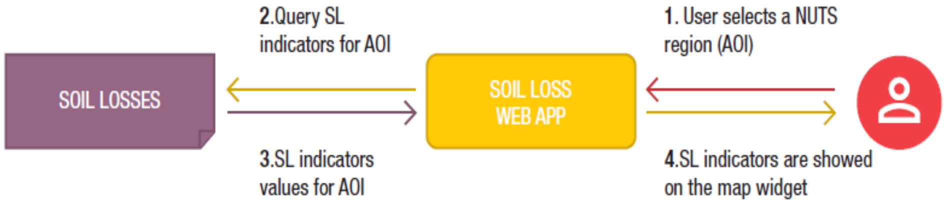
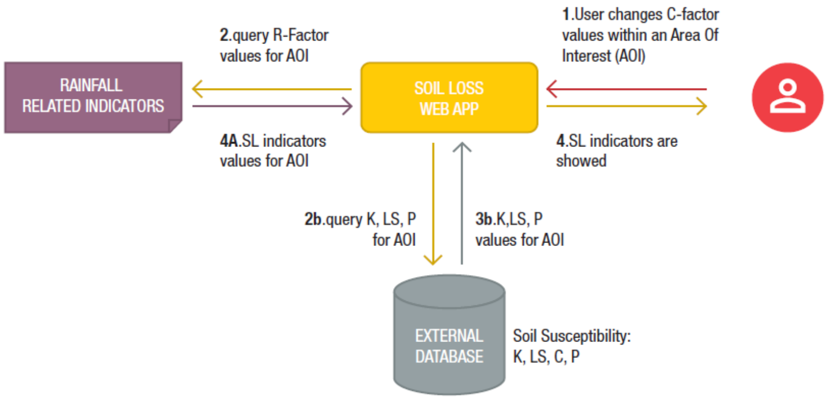
C3S Soil Erosion application functioning:

"Base" Mode



In the "Base" Mode, a user can select a pre-defined AoI and choose the Soil Loss (SL) indicators (e.g. statistics) she/he wants to visualize/analyze.

"Advanced" Mode



In the "Advanced" Mode, a user can select a pre-defined AoI and change the C or P factors at land cover level for the whole AoI.
Then, she/he chooses the Soil Loss (SL) indicators and visualize/analyze the differences vs. the reference SL based on original C or P factor.

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C3S Soil Erosion next stages:

Datasets and web Application will be hopefully released next June.

On June 15th, a second webinar is planned; please check CMCC social channels for updates

Furthermore, feedback are very welcomed by experts, stakeholders and potential Users; for any suggestion, do not hesitate to contact us:
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guido.rianna@cmcc.it

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Dr. Mirko Stojiljkovic, involved in development of datasets and web Application

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THANK YOU FOR YOUR ATTENTION

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