Assessing and monitoring soil health in Europe: opportunities and threats

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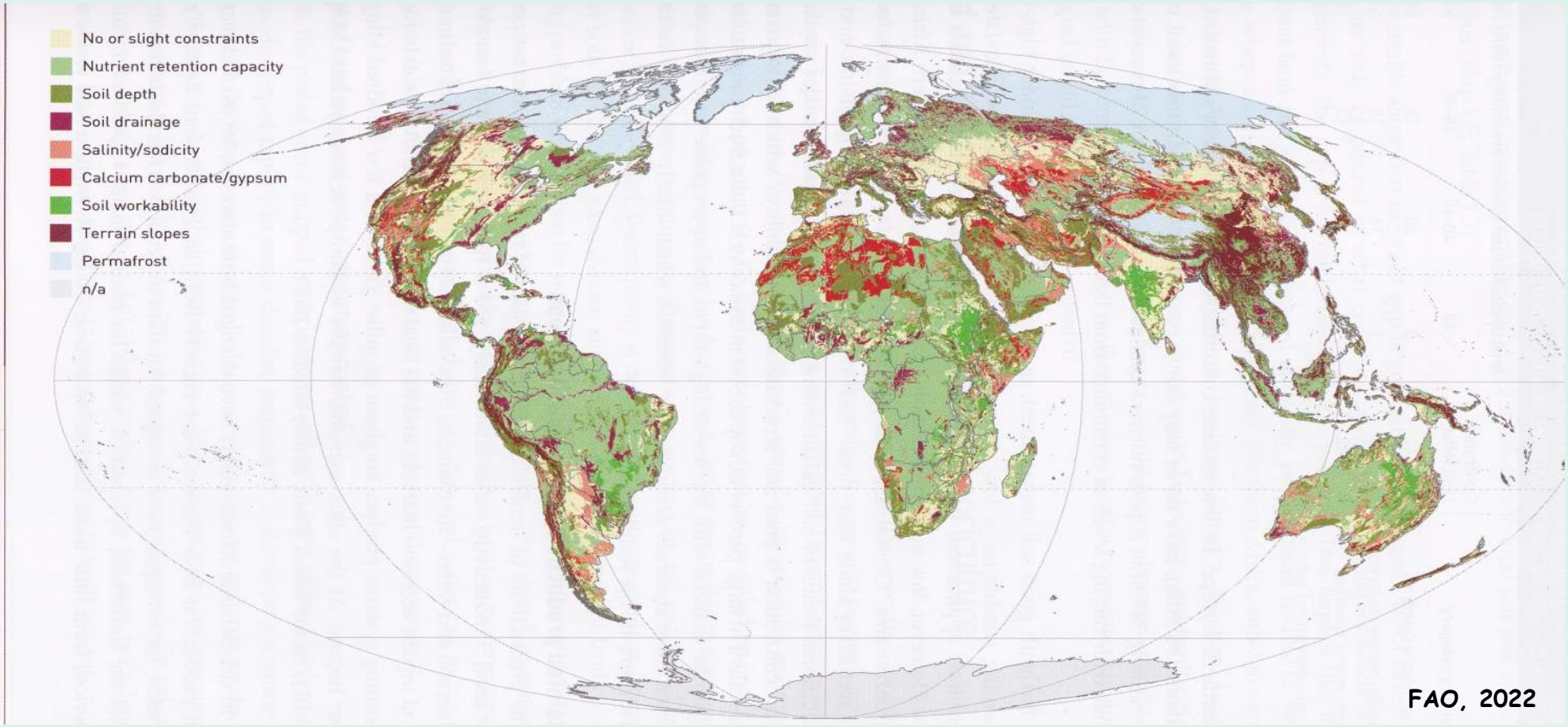
Soil Health 2024 Japan Workshop, Tsukuba (online)

Soil fertility is very variable



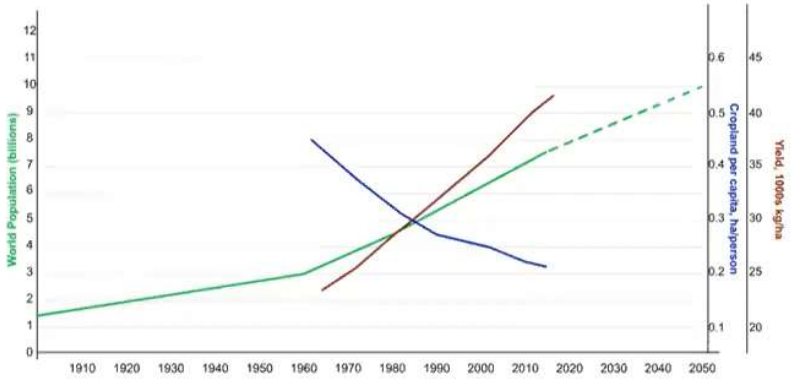
Highly fertile soils cover only 3% of the world's land surface, but produce more than 40% of major crops

- High and medium-income countries: 32% very fertile land
- arable land: 0.37 ha/capita
- Low-income countries: 28% very fertile land
- arable land: 0.17ha/capita

Reduction of cultivated area and increase in productivity: what are the consequences?

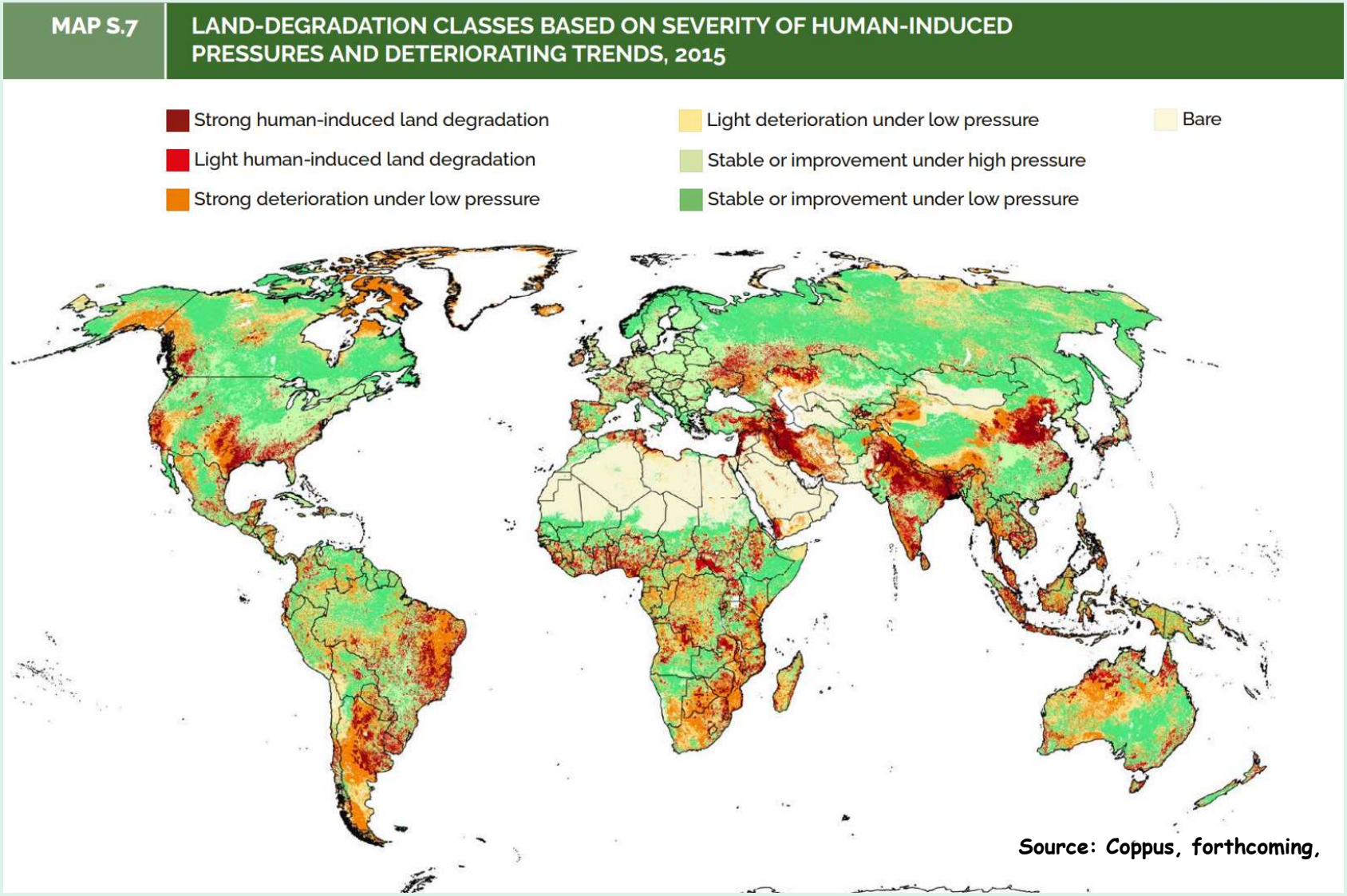
Farmland is being consumed by urban development

Amount of cropland per capita has declined



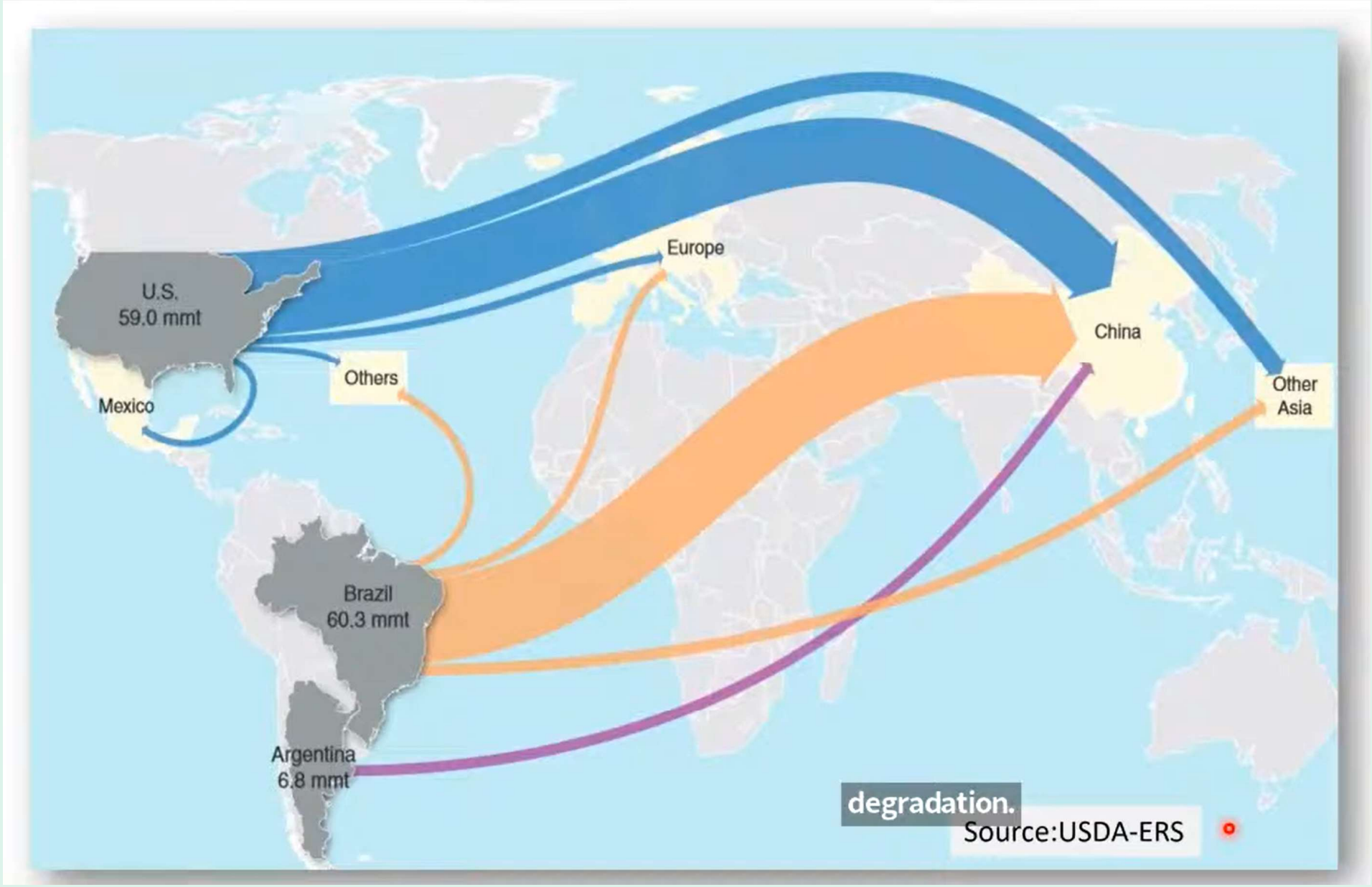
Amount of cropland, in hectares per person, plotted against yield in 1,000s of kilograms and world population (projected population dashed line.) Data from FAO 2019; FAO 2020.

A third of the soil resources is degraded (FAO, 2015)

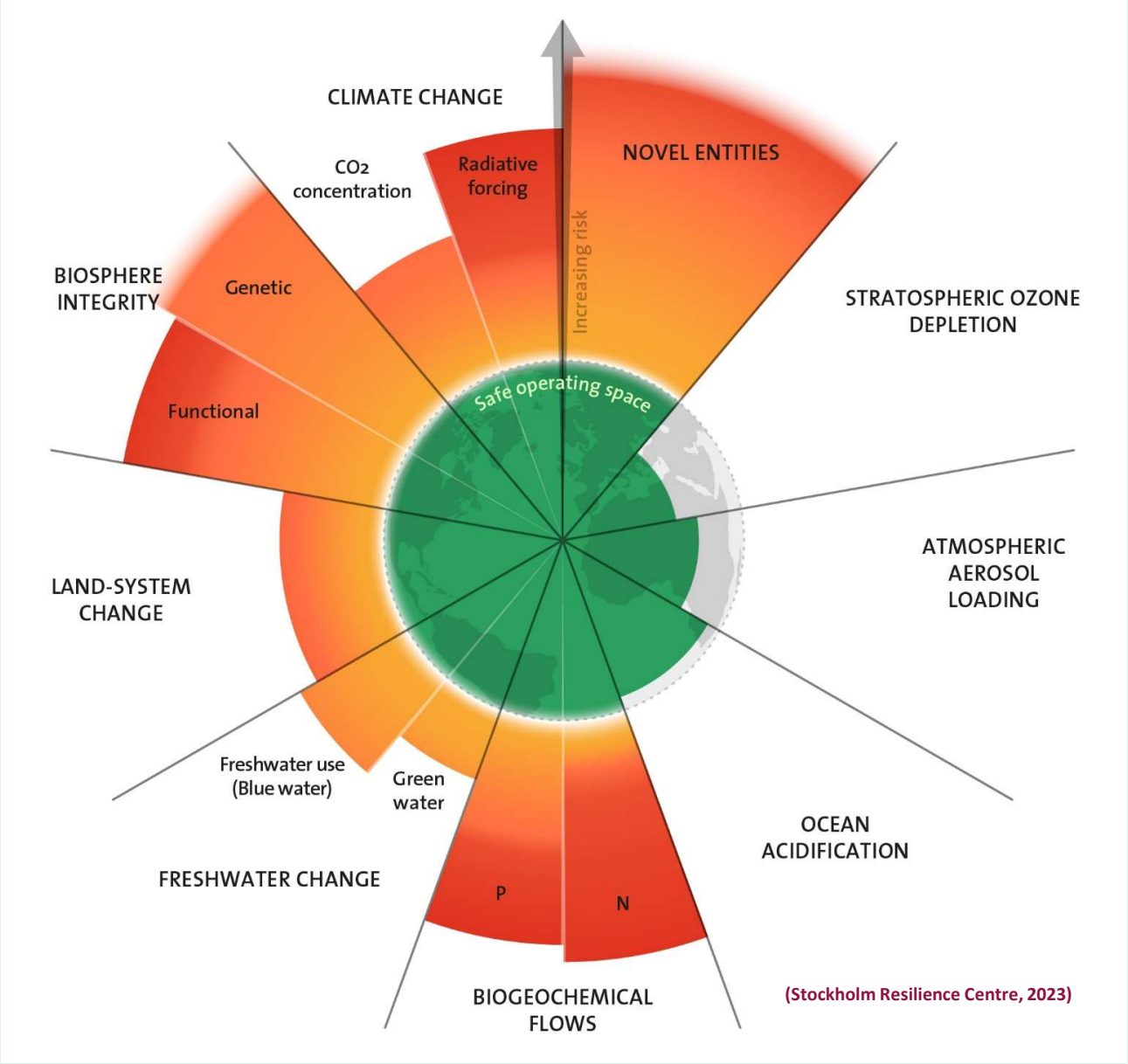


Global Grain Flows

Soybean

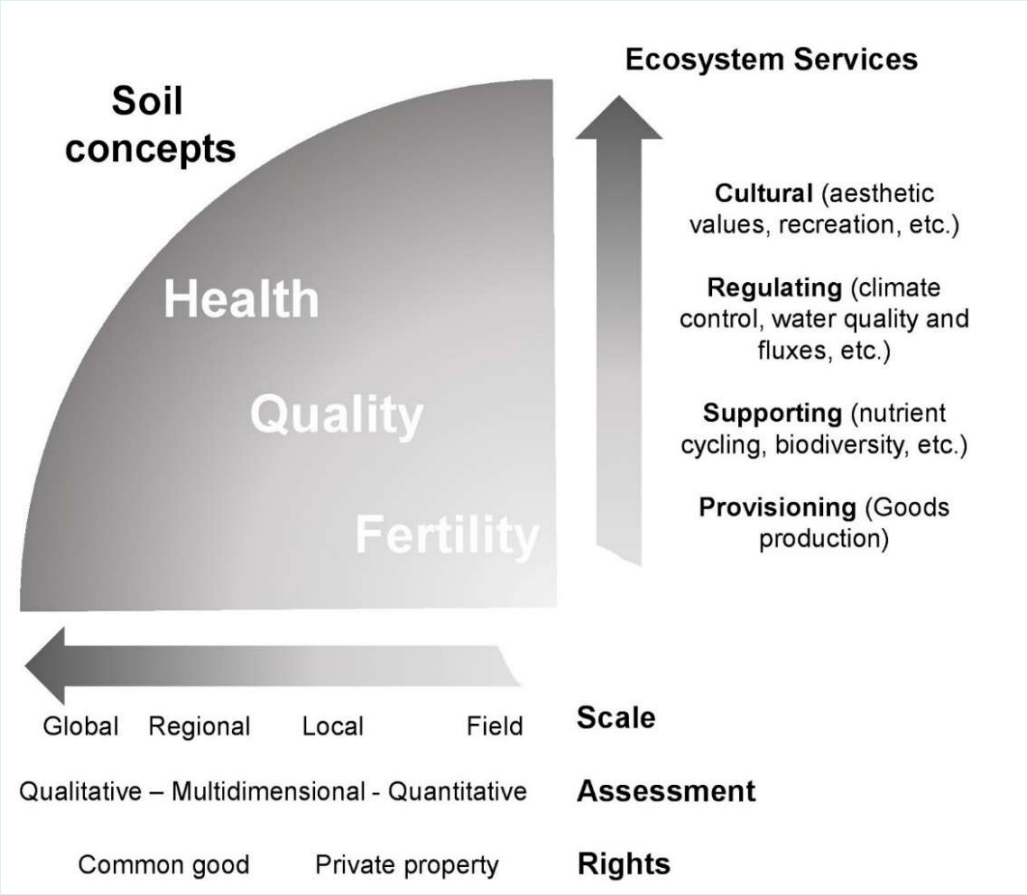


Why is the soil resource not included among the planetary boundaries?



What is soil health?

"the physical, chemical and biological condition of soil that determines its ability to function as a viable system and provide ecosystem services" (EU COM, 2023)



(Source: Costantini and Priori, 2022)

Soil health

Focus on capacity to sustain life

The continued capacity of soils to provide ecological functions for all forms of life

EU Soil Mission, 2020

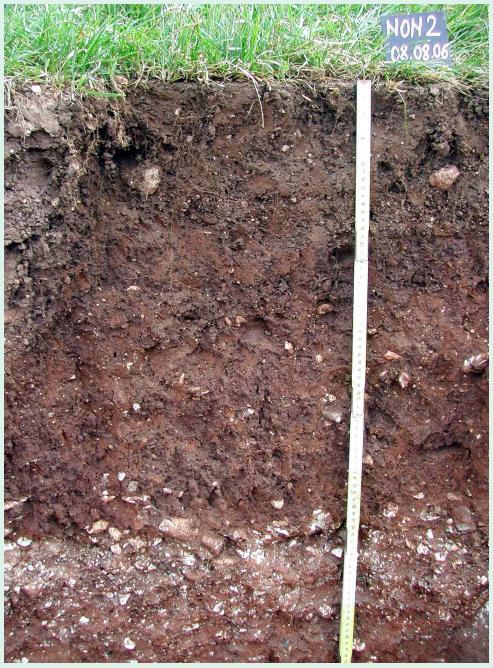
Focus on human needs

1) **provide food and biomass production;**
2) **absorb, store and filter water and transform nutrients and substances, thus protecting groundwater bodies;**
3) **provide the basis for life and biodiversity;**
4) **act as a carbon reservoir;**
5) **provide a physical platform and cultural services for humans and their activities;**
6) **act as a source of raw materials;**
7) **constitute an archive of geological, geomorphological and archaeological heritage.**

EU Soil Strategy, 2021

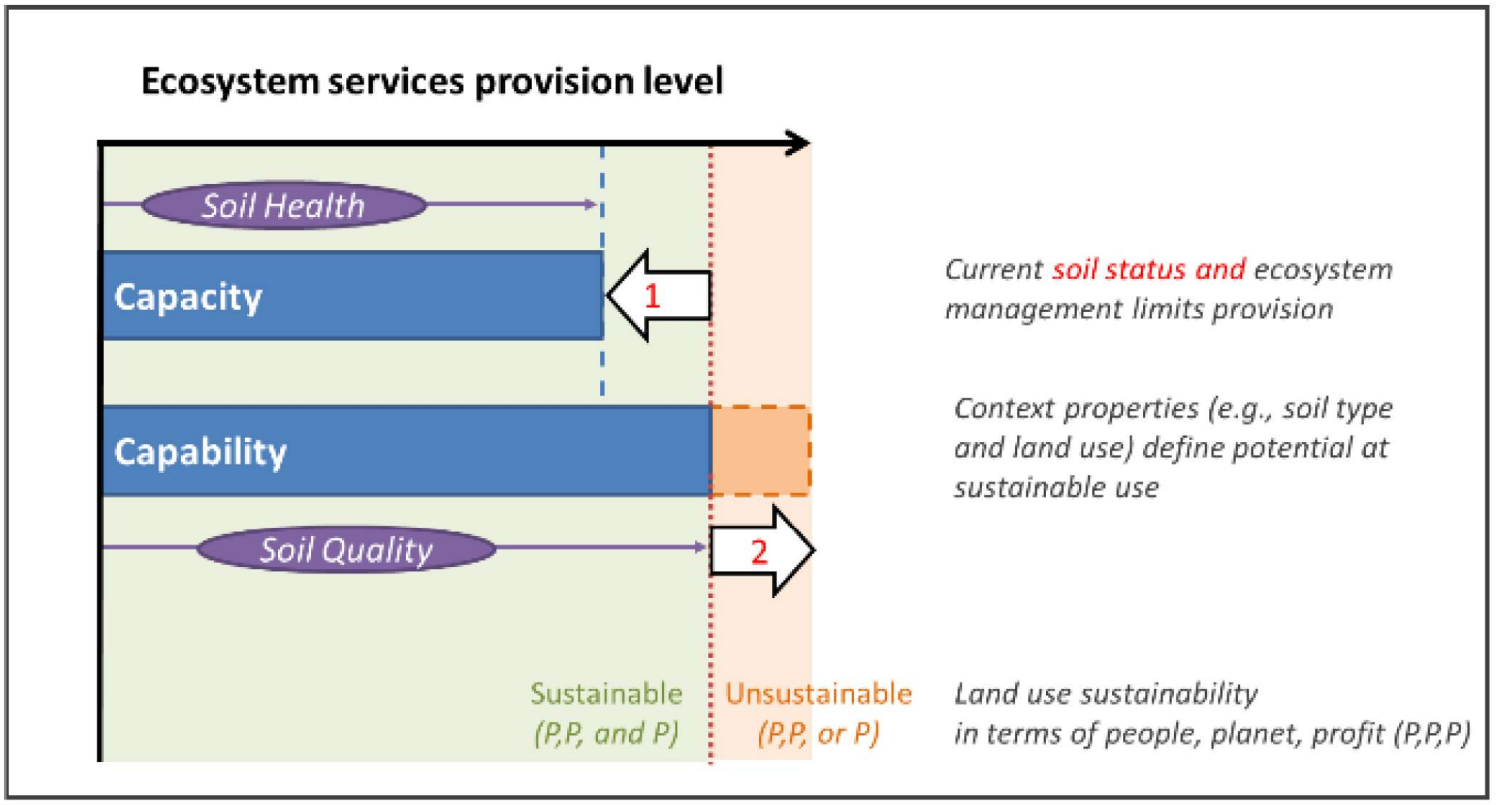
Soil degradation as a temporary or permanent worsening of its health

Soil degradation is a temporary or permanent worsening of its health, i.e. its functionality, due to unsustainable management, exceeding its resilience.



(Source: Costantini and Dazzi (Eds) The Soils of Italy)

Soil health, a relative concept

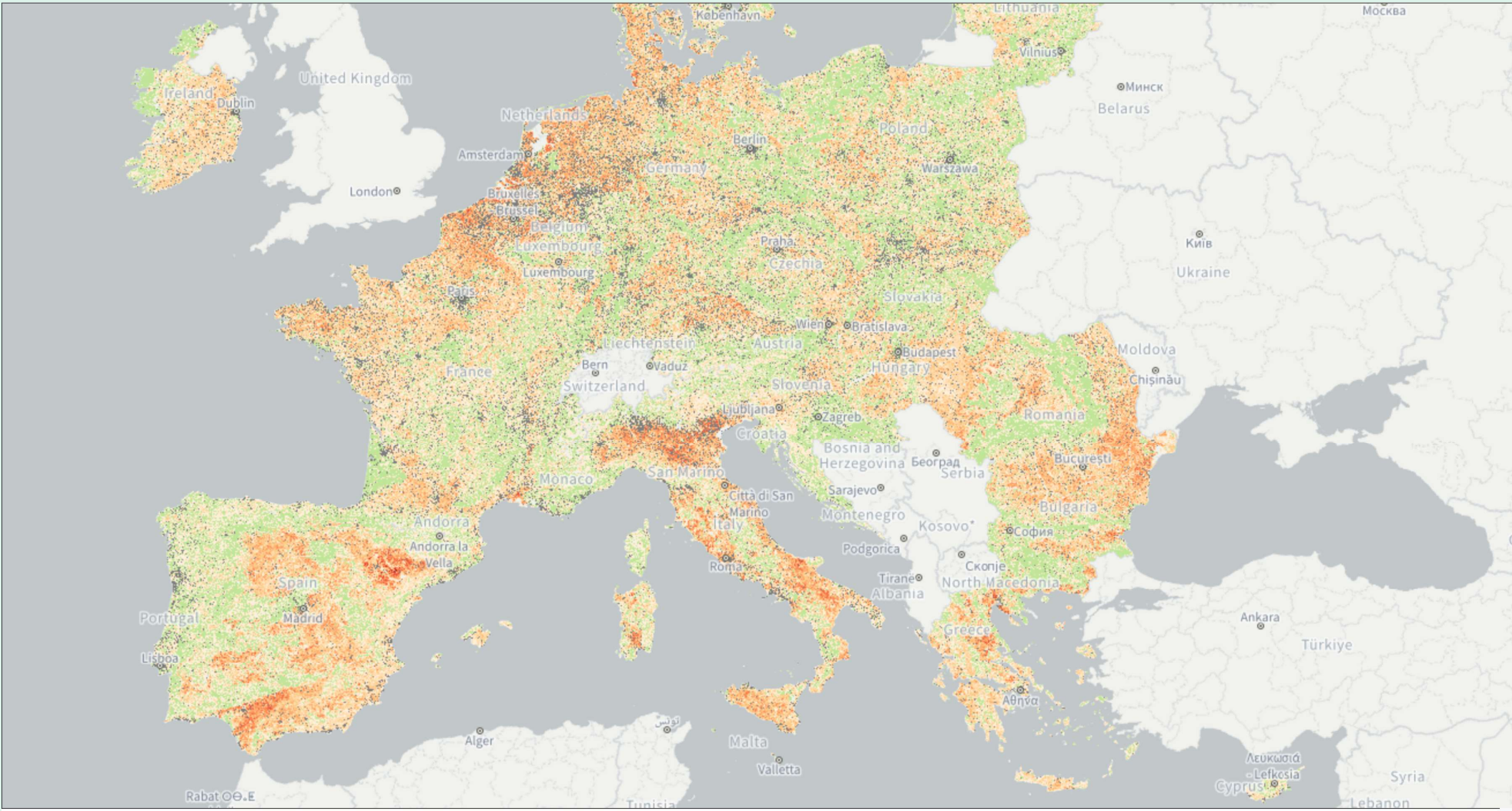


1 Reduction of ecosystem services provision is linked to soil degradation, management practices, climate change, etc.

2 Increase of ecosystem services provision is possible by using fertilizers, pesticides, intensive tillage and other management practices, but lead to increased trade-offs to other services, to other people, elsewhere or later.

(Source: EJP Soil project)

EUSO dashboard: the 61% of European soils is degraded



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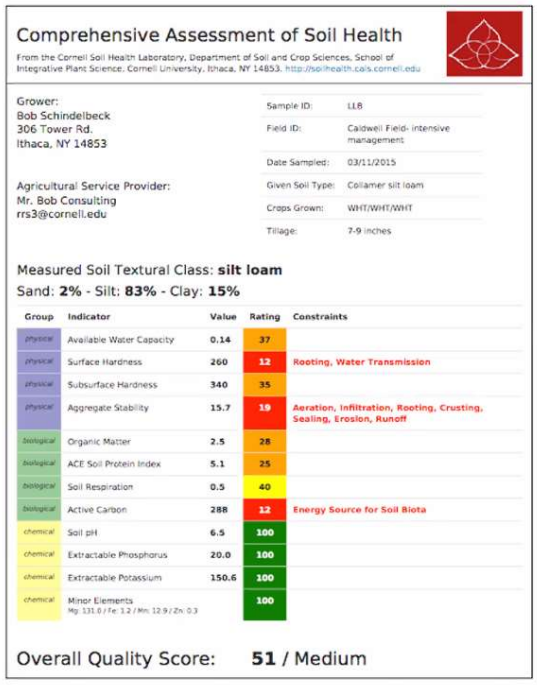
Number of soil degradation processes

The new European law on soil health monitoring and evaluation (EU, 2023)

Aim: facilitating soil health improvement through proper policies and measures

Towards a Soil Health Index and a Soil Health Certificate



Comprehensive Assessment of Soil Health

From the Cornell Soil Health Laboratory, Department of Soil and Crop Sciences, School of Integrative Plant Science, Cornell University, Ithaca, NY 14853. http://soilhealth.cals.cornell.edu

Grower:
Bob Schindelbeck
306 Tower Rd.
Ithaca, NY 14853

Agricultural Service Provider:
Mr. Bob Consulting
rrs3@cornell.edu

Sample ID:	LLB
Field ID:	Caldwell Field- intensive management
Date Sampled:	03/11/2015
Given Soil Type:	Collamer silt loam
Crops Grown:	WHT/WHT/WHT
Tillage:	7-9 inches

Measured Soil Textural Class: **silt loam**
Sand: **2%** - Silt: **83%** - Clay: **15%**

Group	Indicator	Value	Rating	Constraints
physical	Available Water Capacity	0.14	37	
physical	Surface Hardness	260	12	Rooting, Water Transmission
physical	Subsurface Hardness	340	35	
physical	Aggregate Stability	15.7	19	Aeration, Infiltration, Rooting, Crusting, Sealing, Erosion, Runoff
biological	Organic Matter	2.5	28	
biological	ACE Soil Protein Index	5.1	25	
biological	Soil Respiration	0.5	40	
biological	Active Carbon	288	12	Energy Source for Soil Biota
chemical	Soil pH	6.5	100	
chemical	Extractable Phosphorus	20.0	100	
chemical	Extractable Potassium	150.6	100	
chemical	Minor Elements Mg: 131.0 / Fe: 1.2 / Mn: 12.9 / Zn: 0.3		100	

Overall Quality Score: **51** / Medium

European Commission

JRC Scientific and Technical Reports

Implementing Good Agricultural and Environmental Condition in the EU

Results of the 2010 GAEC workshop

Vincenzo Angileri, Philippe Loudjani

EUR 24659 EN - 2010

JRC EUROPEAN COMMISSION

ipsc

The descriptors of soil health (EU, 2023)

Common descriptors at EU level:

- salinization,
- erosion,
- organic carbon,
- subsoil compaction.

At Member State level:

- nutrient content,
- contamination
- water holding capacity.

Other descriptors without threshold criteria:

- acidification,
- soil surface compaction,
- biodiversity
- urbanization.

Thresholds for evaluation

Aspect of soil degradation	Soil descriptor	Criteria for healthy soil condition	Land areas that shall be excluded from achieving the related criterion
Part A: soil descriptors with criteria for healthy soil condition established at Union level			
Salinization	Electrical Conductivity (deci-Siemens per meter)	< 4 dS m−1 when using saturated soil paste extract (eEC)	Naturally saline land areas; Land areas directly affected by sea level rise
Soil erosion	Soil erosion rate (tonnes per hectare per year)	≤ 2 t ha-1 y-1	Badlands and other unmanaged natural land areas
Loss of soil organic carbon	Soil Organic Carbon (SOC) concentration (g per kg)	- For organic soils: respect targets - For mineral soils: SOC/Clay ratio > 1/13; possible corrective factor, taking into account the actual SOC content in permanent grasslands.	- No exclusion - Non- managed soils in natural land areas
Subsoil compaction	Bulk density in subsoil (upper part of B or E horizon);	Range from 1.47 for clay to 1.80 for sand and loam Non-managed soils in natural land areas	Non- managed soils in natural land areas

Part B: soil descriptors with criteria for healthy soil condition established at Member States level			
Excess nutrient content in soil	Extractable phosphorus (mg per kg)	The “maximum value” shall be laid down by the Member State within the range 30-50 mg kg-1	No exclusion
Soil contamination	concentration of heavy metals in soil: As, Sb, Cd, Co, Cr (total), Cr (VI), Cu, Hg, Pb, Ni, Tl, V, Zn (µg per kg)	no unacceptable risk for human health and the environment from soil contamination exists.	No exclusion
Reduction of soil capacity to retain water	Soil water holding capacity of the soil sample	The minimal threshold set at soil district and river basin or subbasin level at such a value that the impacts of floodings following intense rain events or of periods of low soil moisture due to drought events are mitigated.	No exclusion

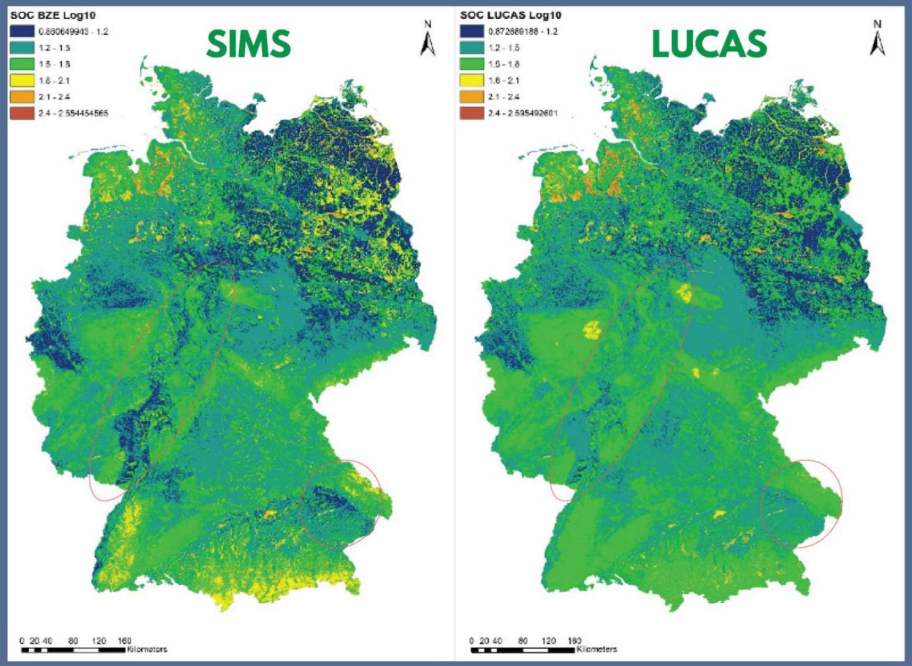
Part C: soil descriptors without criteria	
Aspect of soil degradation	**Soil descriptor**
Excess nutrient content in soil	Nitrogen in soil (mg g-1)
Acidification	Soil acidity (pH)
Topsoil compaction	Bulk density in topsoil (A-horizon) (g cm-3)
Loss of soil biodiversity	Soil basal respiration ((mm3 O2 g-1 hr-1) in dry soil possible: - metabarcoding of bacteria, fungi, protists and animals; - abundance and diversity of nematodes; - microbial biomass; - abundance and diversity of earthworms (in cropland); - invasive alien species and plant pests
Part D: land take and soil sealing indicators	
Aspect of soil degradation	**Land take and soil sealing indicators**
Land take and soil sealing	Total artificial land (km² and % of Member State surface)

Problematics: the datasets

WHAT HAPPENS USING SEPARATELY THE NATIONAL SOIL MONITORING SYSTEM (SIMS) DATA OR LUCAS

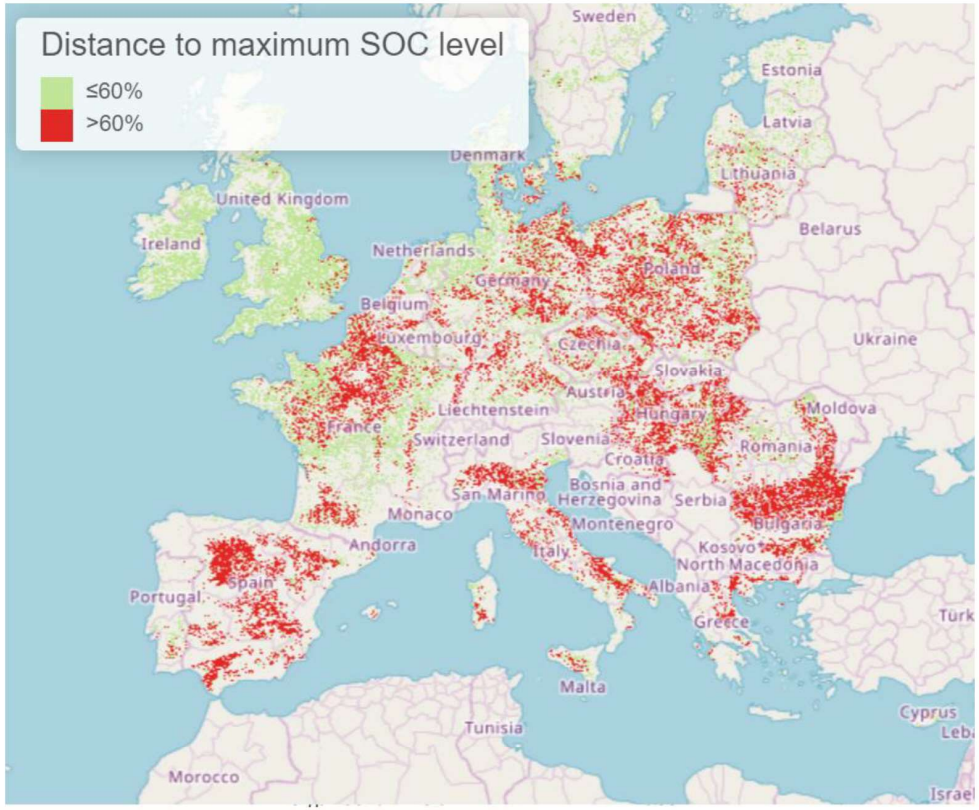
SPATIAL ANALYSIS

SIDE-BY-SIDE



The choice of the modelling approach

Soil degradation indicators – Distance to maximum SOC level - EUSO Dashboard prototype



The layer covers cropland and grassland in the EU+UK. For each pixel, the **maximum SOC level is calculated as the increase in SOC content that would be achievable if the land was kept under continuous grassland for 40 years** (without ploughing). In this layer, soils are considered unhealthy if the distance that separates them from the maximum is more than 60% of current levels. Conversely, soils are healthy if current levels of SOC are close to the maximum (distance less than 60%). The 60% threshold has been chosen as providing a reasonable and pragmatic distance gap from the maximum SOC level achievable. (De Rosa D. et al., 2023, upcoming publication)

IT IS BASED ON SOC MODELING

(Source: EJP Soil project)

EJP SOIL
European Joint Programme

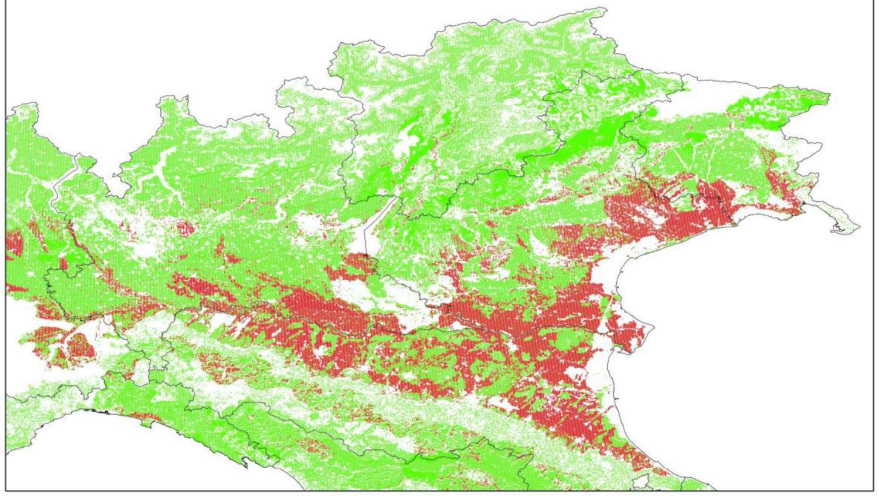
https://esdac.jrc.ec.europa.eu/esdacviewer/euso-dashboard/

Thresholds or reference values?

SOC DECLINE RISK AREAS

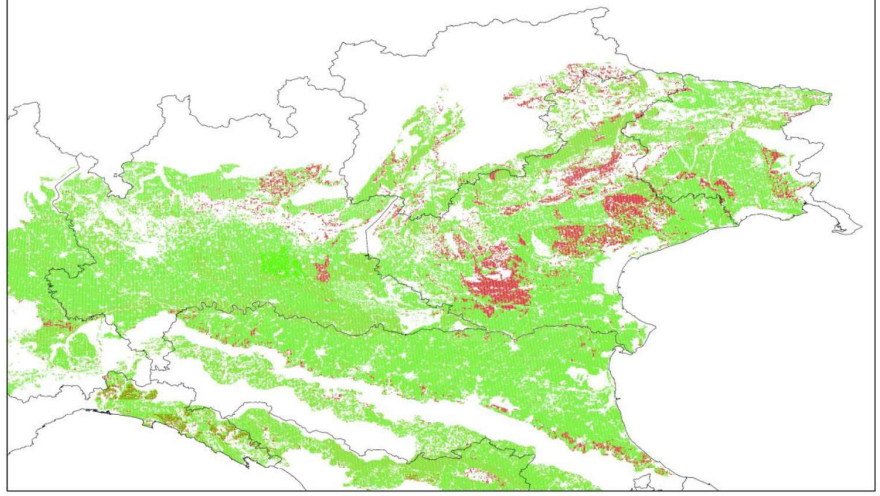
USING NATIONAL DATA

Applying EEA thresholds approach



SOIL TEXT CLASS		SOC target (% soil mass, dag kg-1) - Climatic water balance (mm) during summer <-100
SAND	MINERAL	0.73
SILT	MINERAL	1.89
LOAM AND CLAY	ORGANIC	0.91
LOAM AND CLAY	MINERAL	0.87

Applying reference values



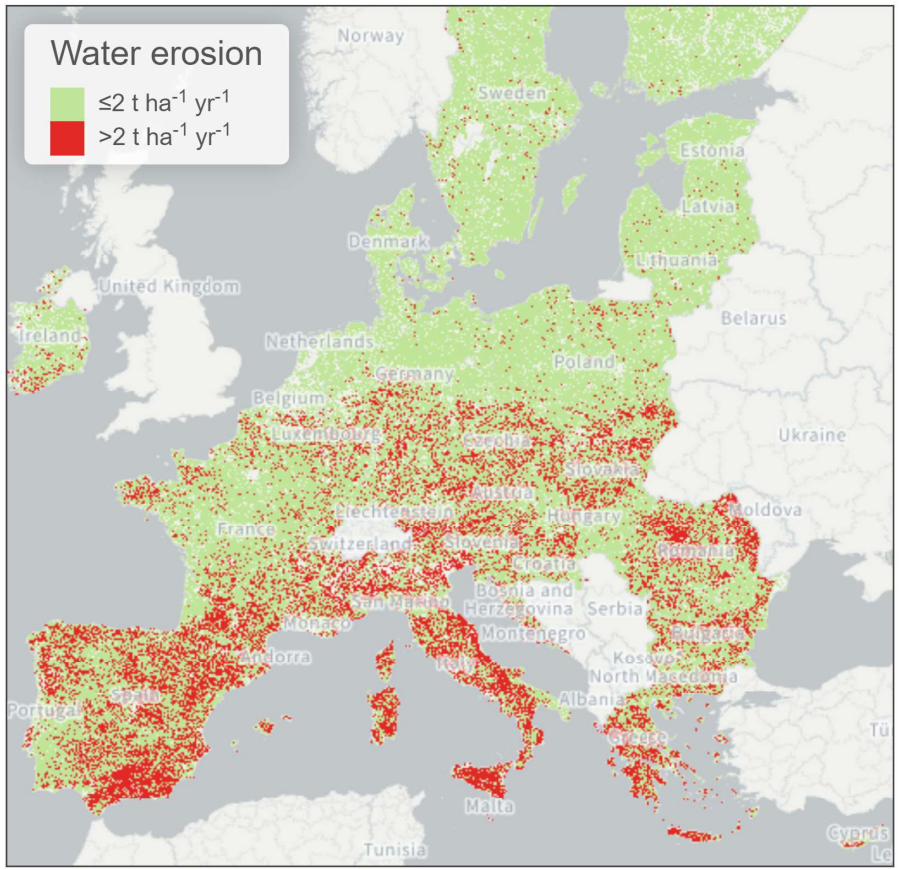
Applying an approach of **reference values in the population of the Soil Types**. The target considered for arable lands was set as reaching the 60% of mean SOC content of meadows in the same Soil Type population.

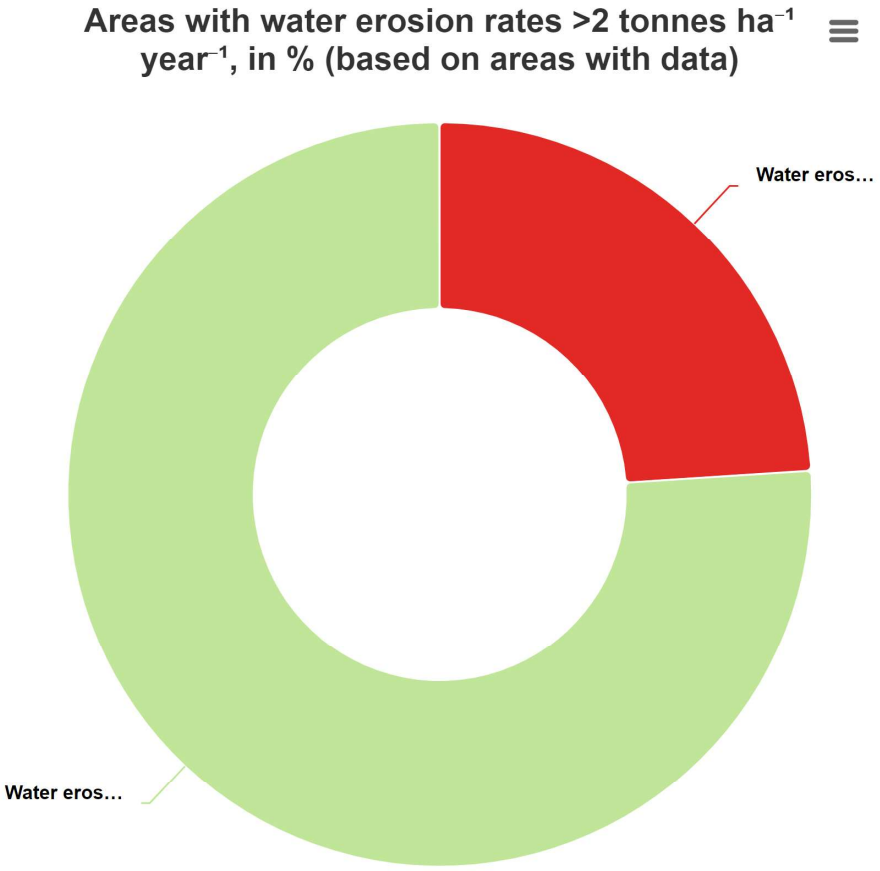
THE ACTUAL HIGHER VALUES IN THE POPULATION ARE LOWER THAN THE OPTIMAL VALUES ESTIMATED BY MODELING

EJP SOIL
European Joint Programme

(Source: EJP Soil project)

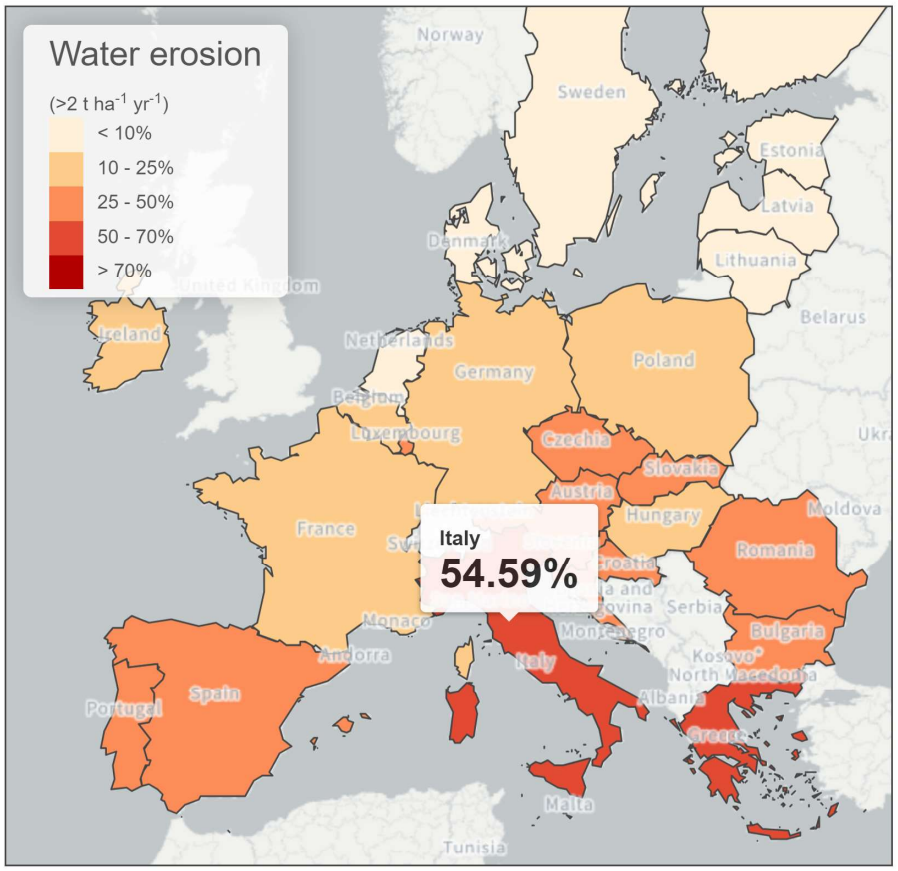
Which thresholds?





(Source: EUSO, 2023)

Which targets?



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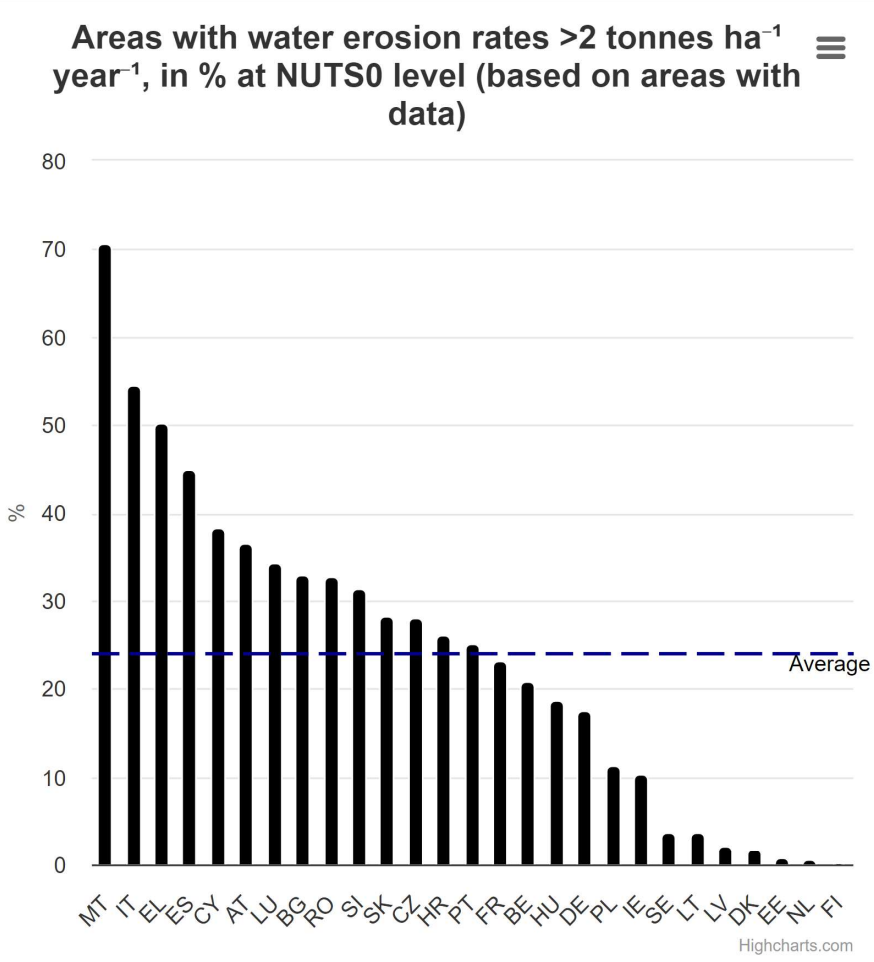

(Source: EUSO, 2023)

Monitoring the effects of applied measures

Table 1
Average soil loss rate (*E*-value) per country (all lands, arable lands), effect of Good Agricultural Environmental Condition (GAEC) practices, and share of EU soil loss.

Country		Overall Mean	Mean in arable lands	Mean in arable lands without GAEC	GAEC effect	% of the total soil loss in EU
		E (t ha^{-1} yr^{-1}) (%)				
AT	Austria	7.19	3.97	5.23	31.8	5.65%
BE	Belgium	1.22	2.06	2.71	31.8	0.30%
BG	Bulgaria	2.05	2.47	3.77	52.5	2.21%
CY	Cyprus	2.89	1.85	2.82	52.6	0.25%
CZ	Czech Republic	1.65	2.52	3.30	31.0	1.24%
DE	Germany	1.25	1.75	2.51	43.5	4.15%
DK	Denmark	0.50	0.61	0.68	11.4	0.20%
EE	Estonia	0.21	0.70	0.88	25.3	0.09%
ES	Spain	3.94	4.27	5.56	30.3	19.61%
FI	Finland	0.06	0.46	0.64	37.9	0.18%
FR	France	2.25	1.99	2.78	39.5	11.85%
GR	Greece	4.13	2.77	3.63	31.1	5.31%
HR	Croatia	3.16	1.67	1.80	7.5	1.74%
HU	Hungary	1.62	2.10	2.35	12.0	1.42%
IE	Ireland	0.96	1.32	1.52	15.7	0.55%
IT	Italy	8.46	8.38	9.80	16.9	24.13%
LT	Lithuania	0.52	0.95	1.02	7.5	0.32%
LU	Luxembourg	2.07	4.54	6.19	36.3	0.05%
LV	Latvia	0.32	1.01	1.11	10.1	0.20%
MT	Malta	6.02	15.93	18.72	17.5	0.01%
NL	Netherlands	0.27	0.54	0.68	24.7	0.08%
PL	Poland	0.96	1.61	1.79	11.2	2.92%
PT	Portugal	2.31	2.94	3.55	20.6	2.01%
RO	Romania	2.84	3.39	3.88	14.3	6.31%
SE	Sweden	0.41	1.12	1.31	16.6	1.57%
SI	Slovenia	7.43	4.63	5.33	15.0	1.49%
SK	Slovakia	2.18	3.54	4.09	15.6	1.03%
UK	United Kingdom	2.38	1.04	1.49	43.2	5.14%

(Source: EUSO, 2023)

Conclusions and perspectives

- The transition between the concepts of fertility, quality and soil health has been favored by the results of scientific research and by the increased sensitivity to environmental issues
- Soil health is a simple and effective concept for communication purposes, but in reality it implies the understanding of complex situations and processes
- The new European law is an important tool for directing measures and interventions aimed at improving the health of European soils
- For many soil conditions, a regional calibration is required that takes into account local environmental, social and agronomic realities

100 years of SOIL SCIENCE
past achievements and future challenges

International Union of Soil Sciences

Centennial of the IUSS

Florence - Italy
May 19 - 21, 2024

www.centennialiuss2024.org

General themes

Soil health in achieving the Sustainable Development Goals
Soil governance
Soil in the circular economy
Soil sciences impact on basic knowledge
Soil in the digital era
Soil and the human society
Equity, diversity and inclusivity in soil sciences

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