Mapping gully erosion across the European Union

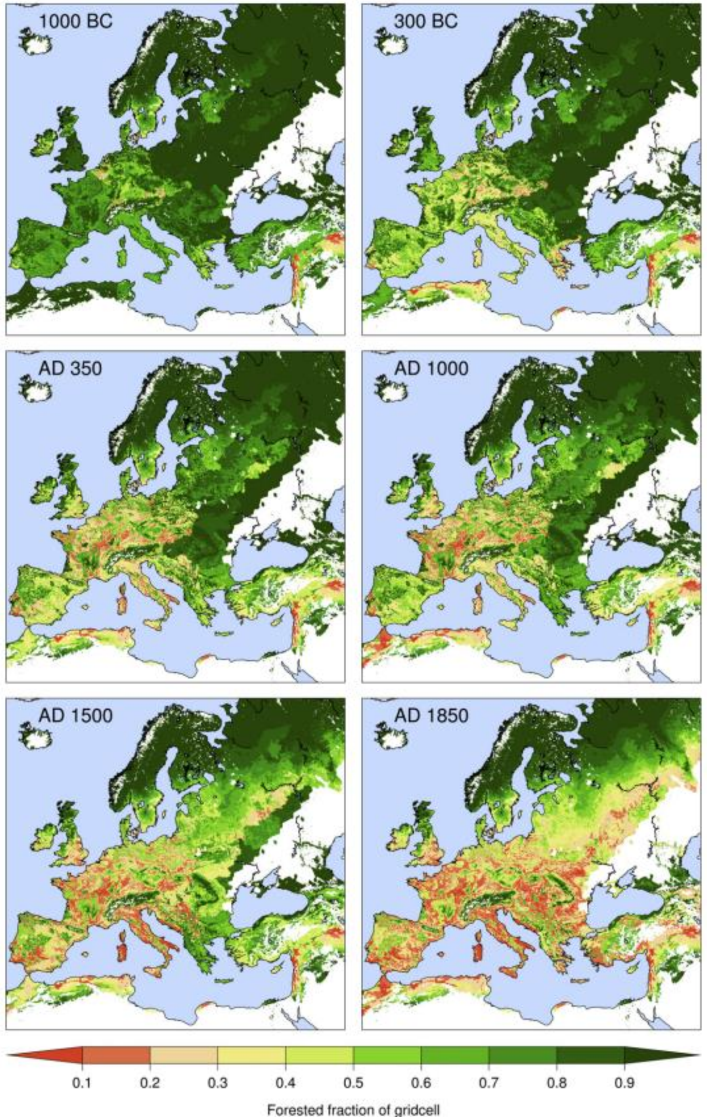
Prof. Dr. Pasquale Borrelli

The 23rd World Congress of Soil Science

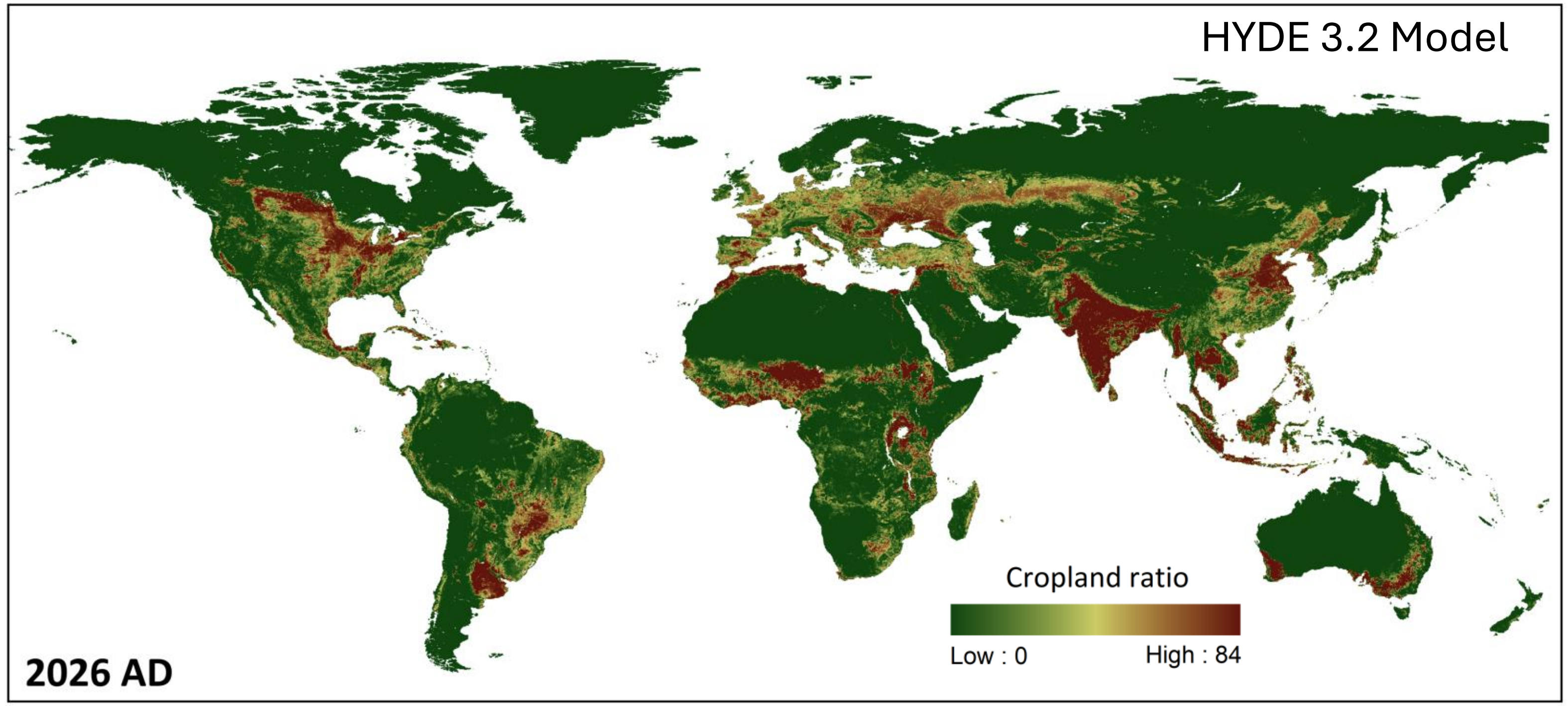
International Union of Soil Sciences

中国土壤学会
SOIL SCIENCE SOCIETY OF CHINA

A Millennia-Long Legacy of Land Use in Europe



Anthropogenic deforestation model



A Millennia-Long Legacy of Soil Degradation in Europe

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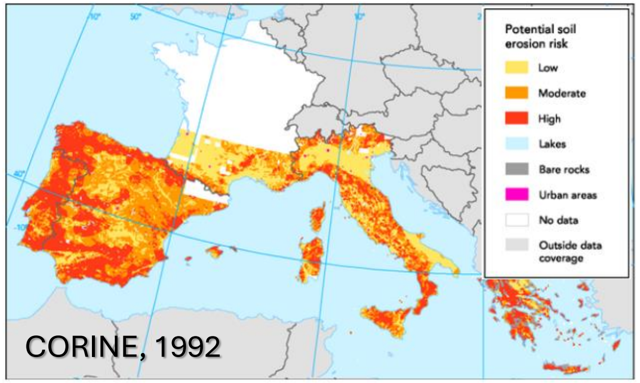
Environmental Modeling & Global Change

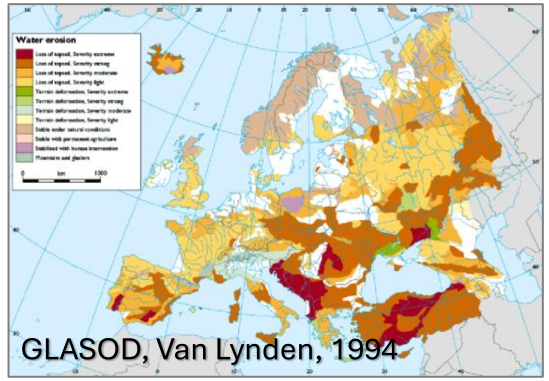
Video: Alewell (Andalusia, Spain)

In Europe, there is a rich heritage in soil erosion modelling

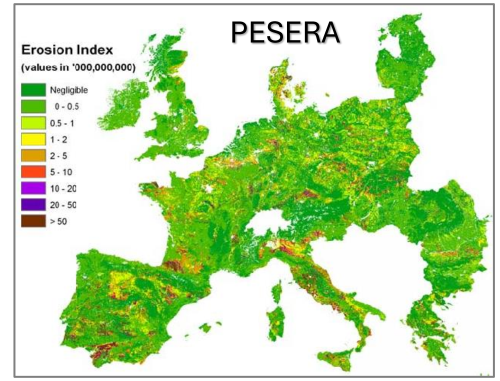
'The implementation of the Soil Thematic Strategy and on-going activities' (Jones et al., 2012) stated that **20% of Europe's land** surface is subject to erosion rates above **10 t ha^{-1} yr^{-1}**

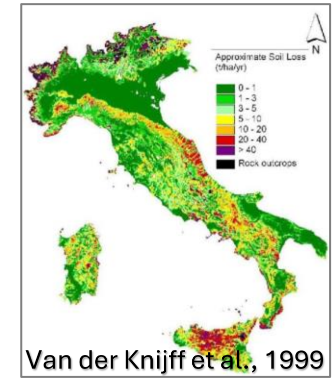


CORINE, 1992



GLASOD, Van Lynden, 1994

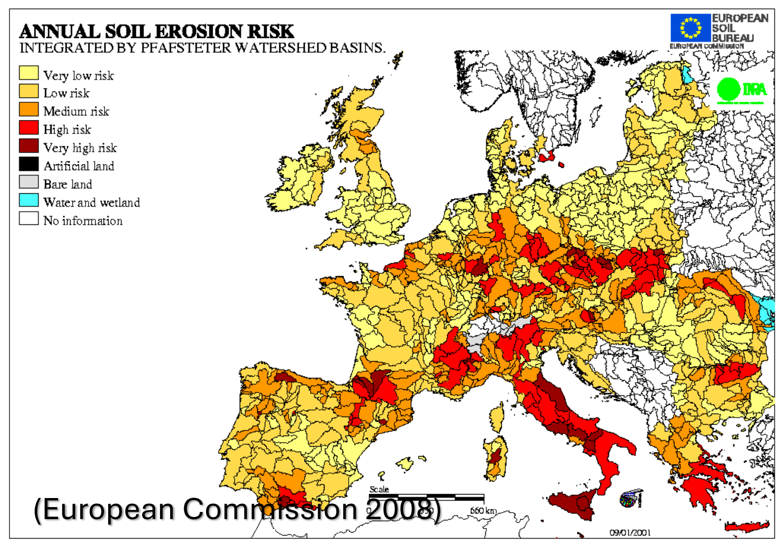




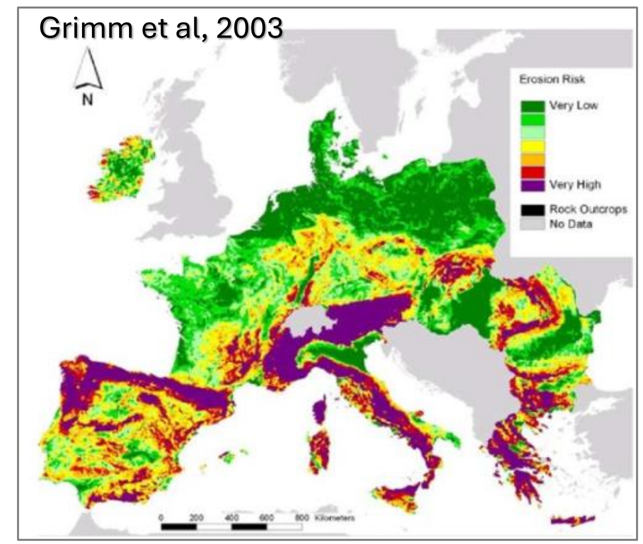
Van der Knijff et al., 1999

Limitations

- Spatial resolution
- Static land uses
- Crop systems
- Conservation practices (CAP)
- Limited remote sensing data



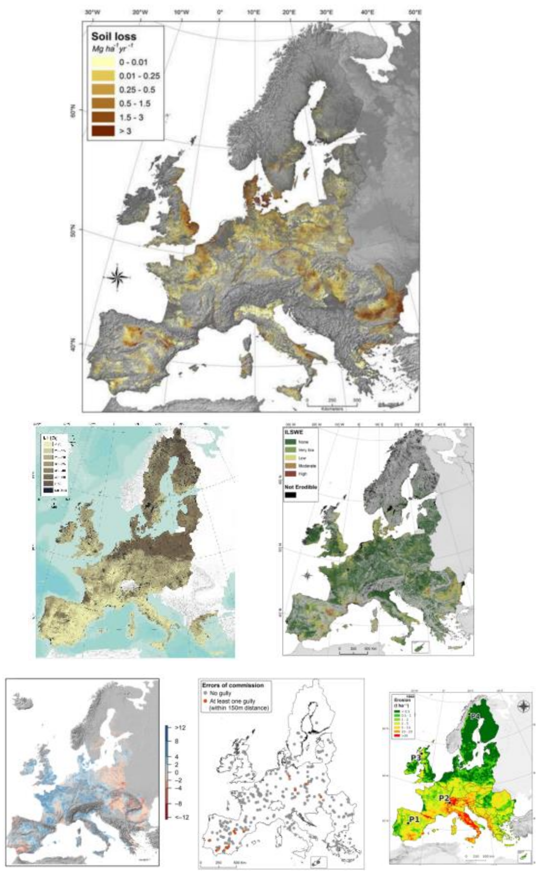
(European Commission 2008)



Grimm et al, 2003

Later studies led by EUSO on pan-EU erosion modelling

Wind Erosion



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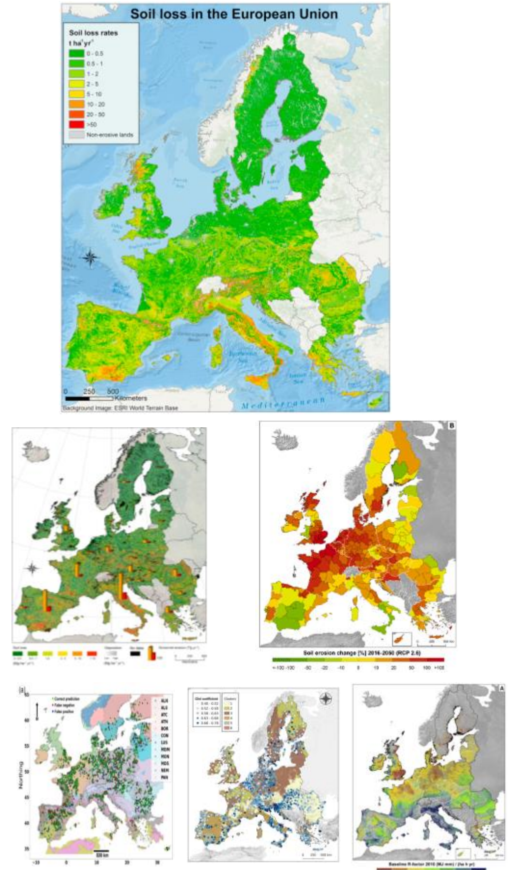
Water Erosion



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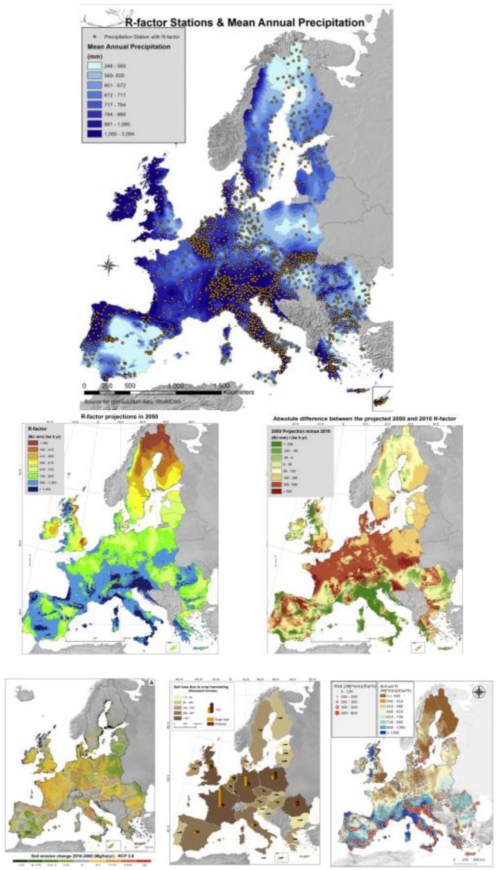
Rainfall Erosivity



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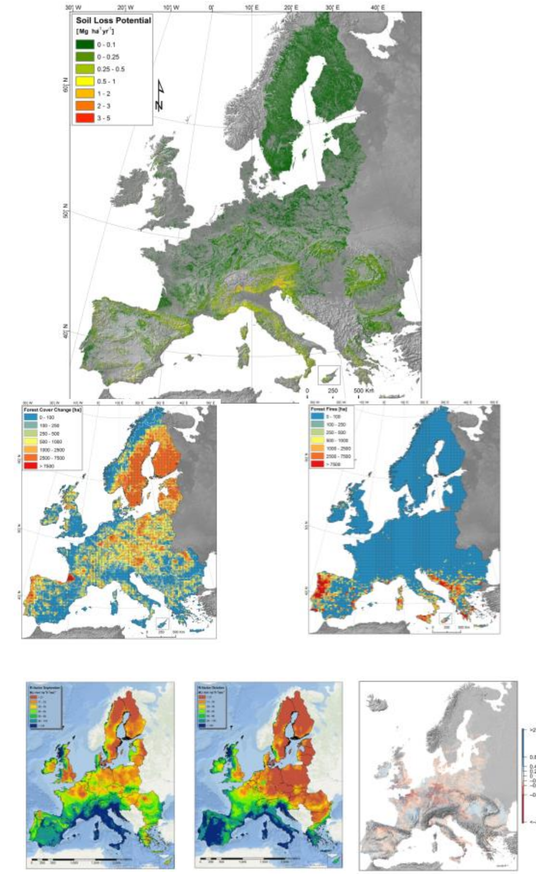
Erosion in Forests



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Multiple concurrent erosion processes modeling in the EU

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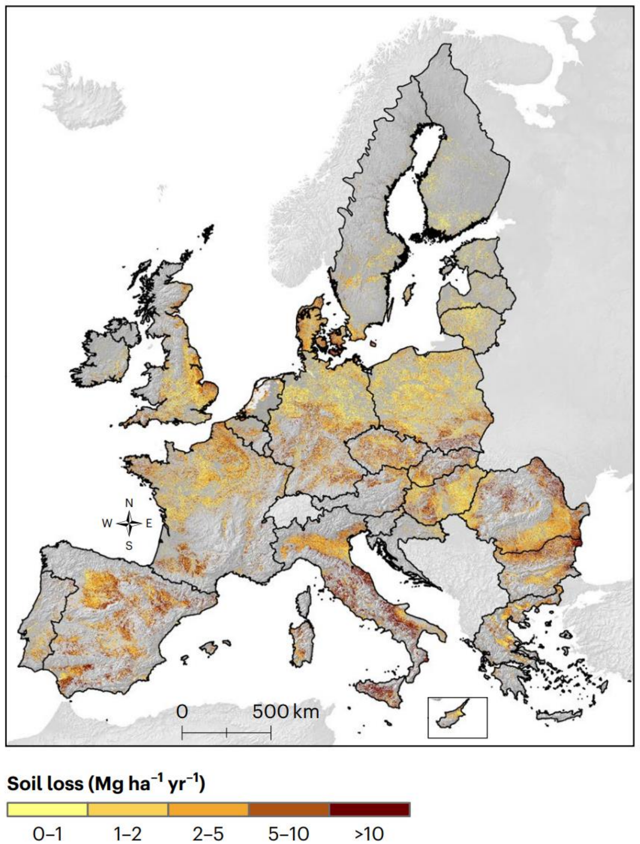
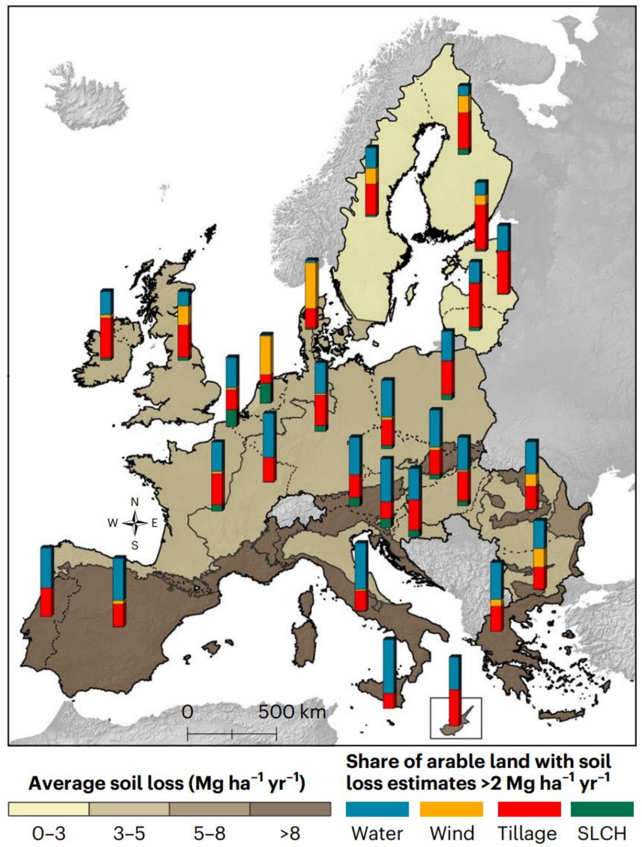




nature sustainability

Analysis

https://doi.org/10.1038/s41893-022-00988-4

Policy implications of multiple concurrent soil erosion processes in European farmland

Received: 4 May 2022

Accepted: 27 September 2022

Published online: 27 October 2022

Pasquale Borrelli[1,2], Panos Panagos[3], Christine Alewell[4], Cristiano Ballabio[3], Hugo de Oliveira Fagundes[5], Nigussie Haregeweyn[6], Emanuele Lugato[3], Michael Maerker[7], Jean Poesen[8,9], Matthias Vanmaercke[8] and David A. Robinson[10]

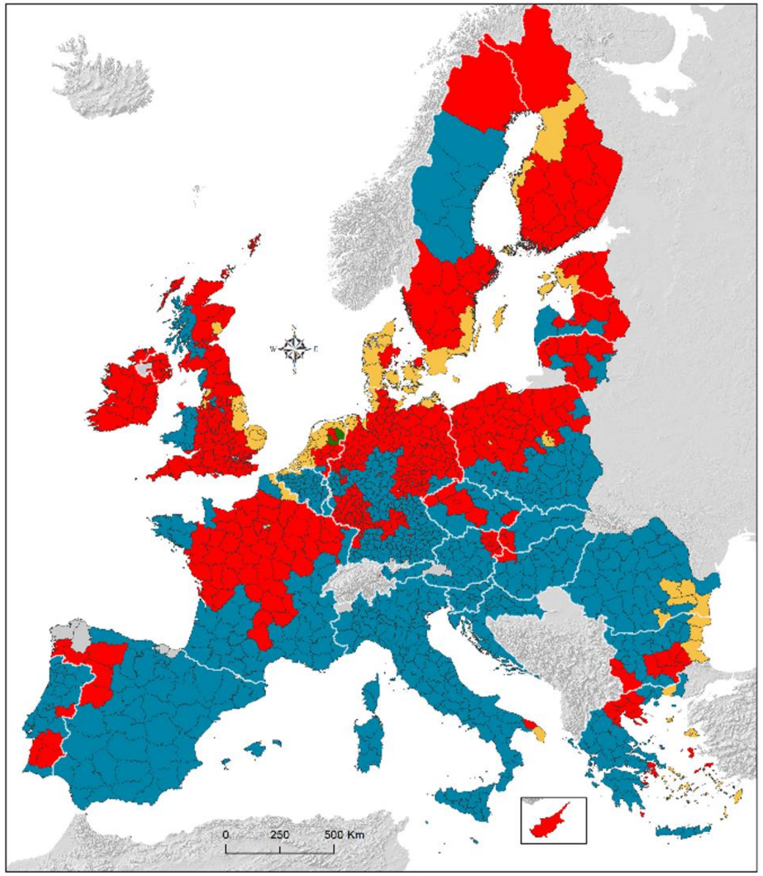
wordclouds.com

The geography of soil erosion looks different when considering multiple processes

In association with:

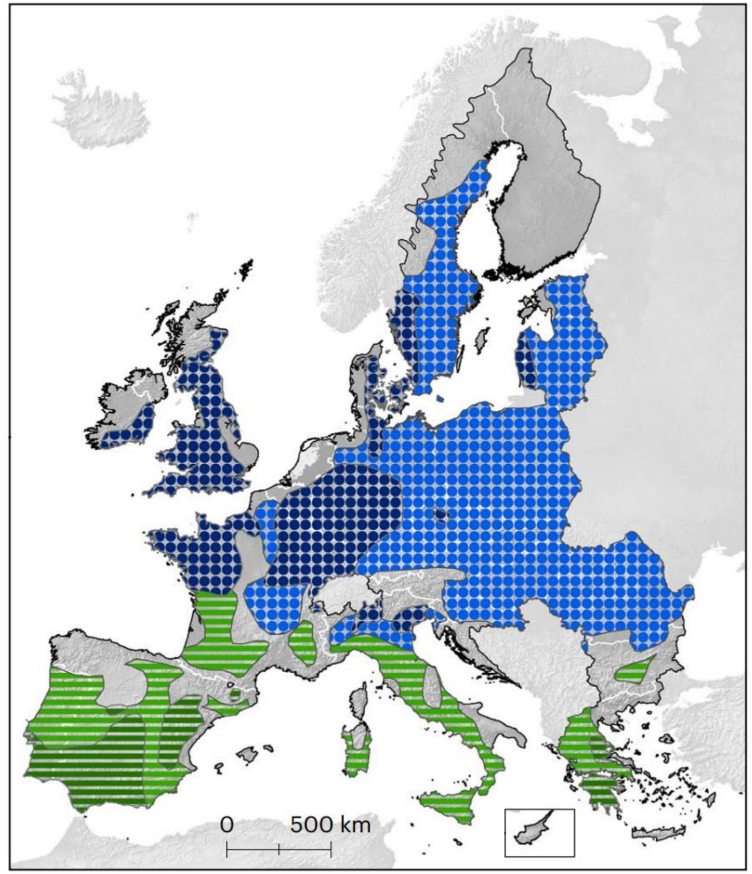
EU SOIL OBSERVATORY
Soil Erosion Working Group

Modelling provides valuable insights into potential future developments



Dominant soil loss process (by cell)

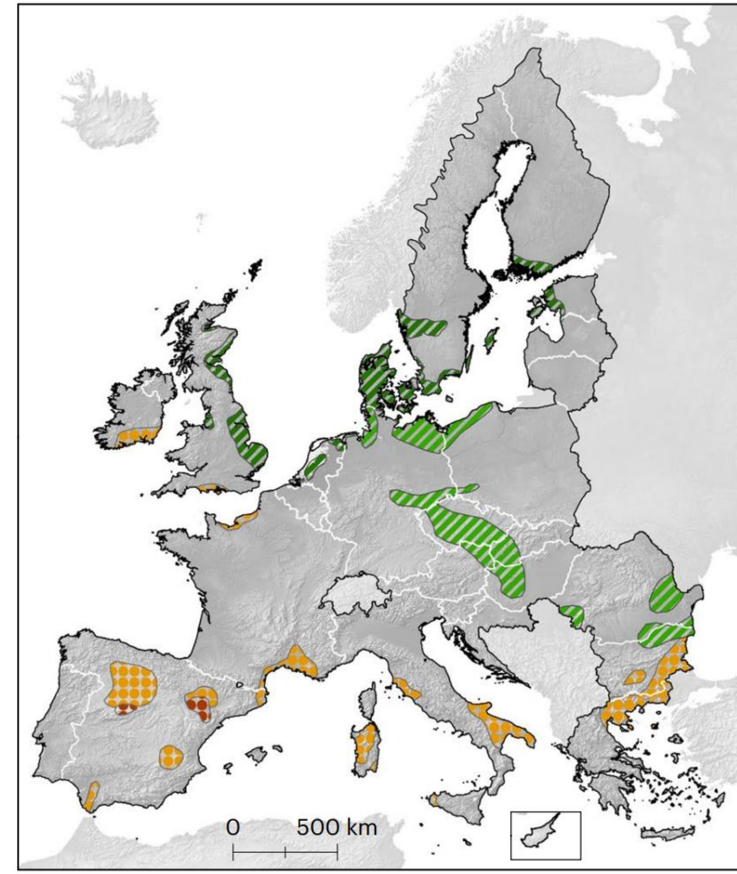
No data | Water | Wind | Tillage | SLCH



Future water erosion vulnerability (WaEV)

Wettest quarter
- WaEV (increasing rain)
- WaEV (decreasing rain)

Driest quarter
- WaEV (decreasing drought)
- WaEV (increasing drought)



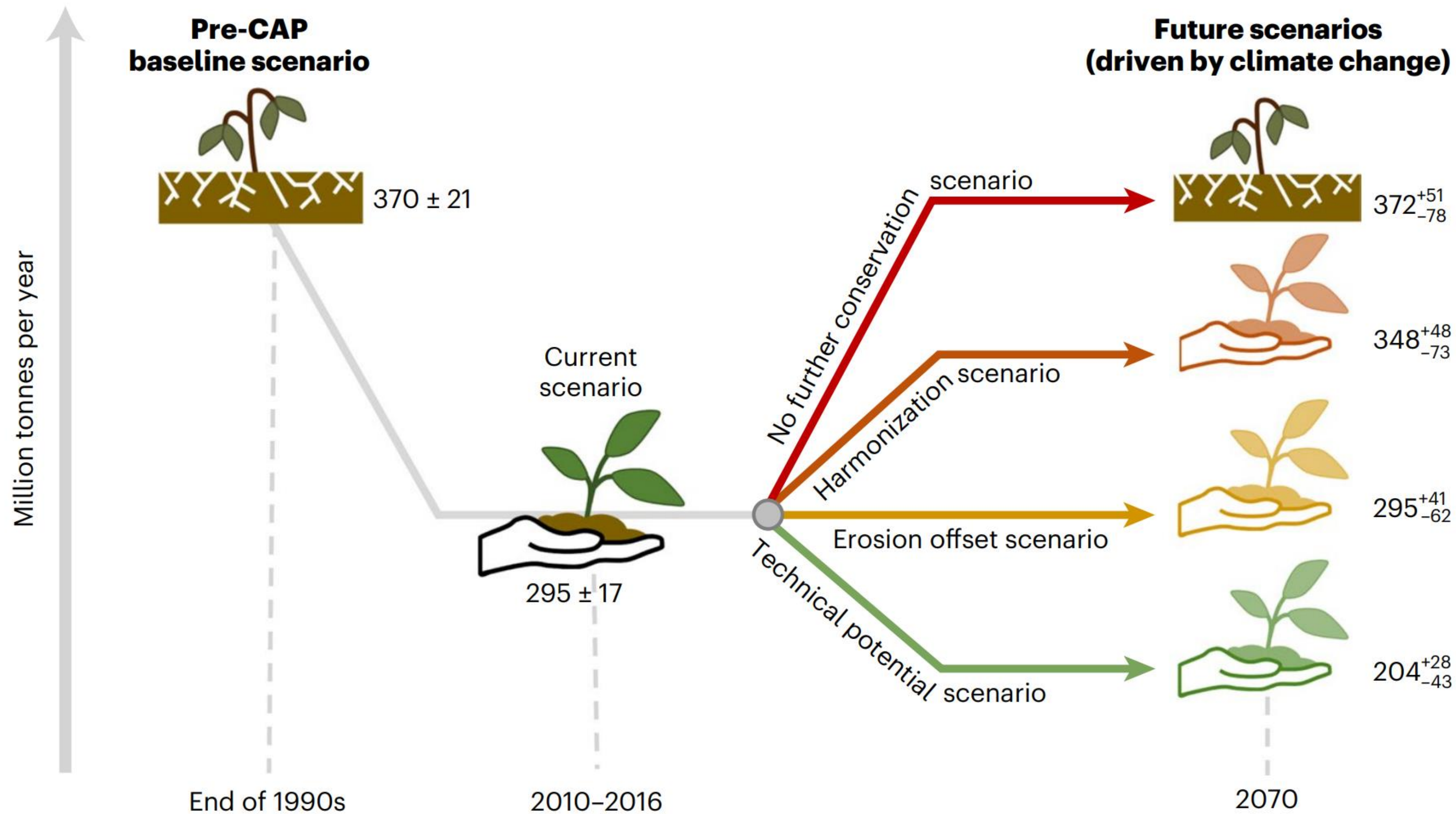
Future wind erosion vulnerability (WiEV)

Wettest quarter
- WiEV (decreasing rain)
- WiEV (increasing rain)

Driest quarter
- WeEV (increasing drought)
- WeEV (decreasing drought)

The modelling approach suggests that compared to the pre-CAP, if we assume no implementation of soil conservation measurements, the EU policy could phonetically reduce soil displacement of a computed:

- -20% water erosion
  - -75 Tg yr^{-1}
- -27% tillage erosion
  - -55 Tg yr^{-1}
- -9% wind erosion
  - -5.3 Tg yr^{-1}



European Commission

JOINT RESEARCH CENTRE

EUROPEAN SOIL DATA CENTRE (ESDAC)

EUROPEAN COMMISSION > JRC > ESDAC

Search | Search

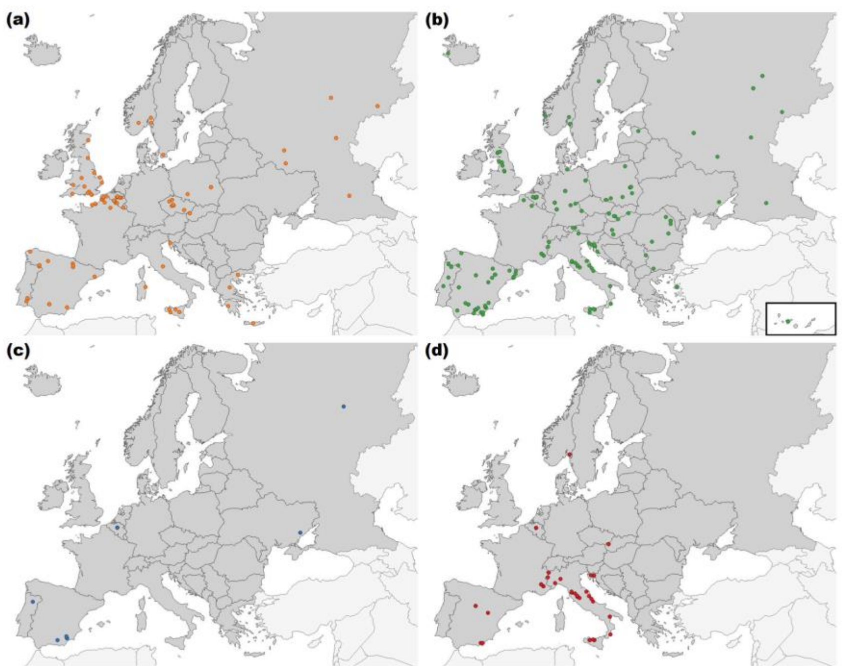
Gully erosion workshop

Date
19/Mar/2018 to 20/Mar/2018

Place
Ispra
Italy

Objective: exchange ideas, proposals, common work and plan an inventory/modeling of gully erosion in Europe

Overview of study areas in Europe



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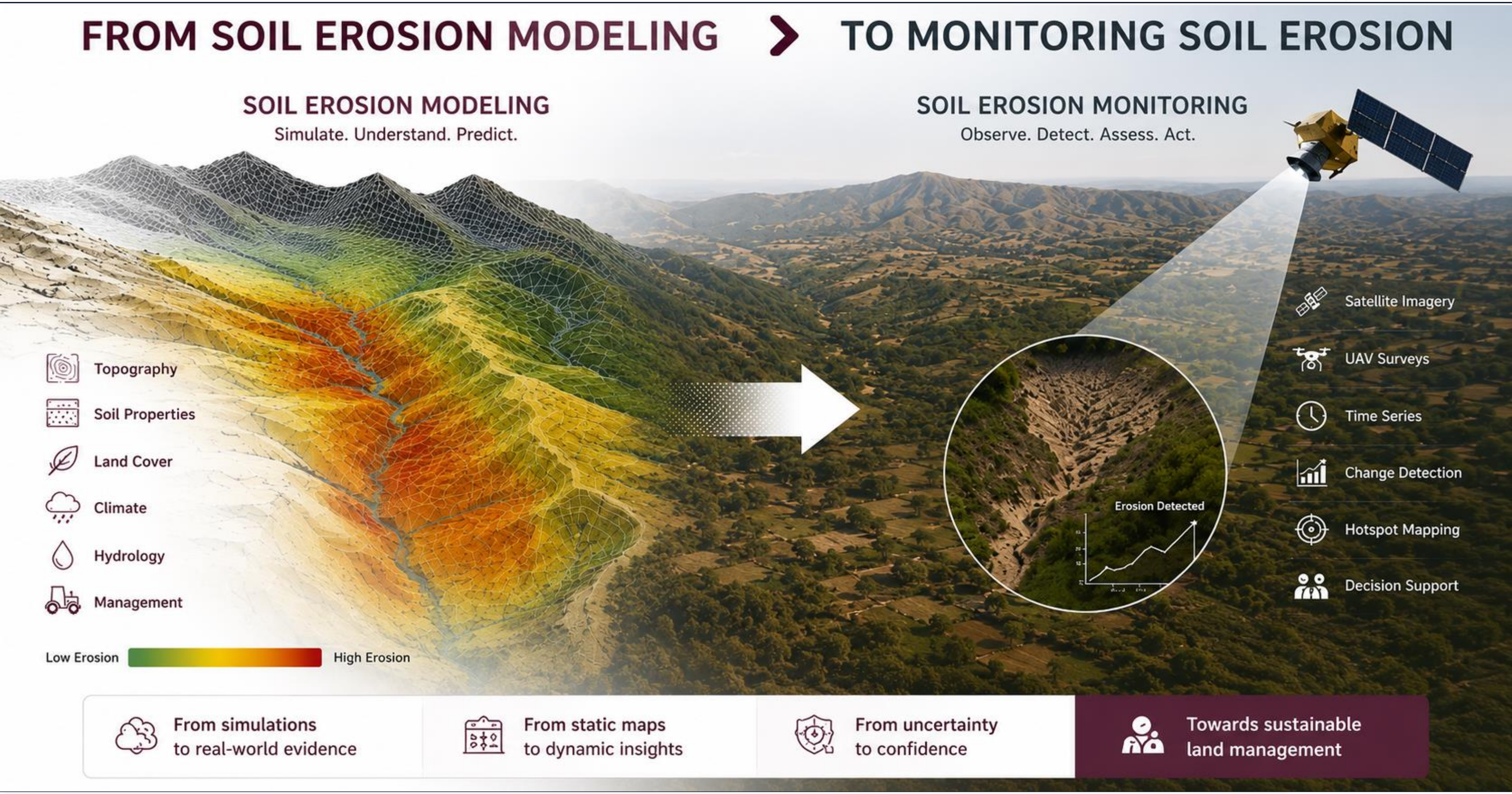
Invited Review

Measuring, modelling and managing gully erosion at large scales: A state of the art

Matthias Vanmaercke[a,b,*], Panos Panagos[c], Tom Vanwalleghem[d], Antonio Hayas[e], Saskia Foerster[f], Pasquale Borrelli[g,h], Mauro Rossi[i], Dino Torri[i], Javier Casali[j], Lorenzo Borselli[k], Olga Vigiak[c], Michael Maerker[l], Nigussie Haregeweyn[m], Sofie De Geeter[a,b], Wojciech Zgłobicki[n], Charles Bielders[o], Artemi Cerdà[p], Christian Conoscenti[q], Tomás de Figueiredo[r], Bob Evans[s], Valentin Golosov[t,u], Ion Ionita[v], Christos Karydas[w], Adam Kertész[x,y], Josef Krása[z], Caroline Le Bouteiller[aa], Maria Radoane[ab], Ratko Ristić[ac], Svetla Rousseva[ad], Milos Stankoviansky[ae], Jannes Stolte[af], Christian Stolz[ag], Rebecca Bartley[ah], Scott Wilkinson[ai], Ben Jarihani[aj,ak], Jean Poesen[b,n]

ROMA TRE UNIVERSITÀ DEGLI STUDI | EU SOIL OBSERVATORY Soil Erosion Working Group | Aroura SOIL SECURITY Think Tank

Vanmaercke et al. (2021) - Earth-Science Reviews 218



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Original Research Article

Monitoring gully erosion in the European Union: A novel approach based on the Land Use/Cover Area frame survey (LUCAS)

Pasquale Borrelli [a, b, *], Jean Poesen [c, d], Matthias Vanmaercke [c, e], Cristiano Ballabio [f], Javier Hervás [f], Michael Maerker [a], Simone Scarpa [f], Panos Panagos [f]

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[b] Department of Biological Environment, Kangwon National University, Chuncheon, 24341, Republic of Korea
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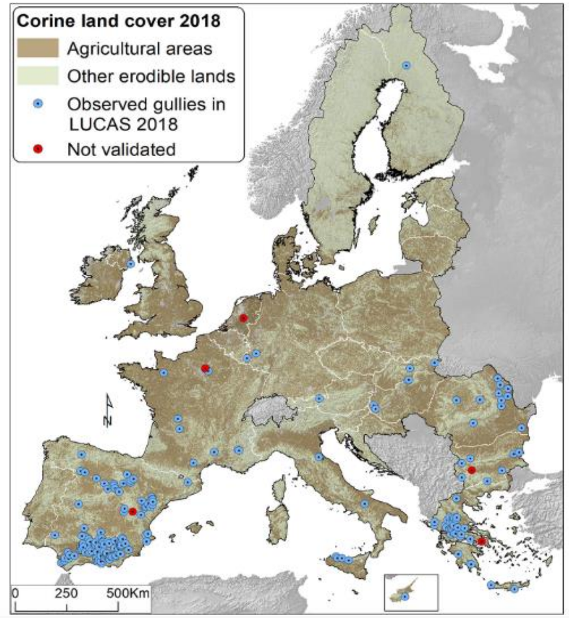
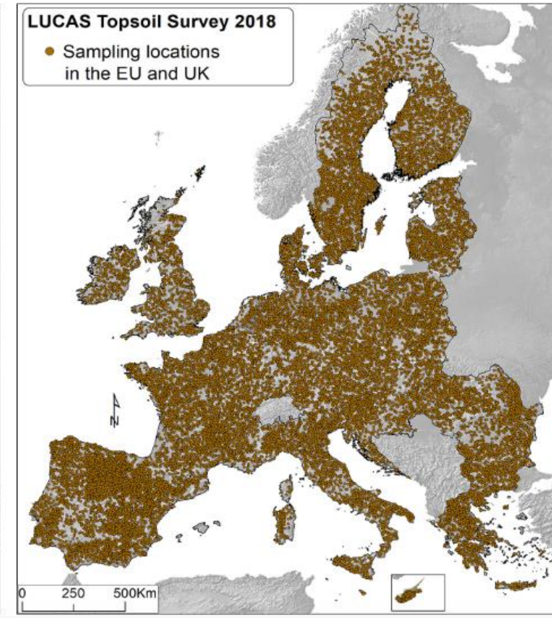
[d] Faculty of Earth Sciences and Spatial Management, Maria-Curie Sklodowska University, Lublin, Poland
[e] Département de Géographie, Université de Liège, Liege, Belgium
[f] European Commission, Joint Research Centre (JRC), Ispra, Italy





Variables included in the LUCAS Topsoil survey 2018.

Property	Type of analysis and units
Physico-chemical properties	Percentage of coarse fragments (>2 mm)
	Particle size distribution (% clay, silt and sand content)
	pH (in CaCl2 and H2O)
	Organic carbon (g/kg)
	Carbonate content (g/kg)
	Phosphorous content (mg/kg)
	Total nitrogen content (g/kg)
	Extractable potassium content (mg/kg)
	Cation exchange capacity (cmol(+)/kg)
	Bulk density (g/cm3)
	Soil moisture (%)
Soil biodiversity	Bacteria and Archaea (16S rRNA)
	Fungi (ITS)
	Eukaryotes (18S rRNA)
	Microfauna (nematodes)
	Mesofauna (arthropods)
	Macrofauna (earthworms)
Field measurements	Soil erosion by water and wind
	Thickness of organic layer in Histosols

Surveyed **24,759** LUCAS Topsoil sites in 2018

(Gully were defined as linear erosion channels with a depth of more than 30 cm)

↓

Walked along a 250m straight line transect (to East) and recorded all gully forms encountered

GE-LUCAS v1.0: Gully erosion survey 2018

Out of 24,759 visited LUCAS Topsoil sites, the surveyors recorded a total of 211 sites with gully erosion channels (ca. 1% of total)

Overall, the majority of observed gully erosion channels were found in Spain (n = 127 sites, 61% of total), especially in the Andalusian region (n = 72 sites, 35% of total).

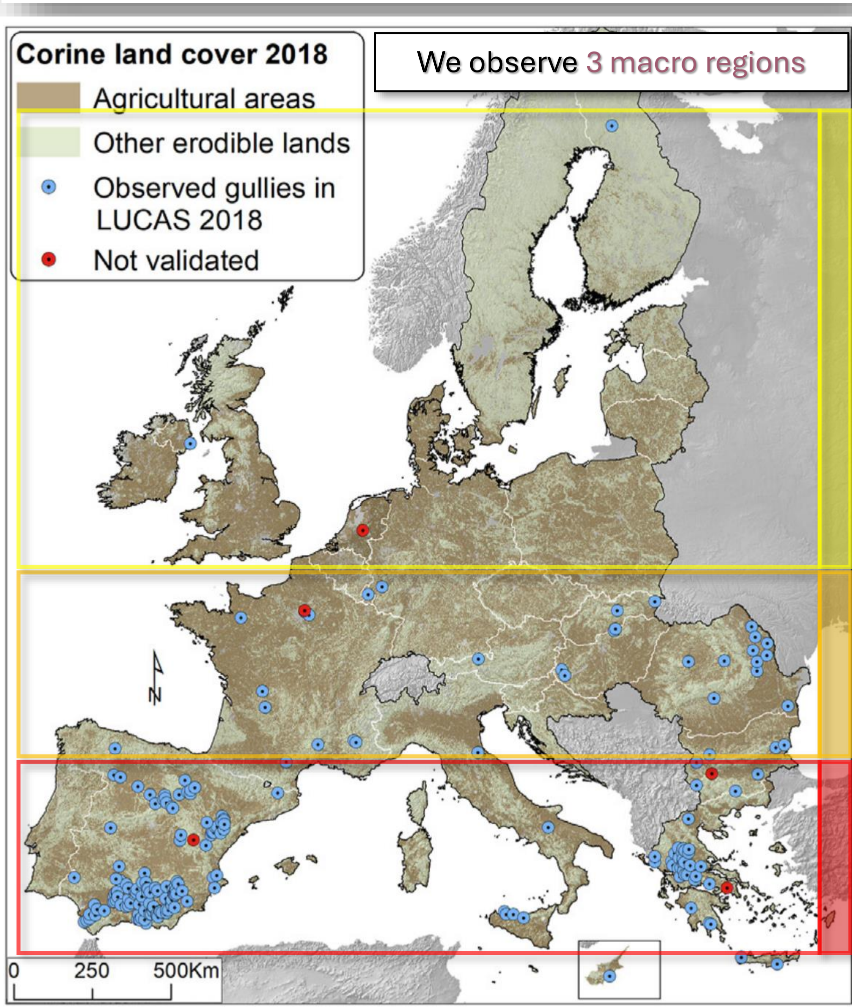


Table 2
Number of sites with gullies aggregated per biogeographical region (EEA, 2020).

Bio-geographical region	Sites with gullies	LUCAS sites [n]	Gully occurrence [%]
Steppic	3	299	1 0.6
Pannonian	4	624	0.6
Mediterranean	168	6669	2.5
Continental	19	7519	0.3
Boreal	1	4213	0
Atlantic	6	3981	0.2
Arctic	0	0	0
Alpine	5	1454	0.3
Total	206	24,759	0.83

Table 3
Number of sites with gullies aggregated per soil textural class

Soil textural	Sites with gullies
Clay	0
Silty Clay	0
Silty Clay-Loam	10
Sandy Clay	0
Sandy Clay-Loam	2
Clay-Loam	49
Silt	0
Silt-Loam	11
Loam	131
Sand	0
Loamy Sand	0
Sandy Loam	3
Total	206

Table 4
Distribution of sites with gullies per land cover category in 2018 LUCAS Topsoil sites.

Land cover	Sites with gullies	LUCAS sites	Gully occurrence [%]
Artificial	0	185	0.00
Cropland	68	9278	0.73
Woodland	58	7069	0.82
Shrubland	34	1001	3.40
Grassland	36	6415	0.56
Bare land	9	719	1.25
Other	1	92	1.09
Total	206	24,759	0.83

Errors:

Commission (false positives, 2.5%)

Omission (false negatives, 5.6%)

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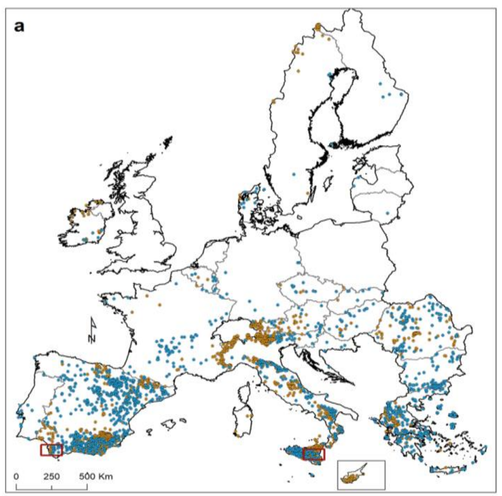
DATA DESCRIPTOR

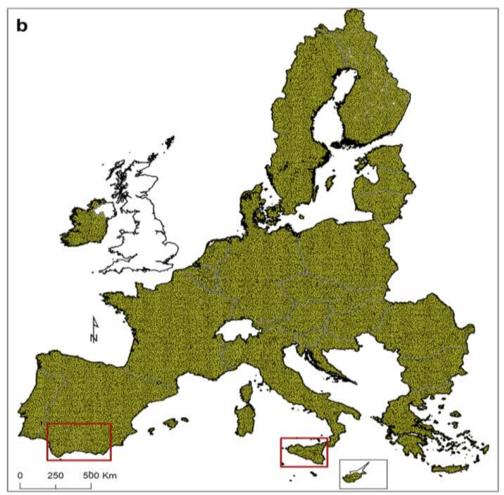
A hybrid *in situ* and on-screen survey to monitor gully erosion across the European Union

Pasquale Borrelli[1,2✉], Francis Matthews[1], Christine Alewell[2], Konstantinos Kaffas[1], Jean Poesen[3,4], Philipp Saggau[1], Remus Prăvălie[5,6,7], Matthias Vanmaercke[3] & Panos Panagos[8✉]

GE-LUCAS v1.1 2022
(200,000 in situ + 200,000 onscreen sites)

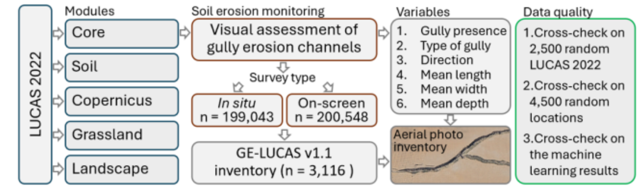


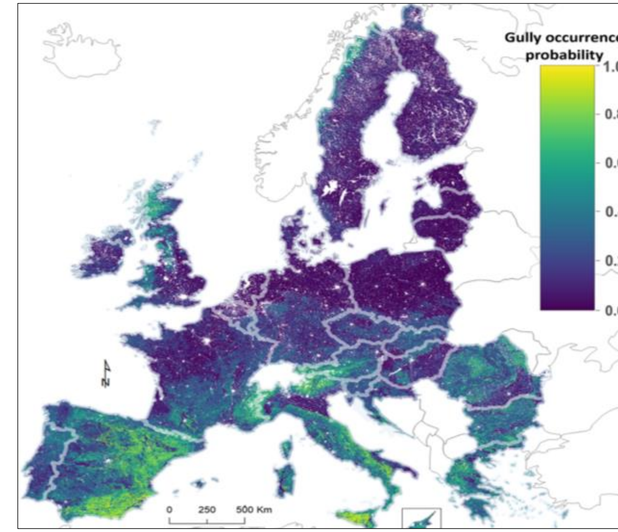
Field and on-screen observed gullies in LUCAS 2022

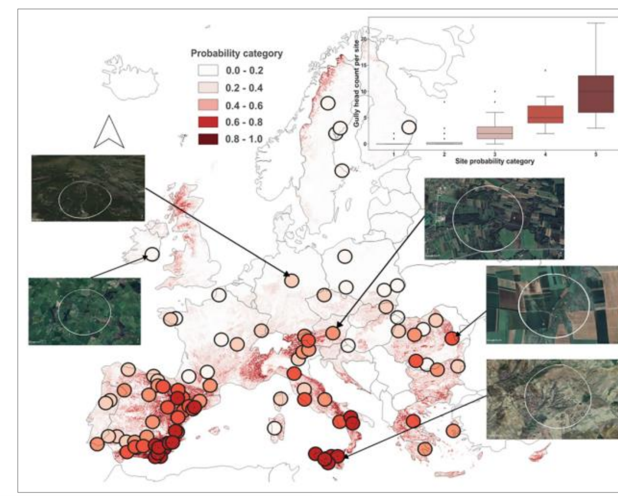


LUCAS 2022 locations in the European Union

LUCAS 2022 ~ US $18,740,000





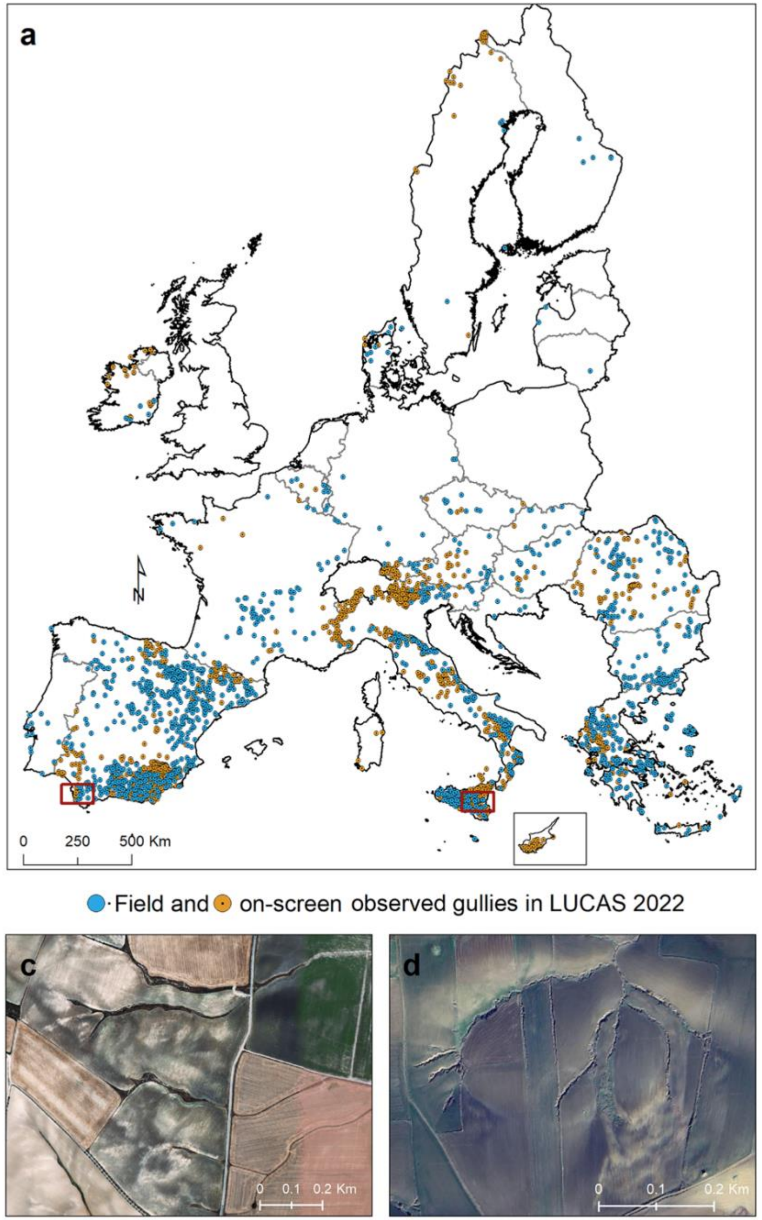


(i) **presence** or absence of gully channels; (ii) **type** of observed gully: ephemeral gully (<0.5 m deep) or permanent gullies (0.5-30 m deep); (iii) **direction** of the gully from the LUCAS point (North, East, South, West); (iv) **mean length** of the gully(m); (v) mean width of the gully in meters; (vi) **mean depth** of the gully in meters.

During the LUCAS 2022 feature detection survey, gully erosion channels were observed at **3,116** out of the **399,591** LUCAS monitored locations, which corresponds to **~0.8%** of the total →

1,649 (**~53%**) were detected via on-screen imagery interpretation

1,467 (**~47%**) were mapped by in situ observations



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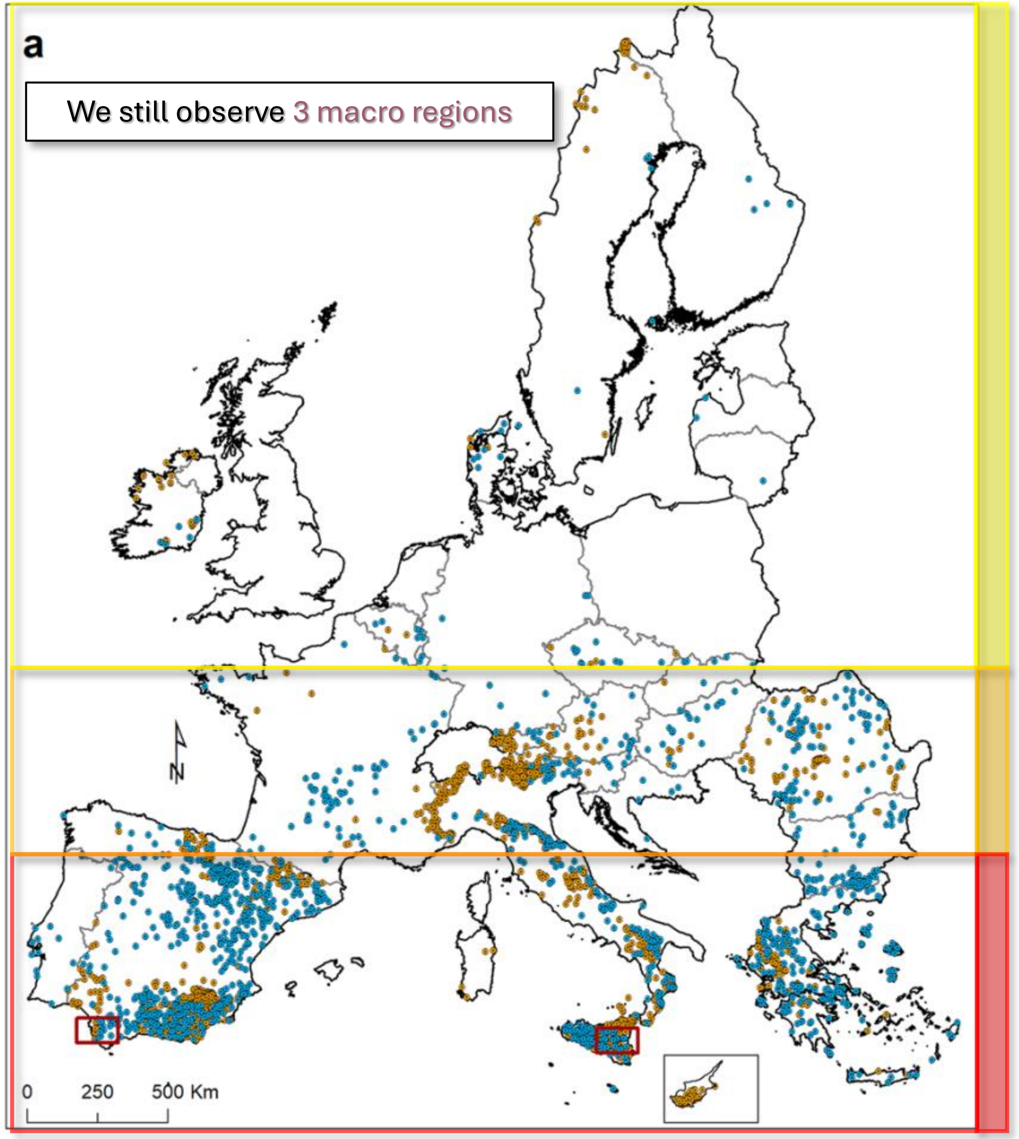


Field and on-screen observed gullies in LUCAS 2022

Bio-geographical region	Locations with gullies	LUCAS locations [n]	Gully occurrence [%]
Alpine	561	35,938	1.56
Atlantic	93	63,070	0.15
Black Sea	3	1,141	0.26
Boreal	14	49,687	0.03
Continental	401	154,195	0.26
Mediterranean	1,998	79,247	2.52
Pannonian	29	12,018	0.24
Steppic	17	4,295	0.40
Total	3,116	399,591	0.78

Table 2. Distribution of LUCAS 2022 sites with gullies by biogeographical region.

Soil texture class	Locations with gullies	LUCAS locations [n]	Gully occurrence [%]
Clay	70	720	9.72
Silty clay	94	1,141	8.24
Silty clay Loam	180	1,6167	1.11
Sandy clay	0	0	0.0
Sandy clay Loam	34	3,284	1.04
Clay loam	777	41,966	1.85
Silt	0	0	0.0
Silt loam	163	54,668	0.30
Loam	1,595	162,732	0.98
Sand	2	3,745	0.05
Total	3,116	399,591	0.78

Table 3. The number of locations with gullies aggregated by USDA soil texture class.

GE-LUCAS v1.1: Gully erosion survey 2022 – Data available online

GE-LUCAS v1.1

Field Name	Options	Database field
LUCAS code	From 26381952 to 65041668	POINT_ID
EU country	27 European Union (EU) Member States	POINT_NUTS
Point latitude	Decimal degrees	POINT_LAT
Point longitude	Decimal degrees	POINT_LONG
Point altitude	Meters	POINT_ALTI
Survey date	Month/Day/Year	SURVEY_DAT
Type of Observation	1 Field survey, point visible, ≤100 m 2 Field survey, point visible, >100 m to point 3 Photo-interpretation in the field 4 Point not visible. PI not possible 5 Out of national territory 6 Out of EU 7 Photo-interpretation in the office	SURVEY_OBS
Land cover (LC1)	A: Artificial Land B: Cropland C: Woodland D: Shrubland E: Grassland F: Bare soil and Lichens G: Water Areas H: Wetlands	SURVEY_LC1
Land use (LU1)	U111 (agriculture): U112 Shrub areas in fallow land: U120 Forestry (Wood production): U140 (Small buildings used for mining and quarrying purposes): U210 (Small buildings used for energy production): U223 (Coal, oil and metal processing purposes): U224 (Production of non-metal mineral goods): U227 (Wood based products): U312 (Road transport on a viaduct): U313 (Bodies of water use for transport): U321 (Water supply and treatment): U361 (Greenhouses of botanical gardens): U370 (Individual residential houses): U411 (Abandoned industrial areas): U415 (Other abandoned areas): U314 (Air transport): U420 (Not used wooded areas)	SURVEY_LU1
Presence of gully	1 Yes 2 No	SURVEY_GUL
Type of gully	1 Ephemeral gully (<0.5 m deep) 2 Permanent gullies (0.5–30 m deep) 3 Badlands (i.e., gullied landscape areas)	SURVEY_G_1
Direction from point	1 North (315-45°) 2 East (45–135°) 3 South (135–225°) 4 West (225–215°)	SURVEY_G_2
Mean length in meters	(1, <1), (2, 1–10), (3, 10–50), (4, 50–100), (5, >100)	SURVEY_G_3
Mean width in meters	(1, <1), (2, 1–5), (3, 5–10), (4, 10–20), (5, >20)	SURVEY_G_4
Mean depth in meters	(1, <0.3), (2, 0.3–1), (3, 1–5), (4, 5–10), (5, >10)	SURVEY_G_5

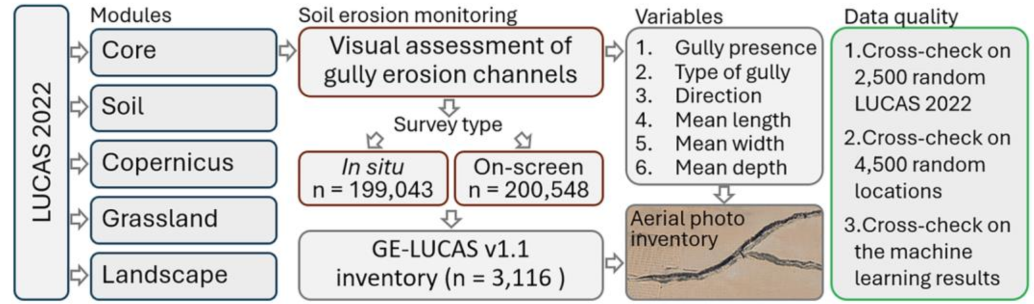
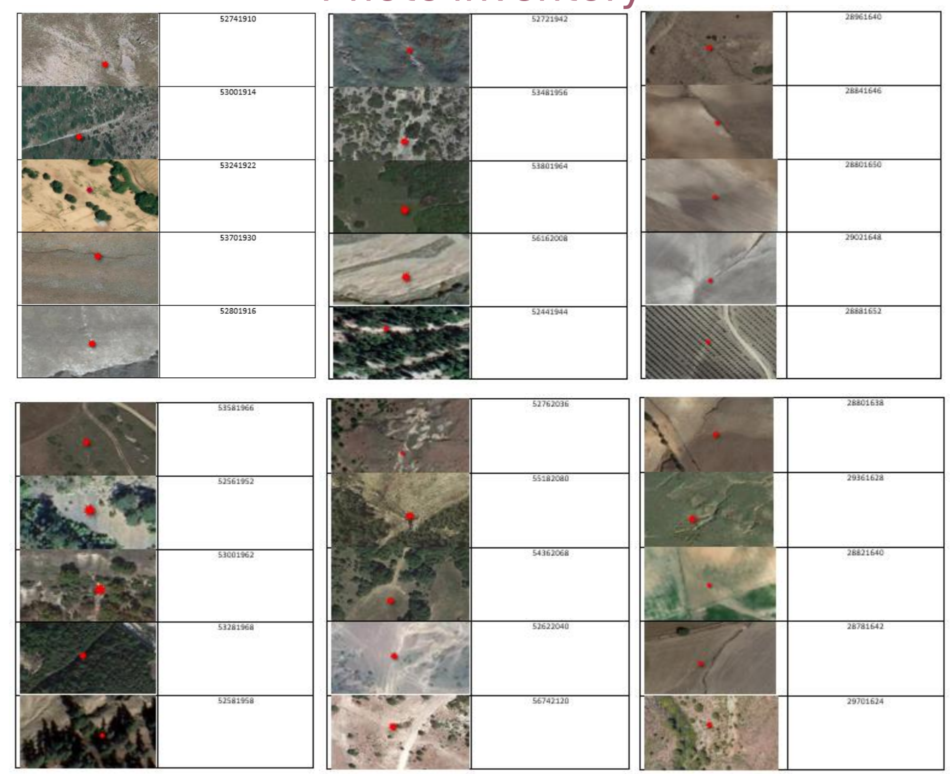
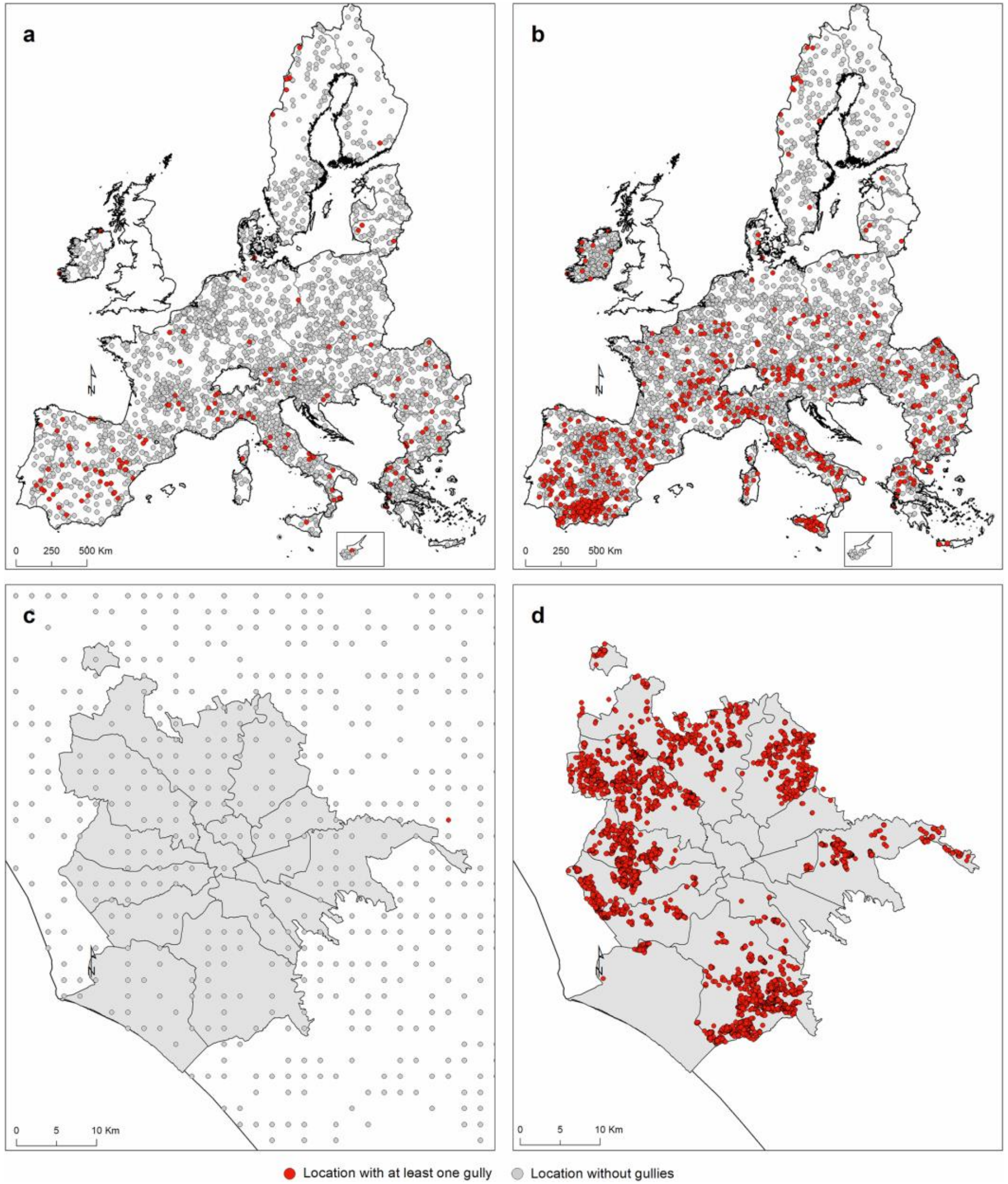


Photo inventory



Funded by the European Union



Cross-checking:

- 1st cross-check on **2,500** randomly selected LUCAS 2022 locations where the surveyors did not report any gully erosion channels.

  [**5.6**% of false negative]

- 2nd cross-check on **4,500** randomly selected locations (~1% of the LUCAS 2022 locations).

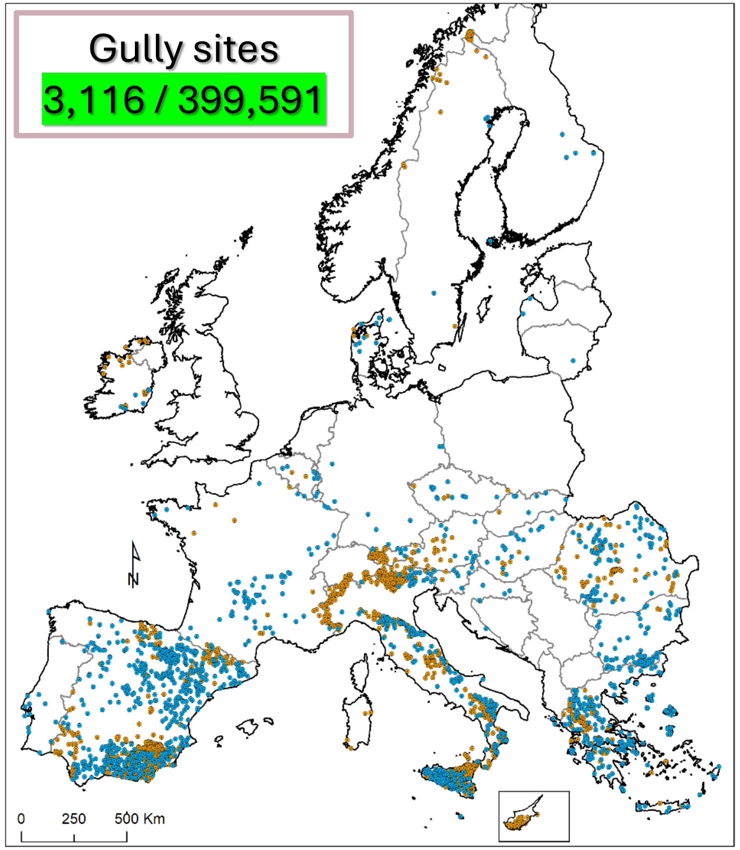
  [n = **605**; ~**13.5**% occurrence]

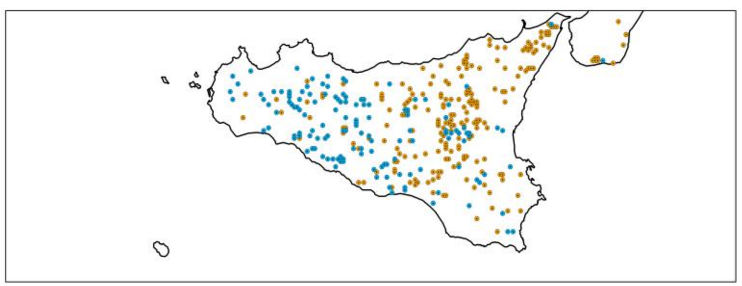
- 3rd cross-check on LUCAS 2022 locations situated around the Municipality of Rome (Central Italy)

  [**0** LUCAS *vs* **6,354** gully features]

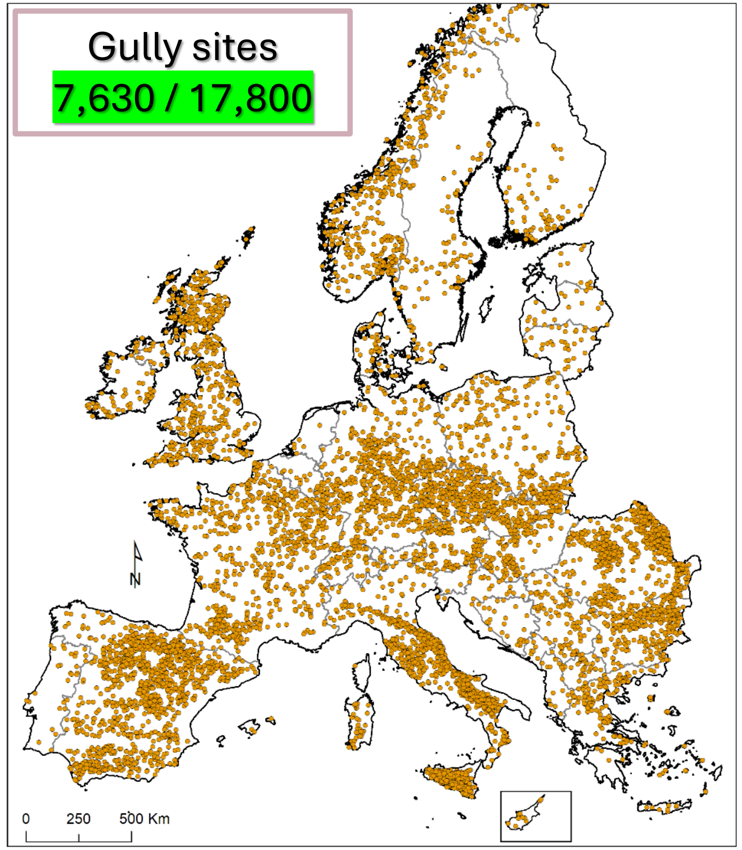
Regular grid GE-LUCAS v1.1 sampling vs stratified Global Initiative

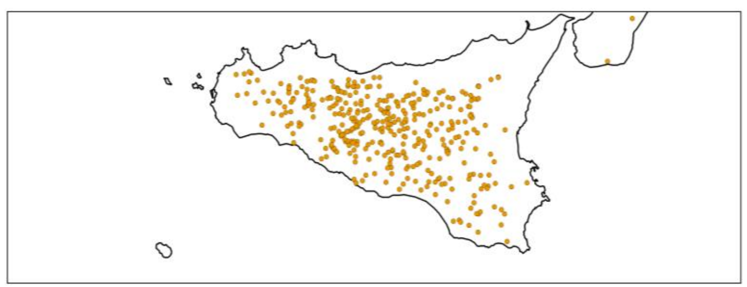
GE-LUCAS

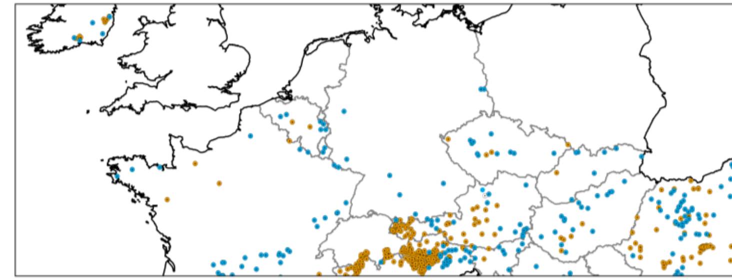


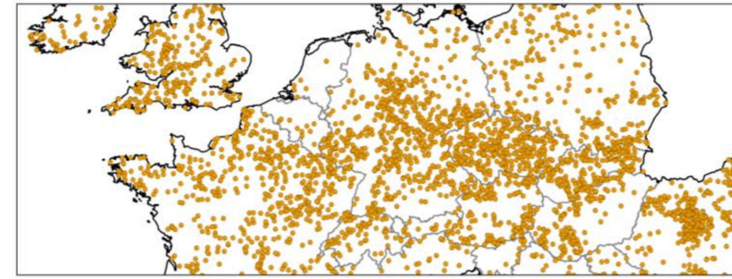


Global Initiative









GLOBAL SOIL EROSION MAPPING INITIATIVE

Borrelli et al. *in progress*

Thank you!

Comment

nature sustainability

https://doi.org/10.1038/s41893-025-01628-3

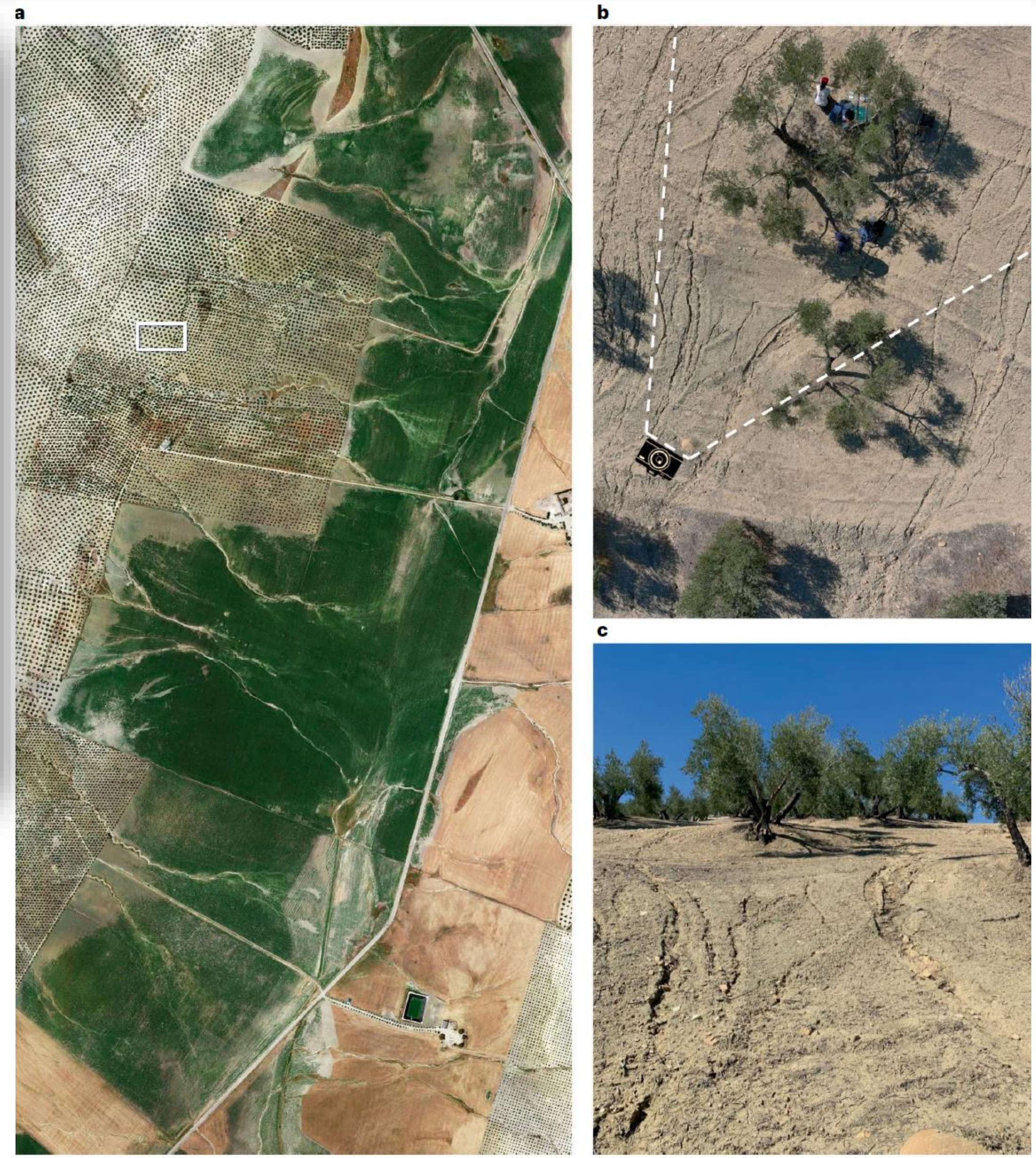
Unsustainably losing ground

Pasquale Borrelli, Francis Matthews, Philipp Saggau, Antonio J. Manzaneda, Panos Panagos, Konstantinos Kaffas & Christine Alewell

Check for updates

Mediterranean olive groves, which have long been symbols of tradition and culinary heritage, now reveal warning signs of rapidly declining soil health across Europe's agricultural landscapes. Driven by intensive farming, climate pressures and policy gaps, accelerating soil loss threatens both ecosystem health and rural livelihoods, signalling a critical need for sustainable soil management and adaptive strategies.

impacts of EU olive production and its derivatives, such as olive oil, serve as a clear example of the complex interplay between policy choices, soil management, market dynamics and climate pressures. The resilience of this system rests on a fragile balance. The cultivation of *Olea europaea* (olive trees) is the most prominent and socioeconomically important of fruit trees in Mediterranean Europe. Domesticated around 5000 BCE, olives remain integral to Mediterranean agroecosystems, producing 70% of global olive oil (~3 million tonnes per year)[7]. In 2024, the EU's approximately 5 million hectares of olive groves (approximately 3% of utilized agricultural area) generated an annual production value of €8.5 billion. In the past five years, growing sustainability threats have affected olive oil-related food security. Andalusia, Spain, the EU's top olive-growing region, producing ~35% of global olive oil, has experienced a 55% yield decline over the past three years owing to rising temperatures and prolonged droughts



Funded by the European Union

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Acknowledgements

This work was funded by the EU's NextGenerationEU instrument through the National Recovery and Resilience Plan of Romania – Pillar III-C9-2022-I8, managed by the Ministry of Research, Innovation and Digitalization, within the project entitled "Complex modelling of multiple land degradation processes in Europe. Towards an integrative scientific framework for sustainable land management across the continent", contract no. 760051/23.05.2023, code CF 216/29.11.2022.