THE 6TH WASWAC World Conference
September 15-17, 2025 | Rabat, Morocco

BorrelliLab

Advancing global soil erosion assessment: Modelling, mapping, hotspots, and resilience strategies

Pasquale Borrelli

WASWAC

ROMA TRE UNIVERSITÀ DEGLI STUDI

ChatGPT

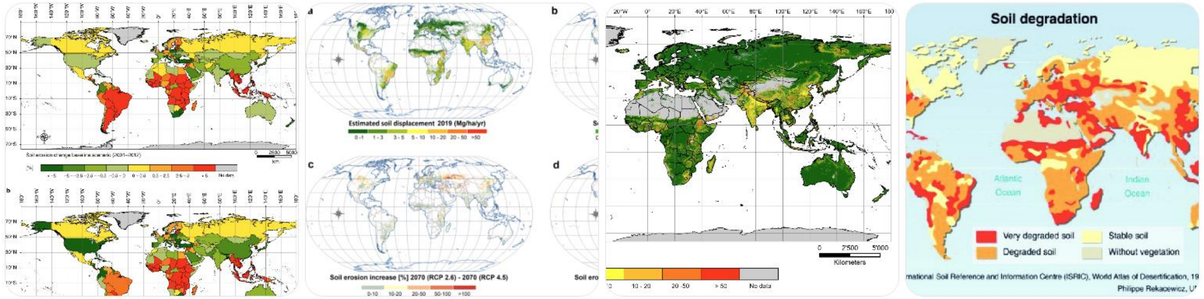
September 2024, GPT-3.5

Can you show me in a map the global geography of soil erosion?

ChatGPT

September 2025, GPT-4-turbo

Please create a map showing the global patterns of water erosion. Use a color gradient from green to red to represent varying levels of land susceptibility to soil erosion, with green indicating low susceptibility and red indicating high susceptibility.



Here's a map (several versions) showing global patterns of water erosion / soil erosion susceptibility, using a color scale from green (low) to red (high). I've included descriptions & key takeaways.

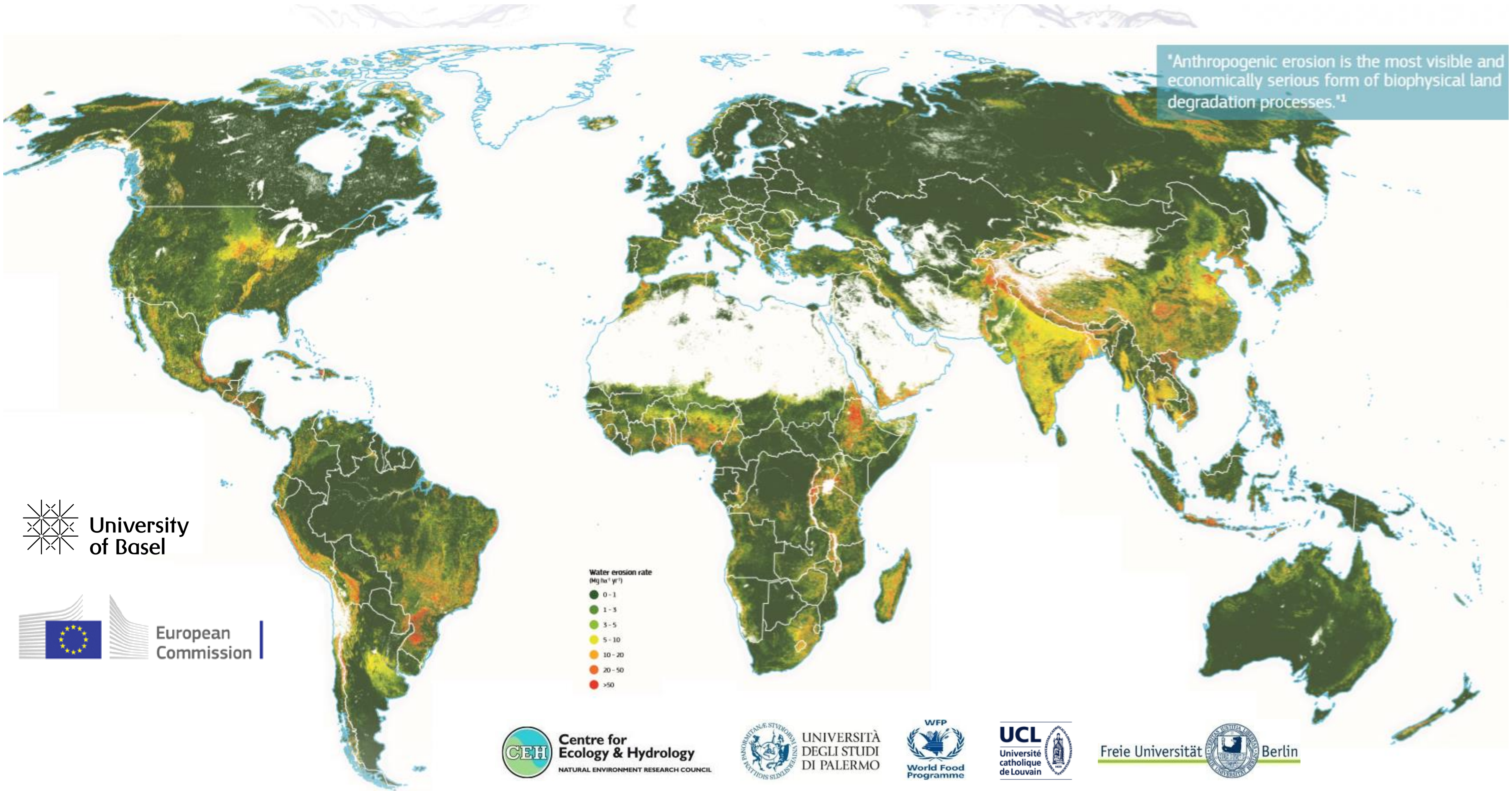
Map Description & Interpretation

These maps draw on global soil erosion models (e.g. GloSEM, RUSLE-based studies) which estimate the susceptibility of land surfaces to erosion by water. The colors indicate levels of soil loss or soil displacement per area per year — green being low, yellow-orange moderate, red high susceptibility.

Limitations & Caveats

- The data is modeled, so in some areas with poor input data (rainfall, soil type, land cover) uncertainty is higher.
- Some maps exclude deserts, ice-covered areas, bare rock, or places with no soil cover. Thus large red or green zones may miss these gaps.
- Human land management (e.g. terracing, conservation agriculture) can reduce actual erosion vs what raw susceptibility suggests.
- Temporal variation: the risk changes with climate change (rainfall patterns) and with land use change.

We began to understand global soil erosion patterns



University of Basel

European Commission

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

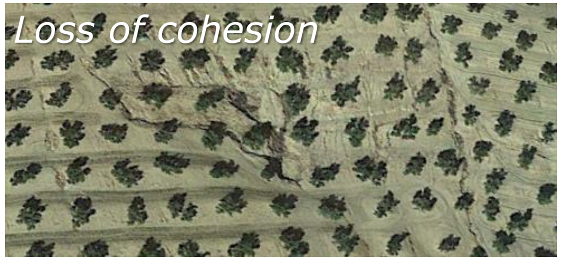
UNIVERSITÀ DEGLI STUDI DI PALERMO

WFP World Food Programme

UCL Université catholique de Louvain

Freie Universität Berlin

GloSEM enabled us to begin exploring the soil-land-water nexus



nature COMMUNICATIONS

An assessment of the global impact of 21st century land use change on soil erosion

Pasquale Borrelli[1,2], David A. Robinson[3], Larissa R. Fleischer[4], Emanuele Lugato[2], Cristiano Ballabio[2], Christine Alewell[1], Katrin Meusburger[1], Sirio Modugno[5], Brigitta Schütt[6], Vito Ferro[7], Vincenzo Bagarello[8], Kristof Van Oost[9], Luca Montanarella[2] & Panos Panagos[2]

nature COMMUNICATIONS

Global phosphorus shortage will be aggravated by soil erosion

Christine Alewell[1], Bruno Ringeval[2], Cristiano Ballabio[3], David A. Robinson[4], Panos Panagos[3] & Pasquale Borrelli[1,5]

ARTICLE nature https://doi.org/10.1038/s41586-019-1111-9

Mapping the world's free-flowing rivers

G. Grill[1*], B. Lehner[1*], M. Thieme[2], B. Geenen[3], D. Tickner[4], F. Antonelli[5], S. Babu[6], P. Borrelli[7,8], L. Cheng[9], H. Crochetiere[10], H. Ehalt Macedo[1], R. Filgueiras[11,36], M. Goichot[12], J. Higgins[13], Z. Hogan[14], B. Lip[15], M. E. McClain[16,17], J. Meng[18,19], M. Mulligan[20], C. Nilsson[21,22], J. D. Olden[23], J. J. Opperman[2], P. Petry[24,25], C. Reidy Liermann[26], L. Sáenz[27,28], S. Salinas-Rodriguez[29], P. Schelle[30], R. J. P. Schmitt[31], J. Snider[10], F. Tan[1], K. Tockner[32,33,37], P. H. Valdujo[34], A. van Soesbergen[20] & C. Zarfl[35]

Global Change Biology

PRIMARY RESEARCH ARTICLE

Global forest restoration opportunities to foster coral reef conservation

Andrés F. Suárez-Castro, Hawthorne L. Beyer, Caitlin D. Kuempel, Simon Linke, Pasquale Borrelli, Ove Hoegh-Guldberg

PNAS Proceedings of the National Academy of Sciences of the United States of America

Land use and climate change impacts on global soil erosion by water (2015-2070)

Pasquale Borrelli[a,b,1], David A. Robinson[c], Panos Panagos[d], Jae E. Yang[b], Christine Alewell[a], David Wuepper[e], Luca Montanarella[d], and Cristiano Ballabio[d]

Conservation Biology

CONTRIBUTED PAPERS | Open Access

Retaining natural vegetation to safeguard biodiversity and humanity

Jeremy S. Simmonds, Andres Felipe Suarez-Castro, April E. Reside, James E. M. Watson, James R. Allan, Scott C. Atkinson, Pasquale Borrelli, Nigel Dudley, Stephen Edwards, Richard A. Fuller ... See all authors

nature sustainability ANALYSIS https://doi.org/10.1038/s41893-019-0438-4

Countries and the global rate of soil erosion

David Wuepper[1*], Pasquale Borrelli[2] and Robert Finger[1]

nature communications

Article https://doi.org/10.1038/s41467-023-38043-1

Projected landscape-scale repercussions of global action for climate and biodiversity protection

Received: 10 March 2023

Accepted: 13 April 2023

Published online: 16 May 2023

Check for updates

Patrick José von Jeetze[1,2], Isabelle Weindl[1], Justin Andrew Johnson[3], Pasquale Borrelli[4,5], Panos Panagos[6], Edna J. Molina Bacca[1,2], Kristine Karstens[1,2], Florian Humpenöder[1], Jan Philipp Dietrich[1], Sara Minoli[1], Christoph Müller[1], Hermann Lotze-Campen[1,2] & Alexander Popp[1]

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

Check for updates

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]

Global Change Biology

PERSPECTIVE | Open Access

A 'debt' based approach to land degradation as an indicator of global change

David Wuepper, Pasquale Borrelli, Panos Panagos, Thomas Lauber, Thomas Crowther, Amy Thomas, David A. Robinson

Up to data, 19 studies based on GloSEM


nature sustainability

nature portfolio

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]


Contents lists available at ScienceDirect

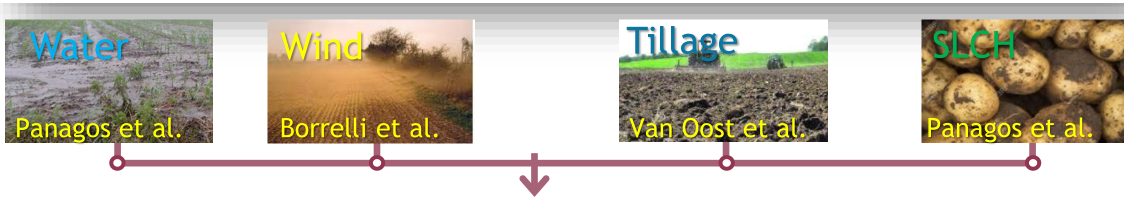
International Soil and Water Conservation Research

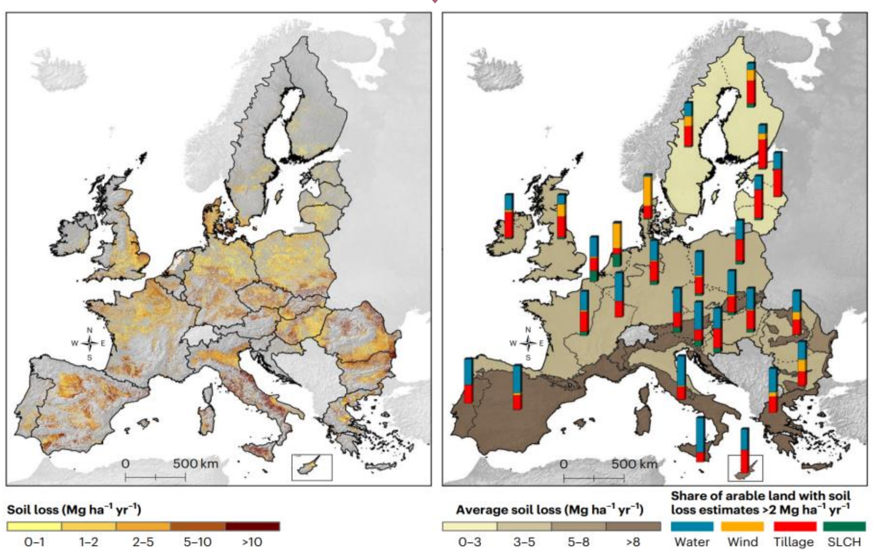
journal homepage: www.elsevier.com/locate/iswcr

Original Research Article

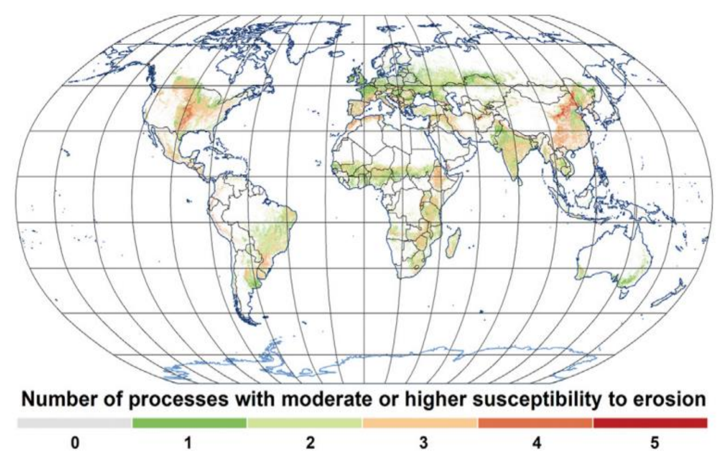
Towards a better understanding of pathways of multiple co-occurring erosion processes on global cropland

Pasquale Borrelli[a,b,c,*], Christine Alewell[a], Jae E. Yang[b], Nejc Bezak[d], Yixian Chen[e], Ayele Almaw Fenta[f], Arthur Nicolaus Fendrich[g,h,i], Surya Gupta[a], Francis Matthews[e,g], Sirio Modugno[j,k], Nigussie Haregeweyn[f], David A. Robinson[l], Florence Tan[e], Matthias Vanmaercke[e], Gert Verstraeten[e], Diana C.S. Vieira[g], Panos Panagos[g]

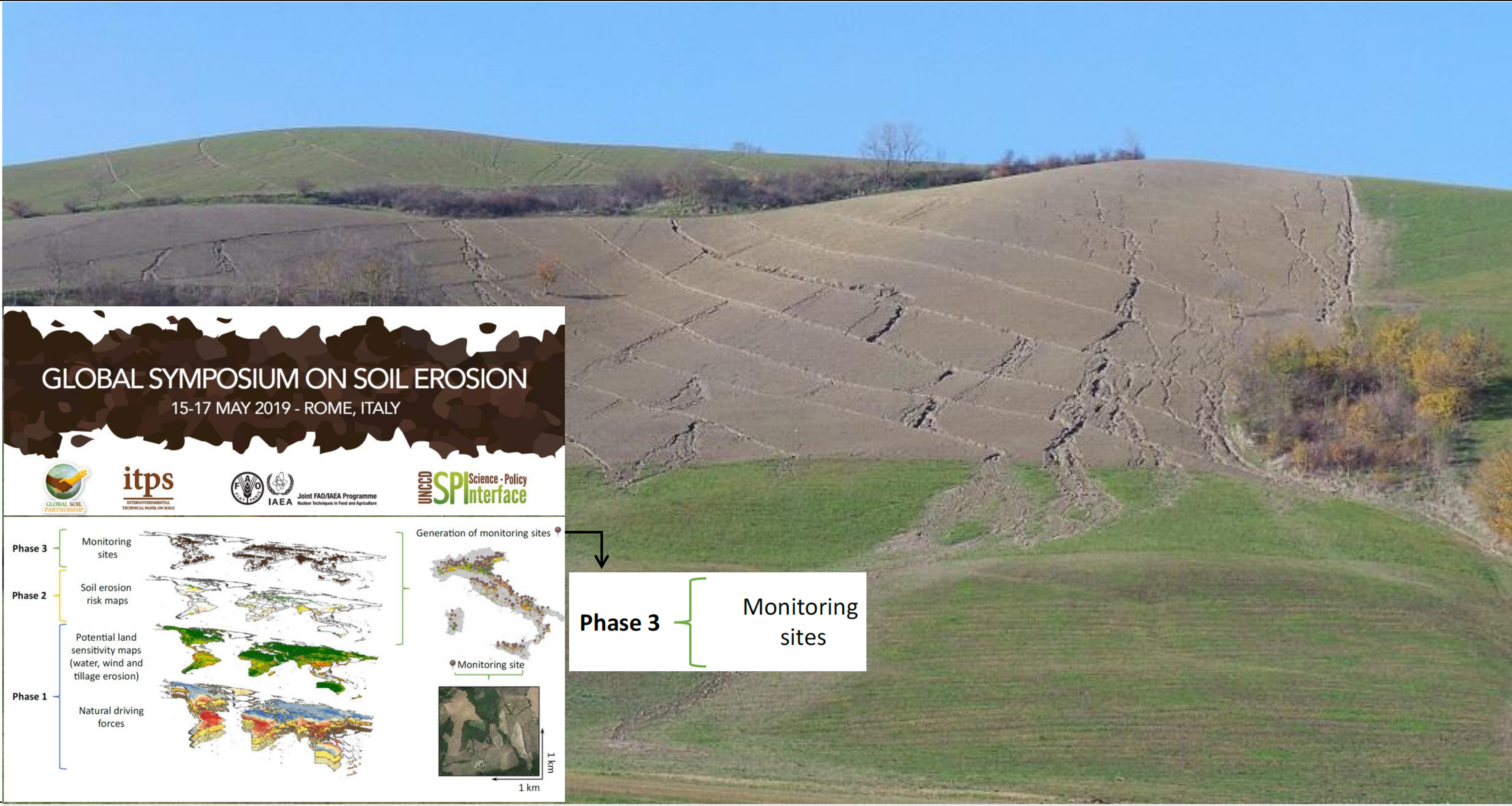




GloSEM



Where can we innovate next?



Phase 3 – Monitoring sites

JOINT RESEARCH CENTRE

EUROPEAN SOIL DATA CENTRE (ESDAC)

European Commission

EUROPEAN COMMISSION > JRC > ESDAC

Search | Search

Home About Us Newsletters Atlases Events Vacancies

Ispra (Italy) 20-22 March 2017

Soil erosion modelling workshop

67 soil-erosion scientists from **25 countries**

8471 articles identified as potentially relevant, we reviewed **1697 appropriate articles**

credits: www.wordclouds.com

Contents lists available at ScienceDirect

Science of the Total Environment

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

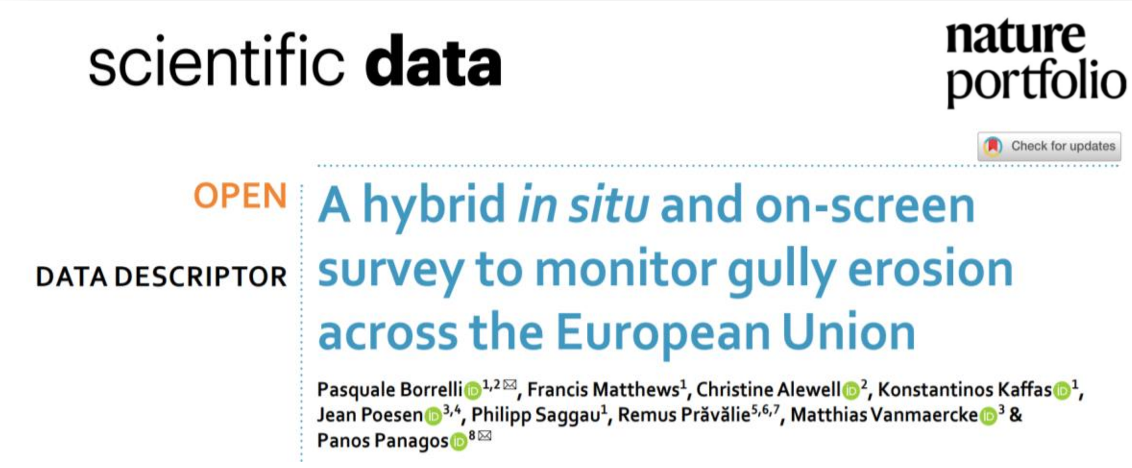
ELSEVIER

Review

Soil erosion modelling: A global review and statistical analysis

Pasquale Borrelli [a,b,c,*], Christine Alewell [b], Pablo Alvarez [d,e], Jamil Alexandre Ayach Anache [f,g], Jantiene Baartman [h], Cristiano Ballabio [i], Nejc Bezak [j], Marcella Biddoccu [k], Artemi Cerdà [l], Devraj Chalise [m], Songchao Chen [n], Walter Chen [o], Anna Maria De Girolamo [p], Gizaw Desta Gessesse [q], Detlef Deumlich [r], Nazzareno Diodato [s], Nikolaos Efthimiou [t], Gunay Erpul [u], Peter Fiener [v], Michele Freppaz [w], Francesco Gentile [x], Andreas Gericke [y], Nigussie Haregeweyn [z], Bifeng Hu [aa,ab], Amelie Jeanneau [ac], Konstantinos Kaffas [ad], Mahboobeh Kiani-Harchegani [ae], Ivan Lizaga Villuendas [af], Changjia Li [ag,ah], Luigi Lombardo [ai], Manuel López-Vicente [aj], Manuel Esteban Lucas-Borja [ak], Michael Märker [a], Francis Matthews [i], Chiyuan Miao [ag], Matjaž Mikoš [j], Sirio Modugno [al,am], Markus Möller [an], Victoria Naipal [ao], Mark Nearing [ap], Stephen Owusu [aq], Dinesh Panday [ar], Edouard Patault [as], Cristian Valeriu Patriche [at], Laura Poggio [au], Raquel Portes [av], Laura Quijano [aw], Mohammad Reza Rahdari [ax], Mohammed Renima [ay], Giovanni Francesco Ricci [x], Jesús Rodrigo-Comino [l,az], Sergio Saia [ba], Aliakbar Nazari Samani [bb], Calogero Schillaci [bc], Vasileios Syrris [i], Hyuck Soo Kim [c], Diogo Noses Spinola [bd], Paulo Tarso Oliveira [g], Hongfen Teng [be], Resham Thapa [bf], Konstantinos Vantas [bg], Diana Vieira [bh], Jae E. Yang [c], Shuiqing Yin [ag], Demetrio Antonio Zema [bi], Guangju Zhao [bj], Panos Panagos [i,**]

Inspired by the LUCAS survey


scientific data

nature portfolio

Check for updates

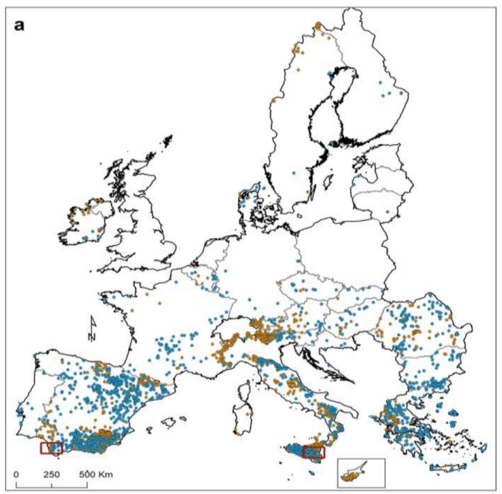
OPEN

DATA DESCRIPTOR

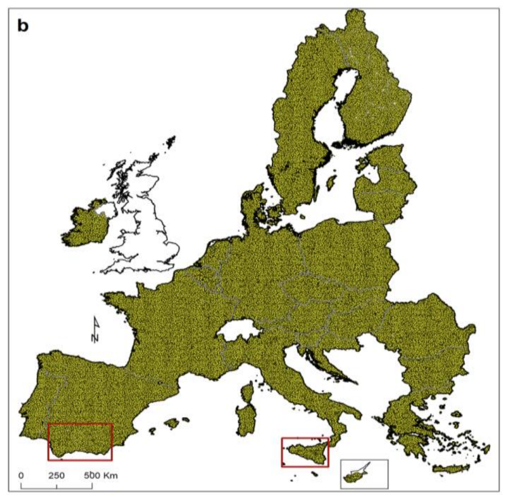
A hybrid *in situ* and on-screen survey to monitor gully erosion across the European Union

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)

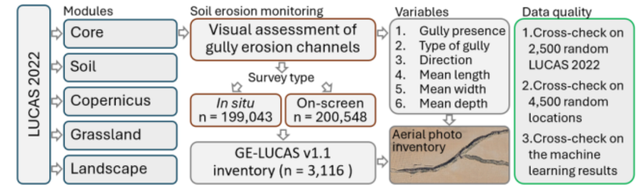


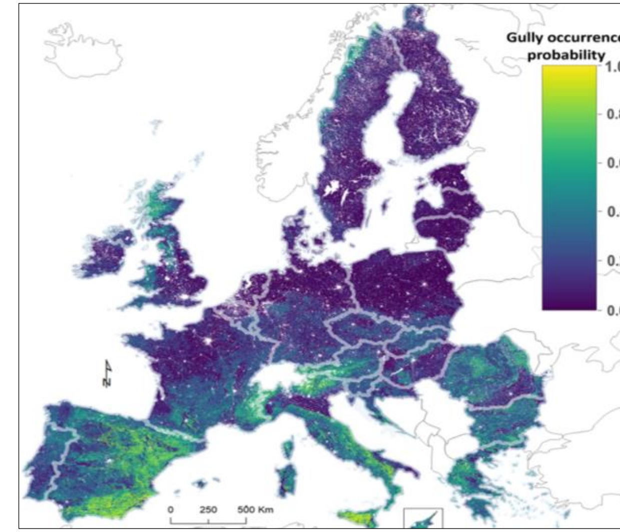
Field and on-screen observed gullies in LUCAS 2022

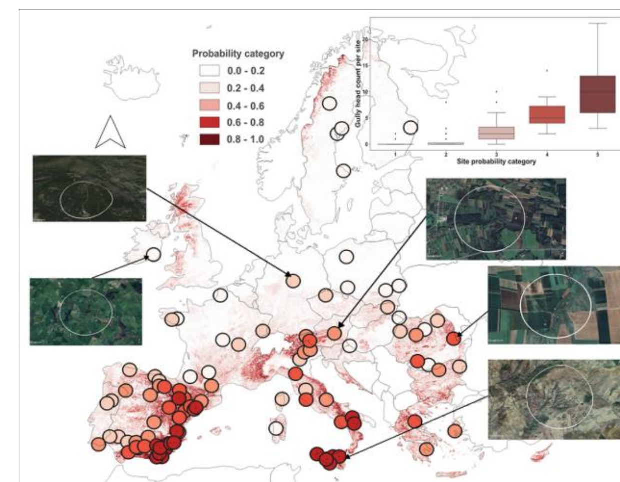


LUCAS 2022 locations in the European Union

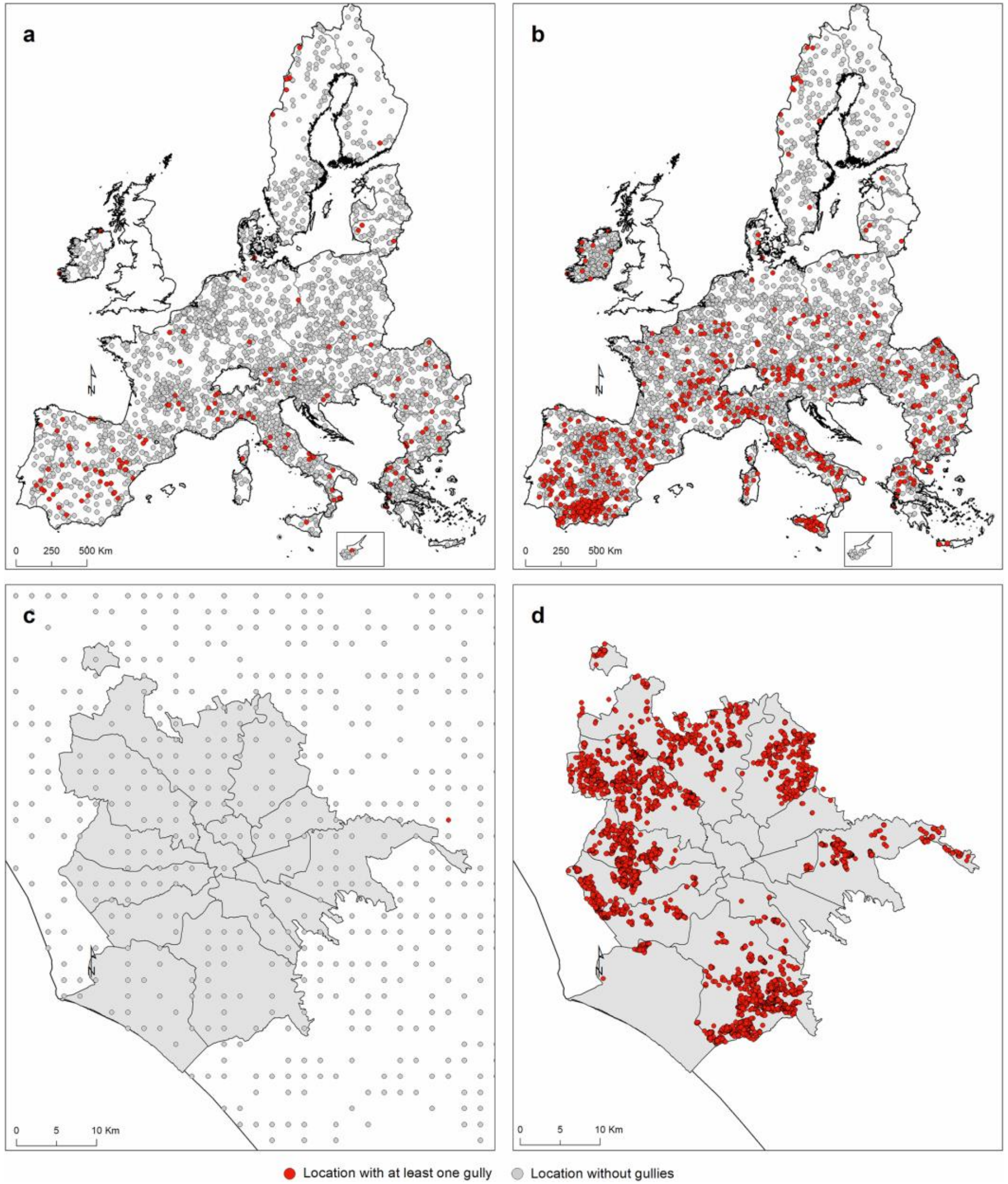
LUCAS 2022 ~ US $18,740,000

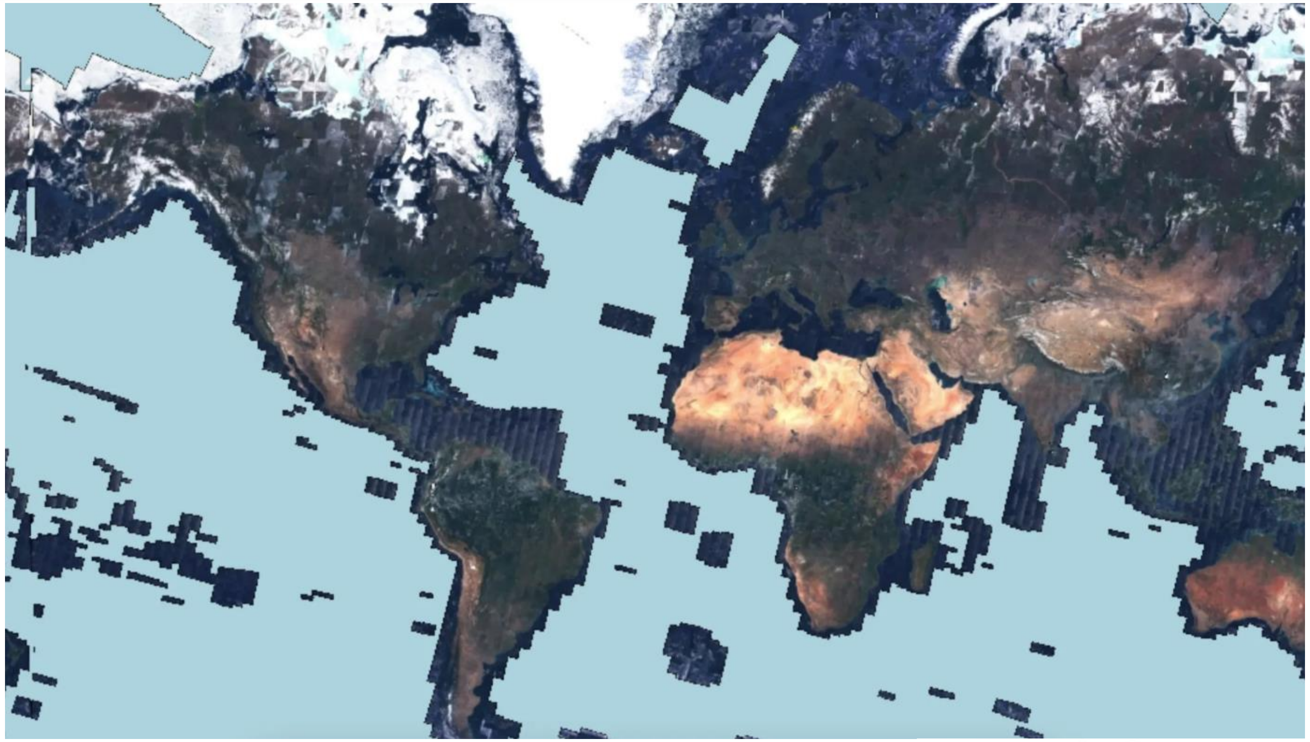






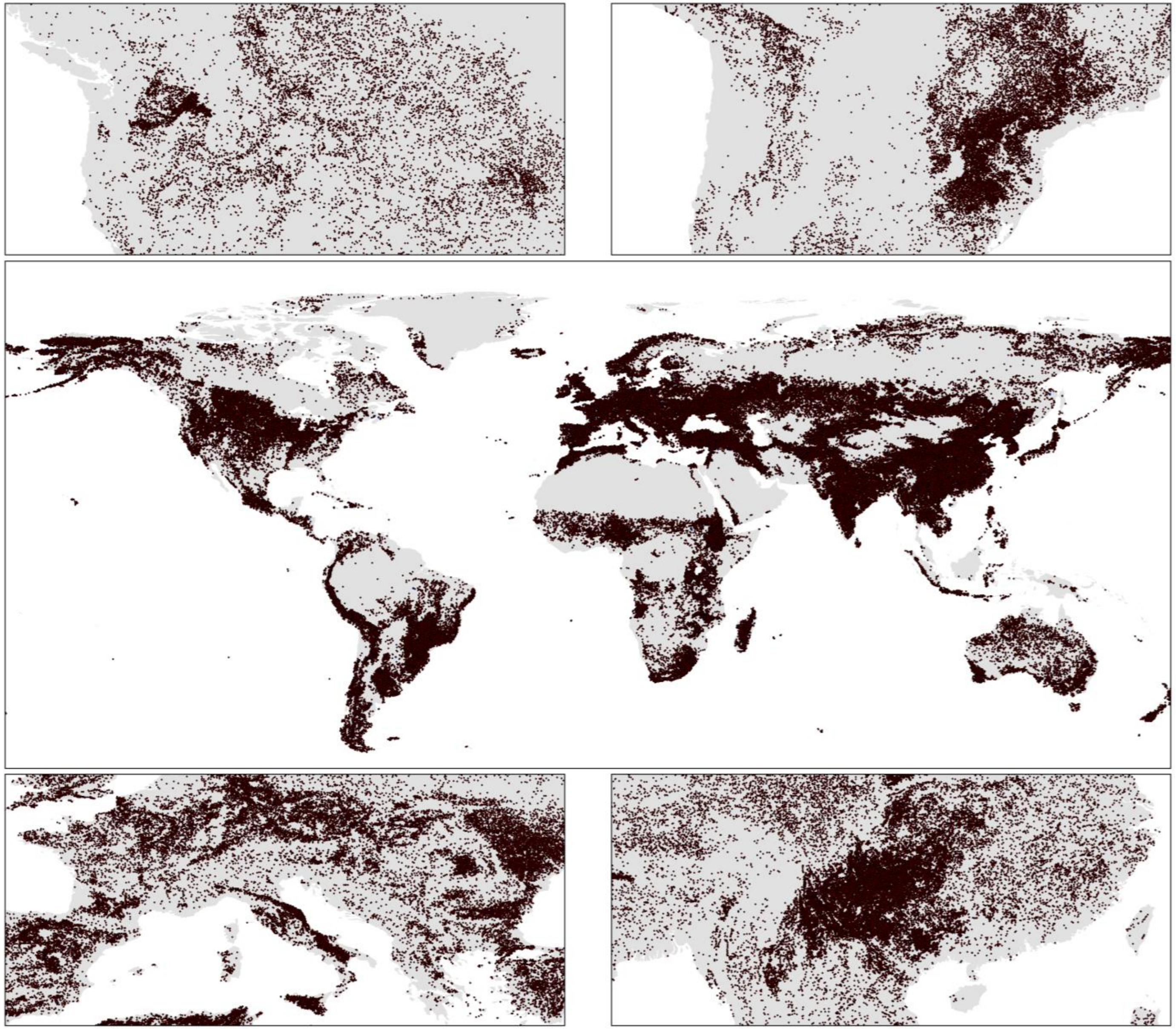
Learning from past lessons, powered by cutting-edge global computation



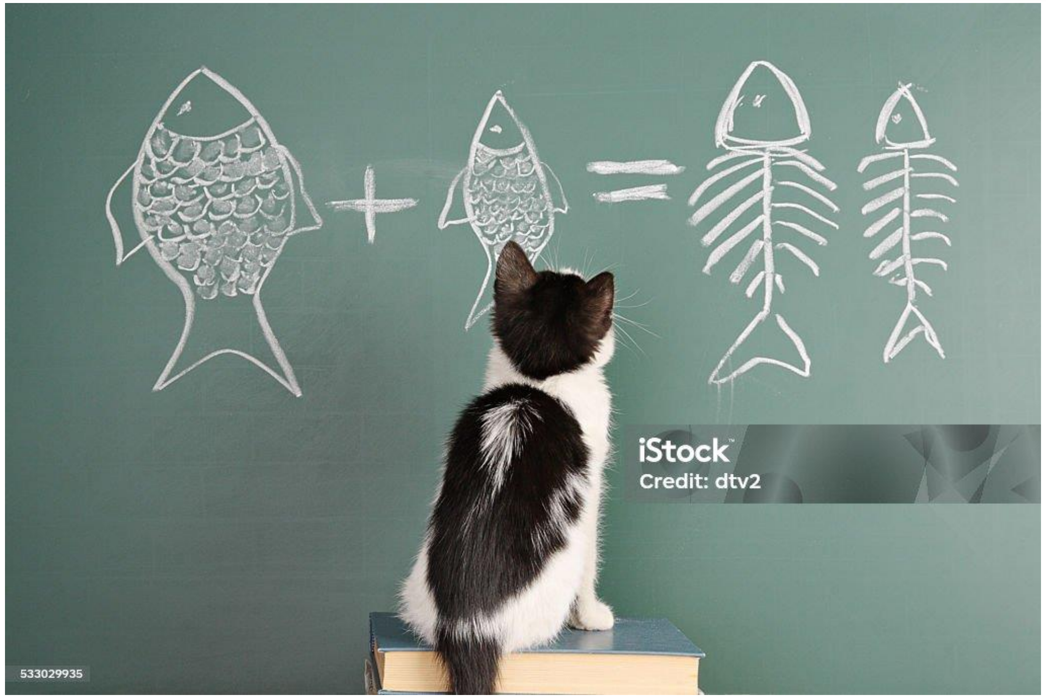


Google Earth Engine

Although the LUCAS 2022 survey reports **1 gully erosion channels in Rome, extensive mapping** efforts identified a total of **6,354 gully features** (i.e., gully heads).



- **Long-Term Research Initiative Overview**
- We're starting a 2–5-year joint effort aiming at mapping 1,000,000 sites.
- **Stage 1: Completion by December 2025**
  - Target: **300,000 sites**
  - Mapping box: **~340x340m**
  - Outcomes: **2** peer-reviewed publications planned for early 2026

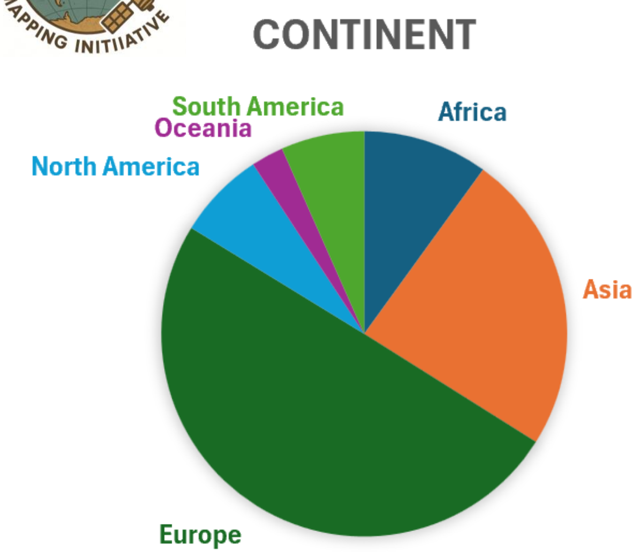


I can map around ~100 sites per day. How many days would it take to map 300,000 sites for Stage 1?

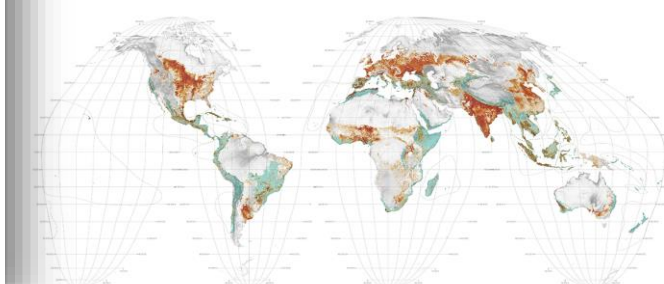
300,000 / 100 = 3,000 days = ~ 14 years

(220 day per year)

Participants: 300 scientists and counting



Global Croplands (80%) and Grassland (20%)



Country	Number
Spain	26
Italy	25
China	21
Germany	16
USA	15
Brazil	13
Iran	13
India	12
Belgium	9
Morocco	8
Poland	8
Australia	7
Greece	7
Ethiopia	6
France	6
South Kore	6
Portugal	5
Romania	5
Türkiye	5
UK	5
Serbia	4
Slovenia	4
Canada	3
Hungary	3
Switzerlan	3
Algeria	2
Czech Rep	2

Country	Number
Ecuador	2
Pakistan	2
Rwanda	2
Slovakia	2
South Afric	2
Sri Lanka	2
Argentina	1
Colombia	1
Democrati	1
Georgia	1
Ghana	1
Japan	1
Lithuania	1
Malta	1
Nairobi	1
Nepal	1
Nigeria	1
Panamá	1
Peru	1
Senegal	1
Sweden	1
Tunisia	1
Turkey	1
UAE	1
Ukraine	1
Zambia	1

It is now ongoing

BorrelliLab

1

Global Soil Erosion Mapping Initiative

Geospatial Mapping Guideline

v1.6

(September 2025)

Contact: pasquale.borrelli@uniroma3.it

BorrelliLab

Supporting organization LOGO

10

The overall pool of sites, from which the final sites were selected using a random stratified approach, is as follows:

Available sites (300m cells)

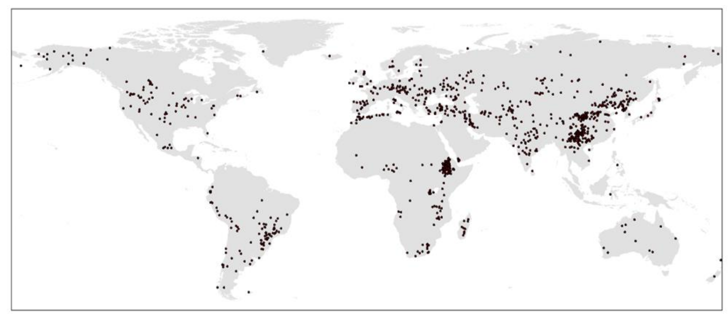
Slope	Crop 50-75%	Crop >75%	Grass 50-75%	Grass >75%	
Slope Class 1	34,988,551	114,957,399	73,082,928	218,177,804	
Slope Class 2	5,976,627	9,385,412	18,650,891	45,586,828	
Slope Class 3	2,706,103	2,290,572	14,494,019	34,248,616	
Slope Class 4	606,706	318,437	7,359,387	16,721,113	
Slope Class 5	167,919	69,250	4,024,651	8,787,849	
Slope Class 6	102,505	33,099	8,244,690	16,185,391	*Sites*
Total	44,548,411	127,054,169	125,856,566	339,707,601	637,166,747

First random subset (300m cells)

Slope	Crop 50-75%	Crop >75%	Grass 50-75%	Grass >75%	
Slope Class 1	2,000,000	2,000,000	2,000,000	2,000,000	
Slope Class 2	2,000,000	2,000,000	2,000,000	2,000,000	
Slope Class 3	2,000,000	2,000,000	2,000,000	2,000,000	
Slope Class 4	606,706	318,437	2,000,000	2,000,000	
Slope Class 5	167,919	69,250	2,000,000	2,000,000	
Slope Class 6	102,505	33,099	2,000,000	2,000,000	*Sites*
Total	6,877,130	6,420,786	12,000,000	12,000,000	37,297,916

Second random subset (300m cells)

Slope	Crop 50-75%	Crop >75%	Grass 50-75%	Grass >75%	
Slope Class 1	4,800	19,200	4,800	1,200	
Slope Class 2	9,600	38,400	9,600	2,400	
Slope Class 3	9,600	38,400	9,600	2,400	
Slope Class 4	9,600	38,400	9,600	2,400	
Slope Class 5	9,600	38,400	9,600	2,400	
Slope Class 6	4,800	19,200	4,800	1,200	*Sites*
Total	48,000	192,000	48,000	12,000	300,000



Contact: pasquale.borrelli@uniroma3.it

BorrelliLab

Supporting organization LOGO

Mapping gullies

Mapping terraces and badlands

GLOBAL SOIL EROSION MAPPING INITIATIVE

340 m

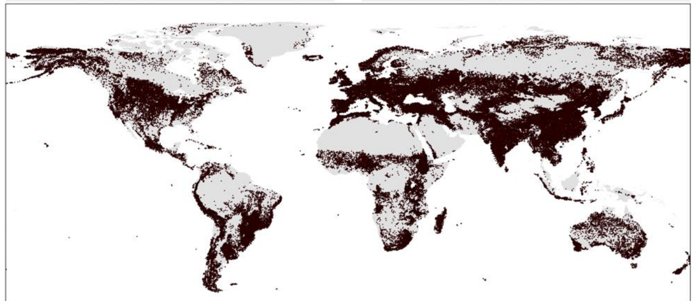
Preliminary results

Based on my 1,000 sites:

- **Features present at** 547 out of 1,000 sites
- **Total individual features identified:** 3,182
  - **Gullies:** 2,974
  - **Terraces:** 208

The stratified random sample is a strength of the research

This is just 1 out of 300 parts



Just published, September 9th 2025 on Nature Portfolio

Comment

nature sustainability

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

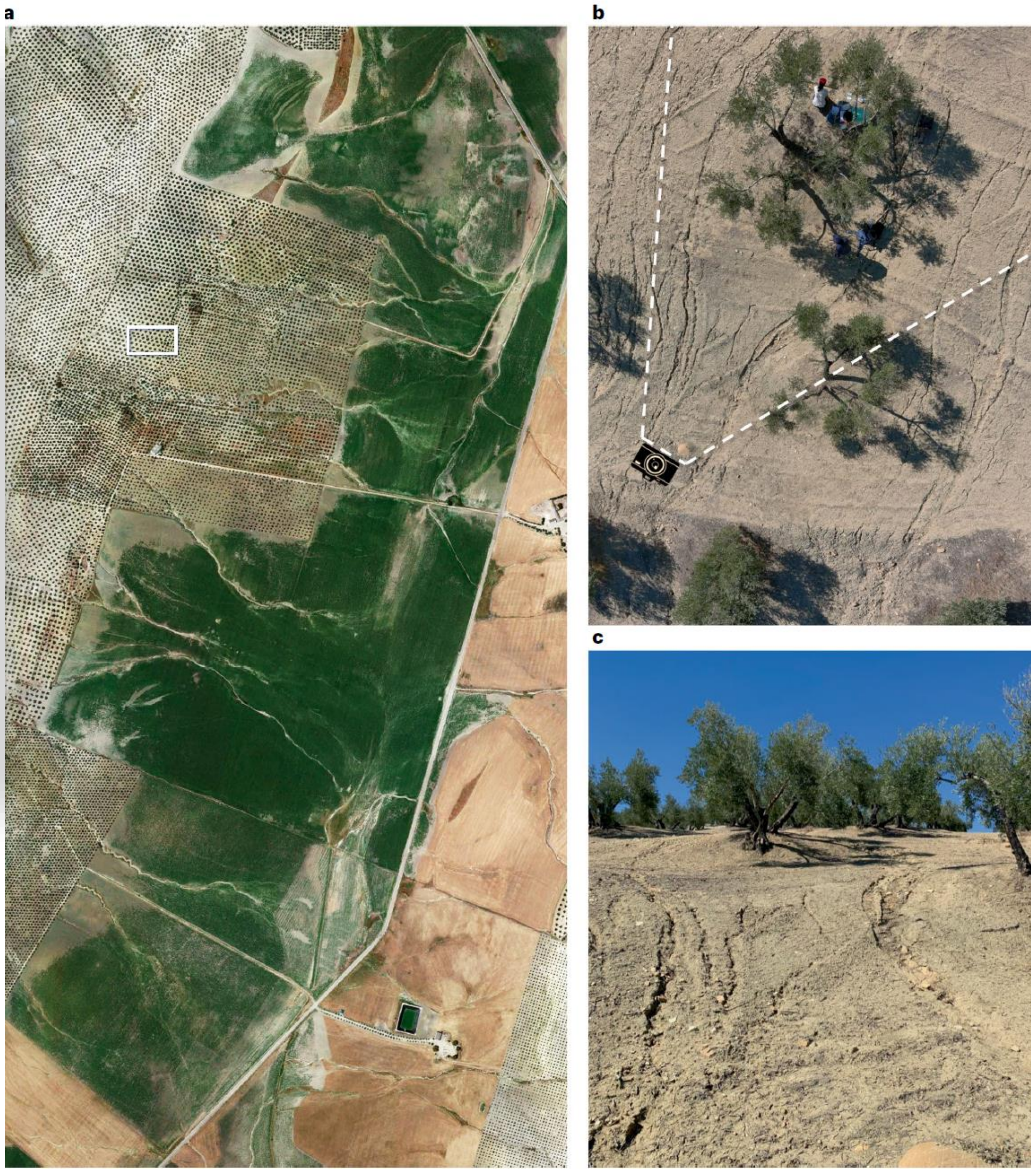
Unsustainably losing ground

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

PNRR

EUroLanD

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.