Conserve and increase soil organic carbon stocks

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European Commission
Joint Research Centre (JRC)
Directorate D Sustainable Resources

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EU Policies relevant to soils

EU Soil Monitoring Law

Other Policies

- Common Agricultural Policy (**CAP**)
- Nature Restoration Law (**NRL**)
- Digital Europe Programme (**DEP**)
- Biodiversity Strategy 2030
- Chemicals Strategy
- Zero Pollution Action Plan
- Nitrates Directive
- Sustainable Development Goals (**SDGs**)

EU Missions - Soil Deal for Europe

Carbon Removals & Carbon Farming

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What is the EU Soil Observatory(EUSO)?

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LUCAS Contributes to EU-Wide Soil Monitoring

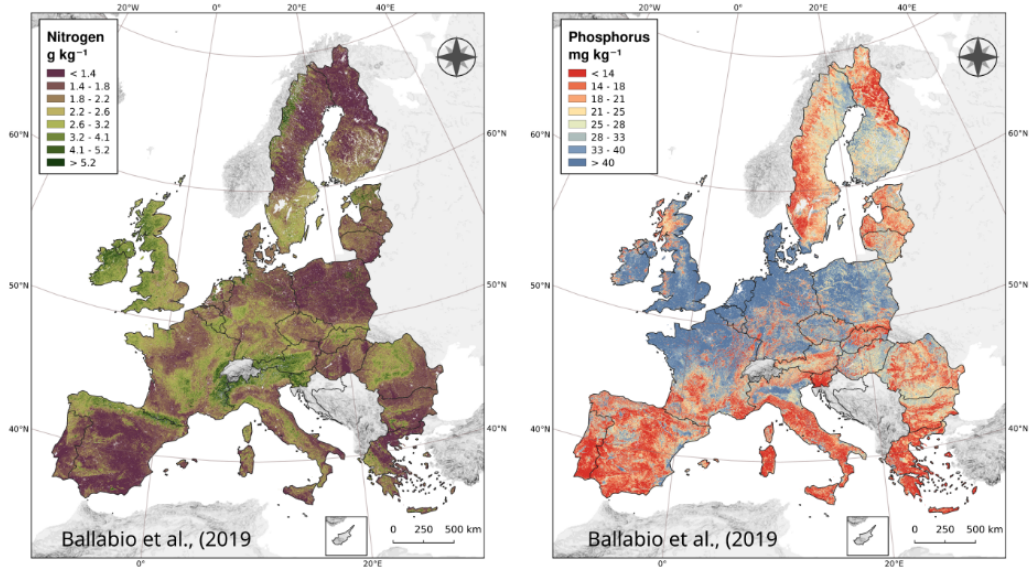
From monitoring physical, chemical and biological soil properties to support EU policies

SOIL PROPERTIES

Organic carbon
Total nitrogen content
Phosphorus content
Heavy Metals
Pesticides
Fungicides
Antibiotics
Soil Biodiversity

MODELLING + AI

DayCent
Cubist
Gaussian process
GAM



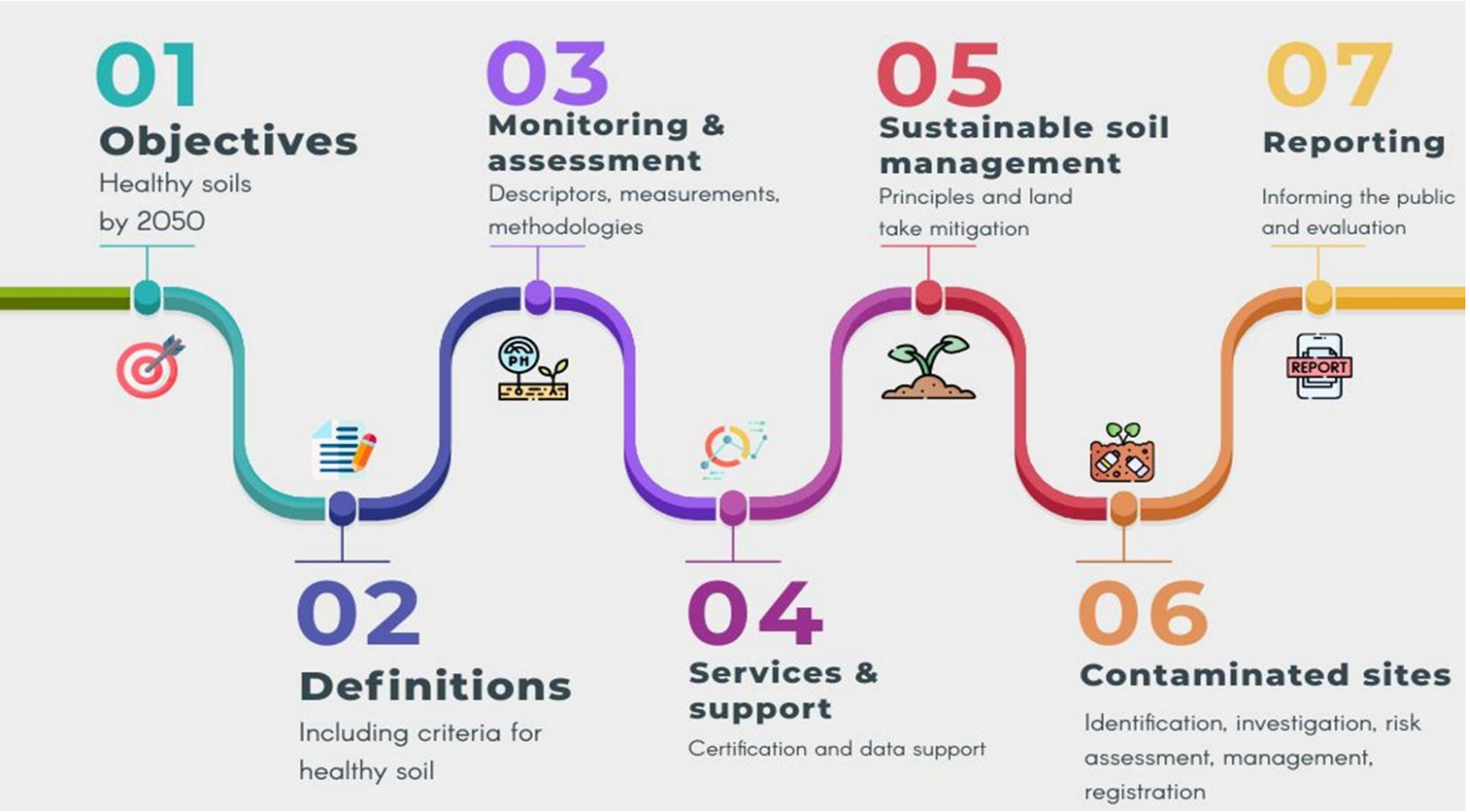
COM(2023)416 - ***Directive***
Soil Monitoring and Resilience (Soil Monitoring Law)

The JRC manages the LUCAS SOIL survey: sampling design, measurement protocols, training of surveyors, Quality assessments….
Periods: 2009, 2015, 2018, 2022
No of samples: 20,000-32,000 per campaign

POLICY MAKING

- EU Soil Strategy 2030
- Soil Mission
- Carbon Farming Certification
- Nature Restoration Law
- Zero Pollution Action Plan
- Common Agricultural Policy (CAP)
- Biodiversity Strategy 2030
- Chemical Strategy

Proposal for a Directive on Soil Monitoring and Resilience
(Soil Monitoring Law, 5 July 2023)



The Proposal for the first-ever EU legislation on soils:

- Provides a harmonised definition of soil health
- Puts in place a comprehensive and coherent monitoring framework
- Initiates the gradual implementation of sustainable soil management
- Addresses situations of unacceptable health and environment risks due to soil contamination.

Directive on Soil Monitoring and Resilience (SMLR)

2025

- trilateral negotiations on the final text and adoption of the Directive

2024

- Council adopts general approach

2024

- Parliament adopts a positive position

2023

- Commission adopts proposal for a Soil Monitoring Law

Following the agreement on a compromise text at the conclusion of the inter-institutional negotiations on 9 April 2025, the 2nd Reading by the European Parliament and Council adoption are **planned for autumn 2025.**

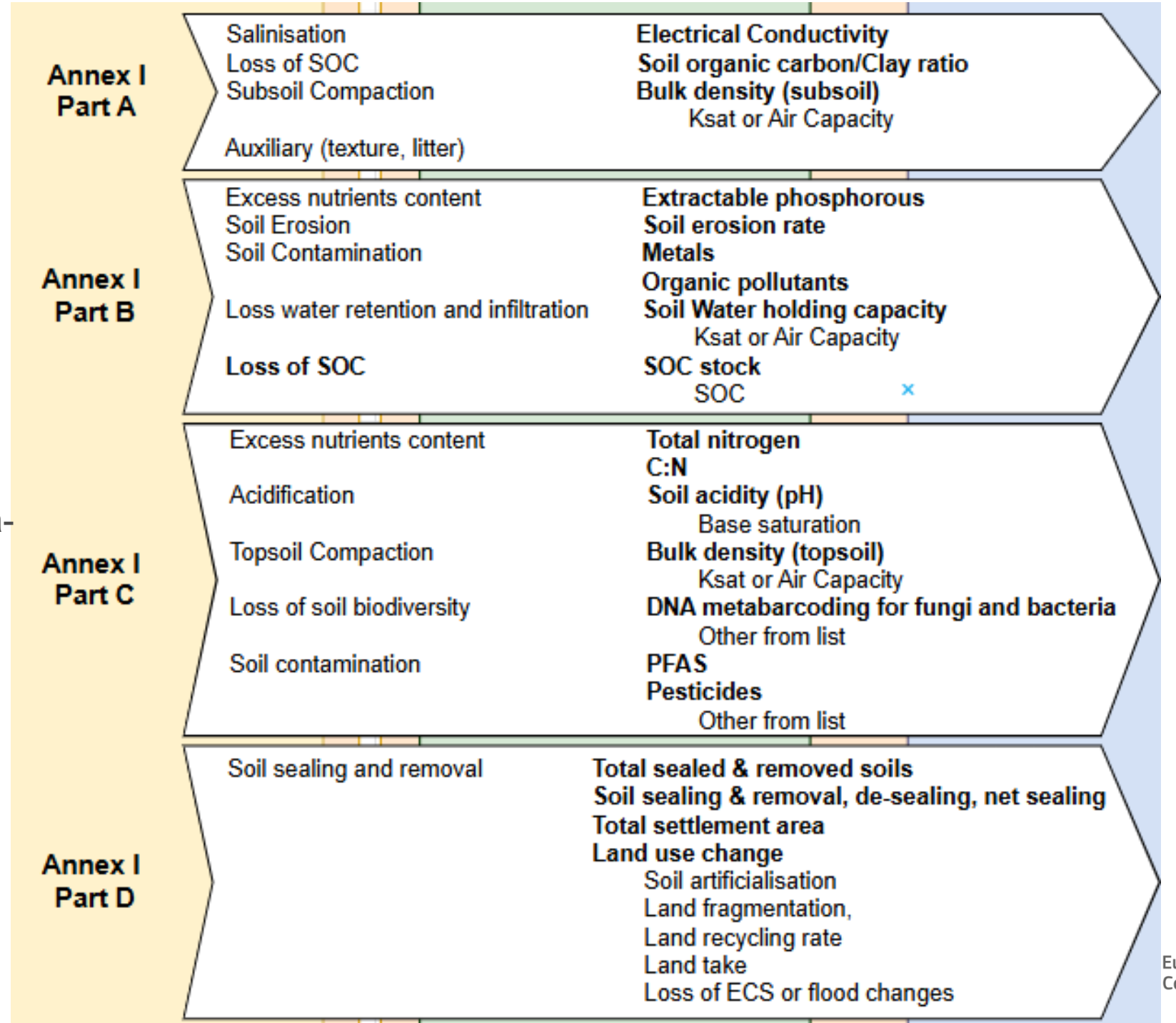
Reporting period and 1st assessment: 2030

Soil descriptors with criteria for healthy soil condition established at **Union level**

Soil descriptors with criteria for healthy soil condition established at **Member States (MS) level**

Soil descriptors without criteria- MS carry out measurements on at least **5% of the total number of sampling points**

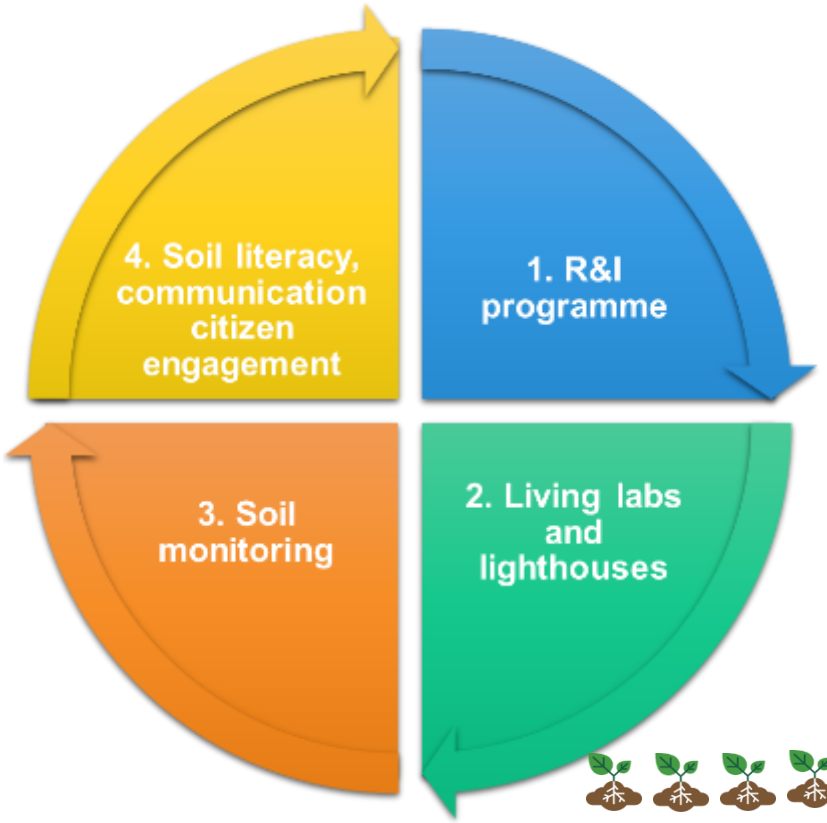
Soil sealing and soil removal indicators



Mission Soil: State of the play

Mission Soil aims to establish **100 Living Labs** to co-create, test and pioneer innovations for soil health, next to advancing the **knowledge on healthy soils**

- Citizen science initiatives
- Promoting self-assessment of soil health by land managers

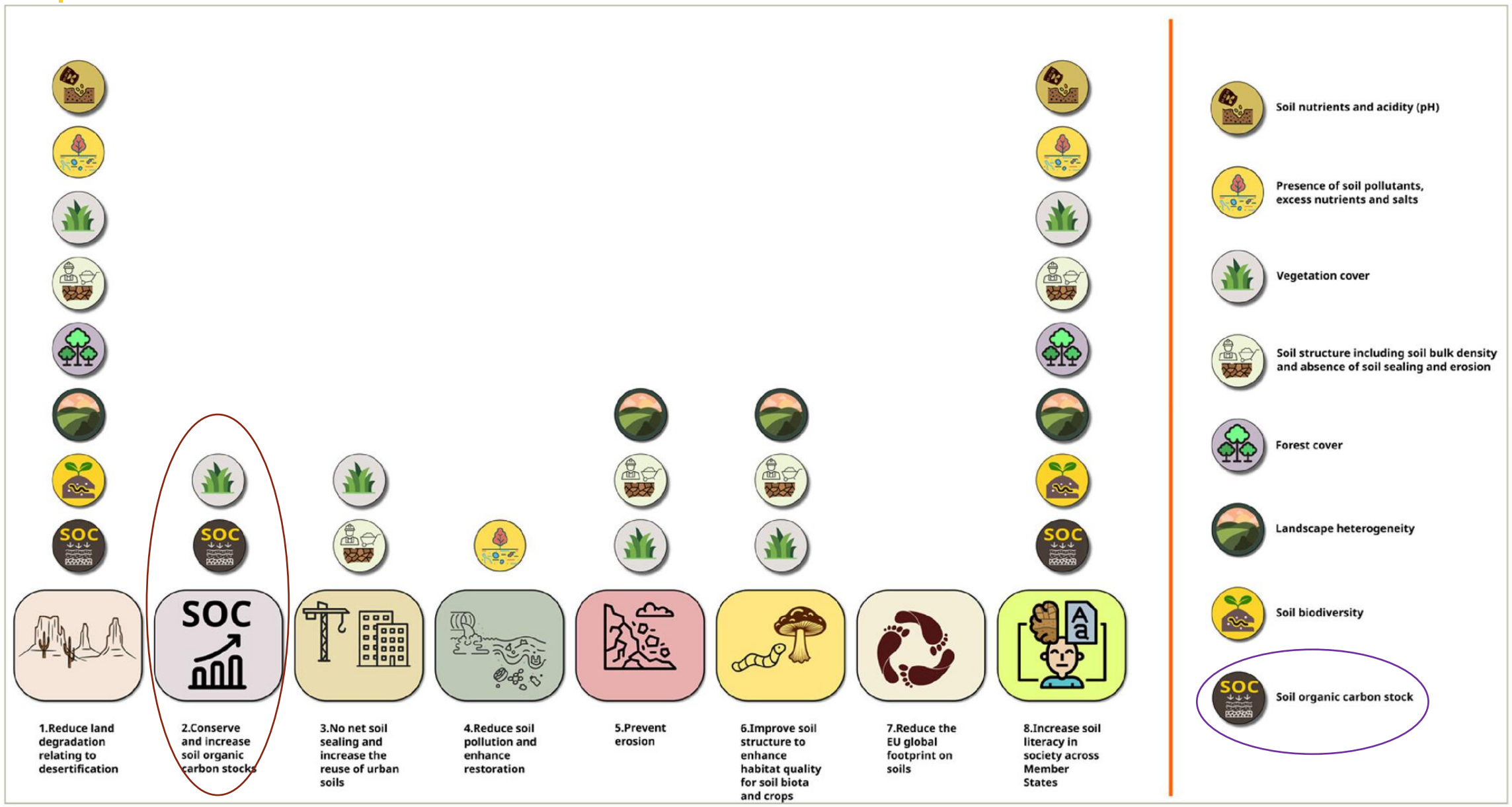


- >590 Million Euro (2021-2025)
- 63 projects funded so far
- New calls open in 2025
- Preparation of calls 2026-27

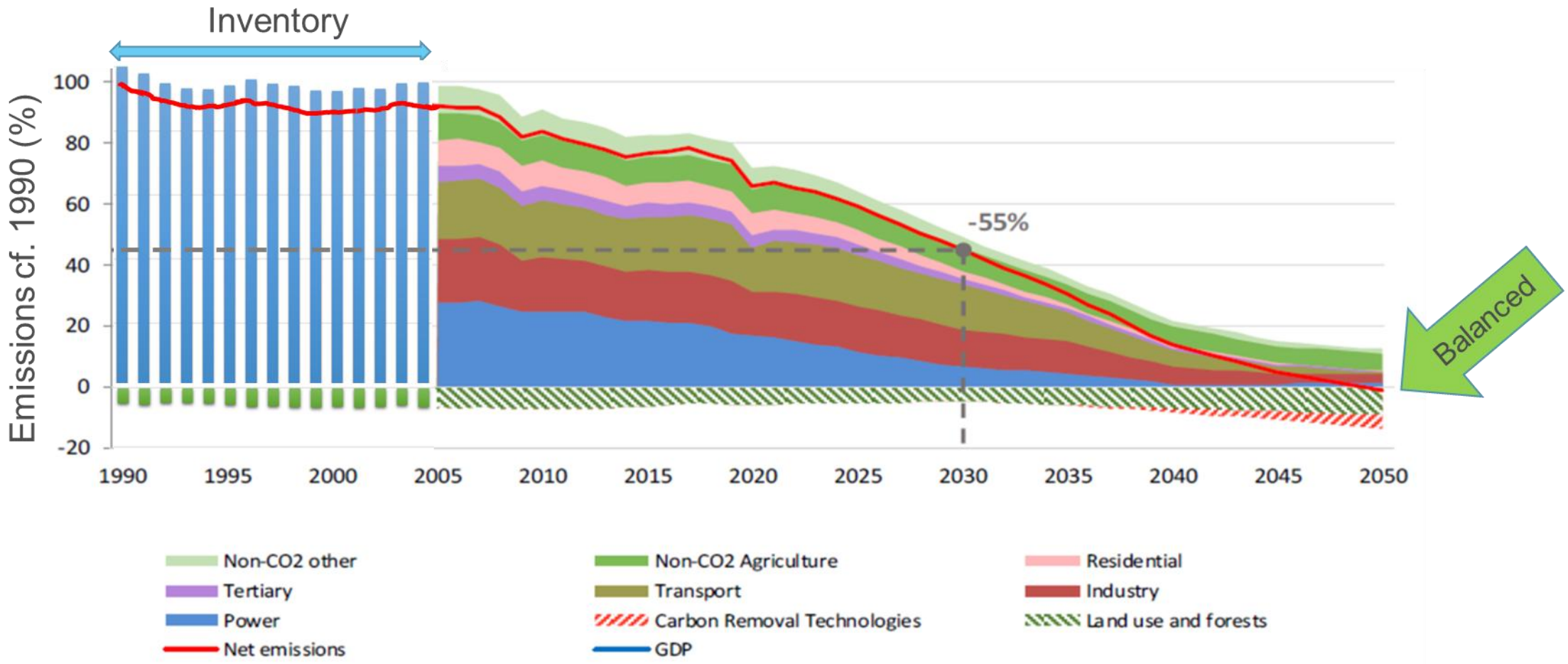
- Harmonisation of indicators and measuring of soil health in EU
- Managed by EUSO

- First 25 LL started in ‘24
- 25 LL start in ‘25
- 100 LL and >1000 sites by 2030

The objectives (bottom) and indicators (right) of the Soil Mission



Pathway to climate neutrality: Climate Law



The land is acting as a C sink mainly because of forests

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Carbon Removal & Carbon Farming (CRCF)

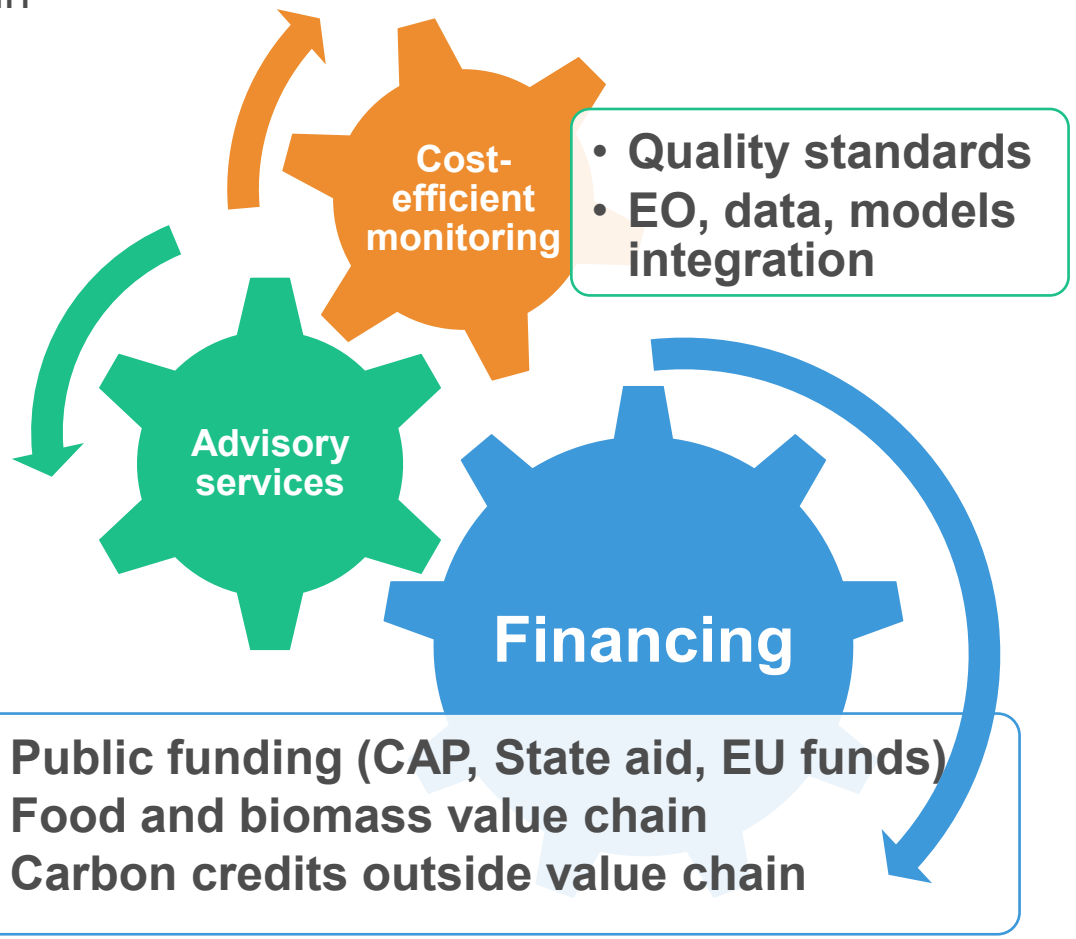
Green business model: rewarding land managers for improved land management practices, resulting in carbon sequestration in ecosystems and reducing carbon release to the atmosphere

Benefits

- Increased carbon removals
- Additional income for land managers
- More biodiversity and nature
- Increased climate resilience of farm and forest land

Mandatory sustainability requirements

Challenges



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Carbon farming

Use of **conservation tillage, catch crops, cover crops** and increasing **landscape features**

Agroforestry and other forms of mixed farming

Restoration, rewetting and conservation of **peatlands and wetlands**

Precision farming and more efficient use of fertilizers

Forest Management and Reforestation according to ecological principles

Blue carbon: coastal wetlands

Emissions reductions

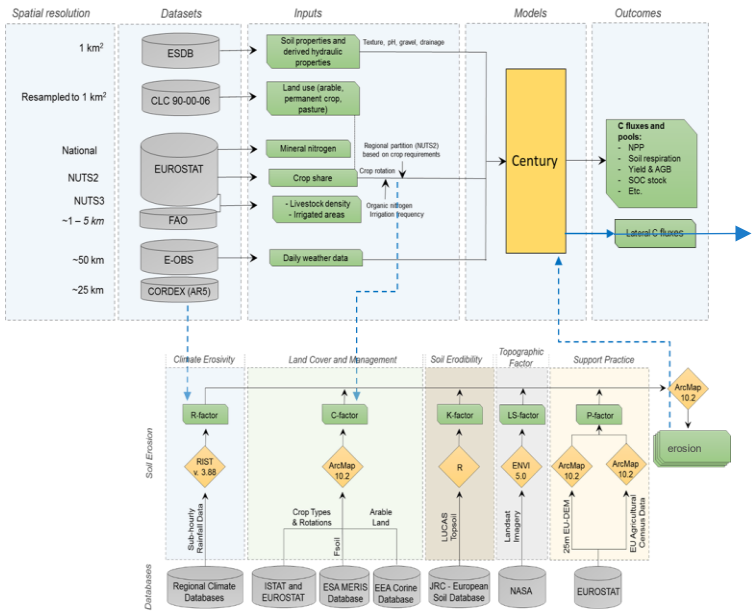
- Soil
- Rewetting of peatlands
- Reductions of fertilizer use

Temporary carbon removals in soils and forests

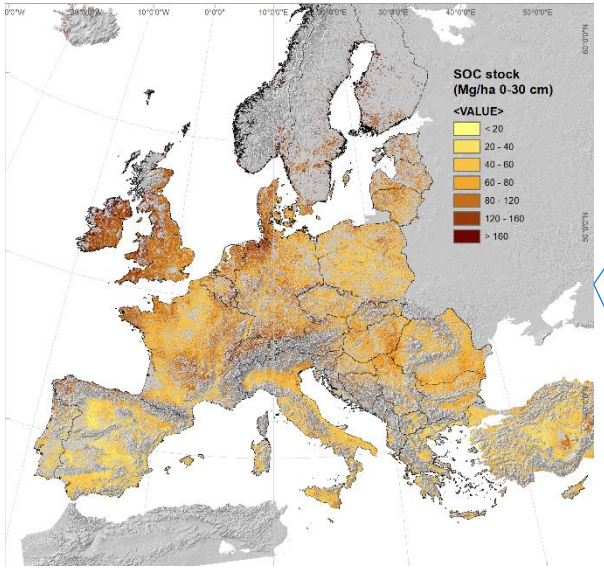
- Time-limited certificate (e.g. 5 or 10 years)
- Certification period can be renewed

Carbon in EU agricultural soils

Biogeochemistry model framework



Carbon fluxes



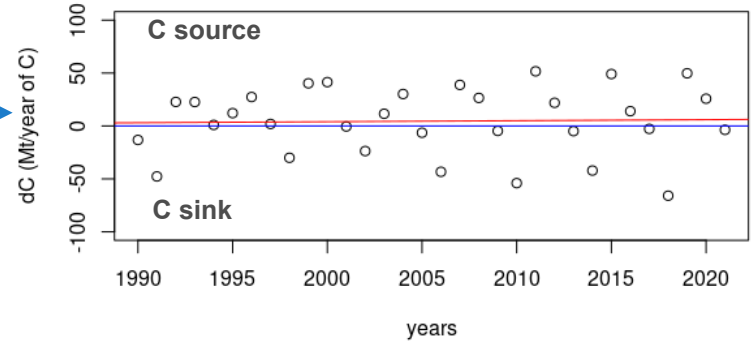
Management practices

Cover crop
Reduced till.
No-till

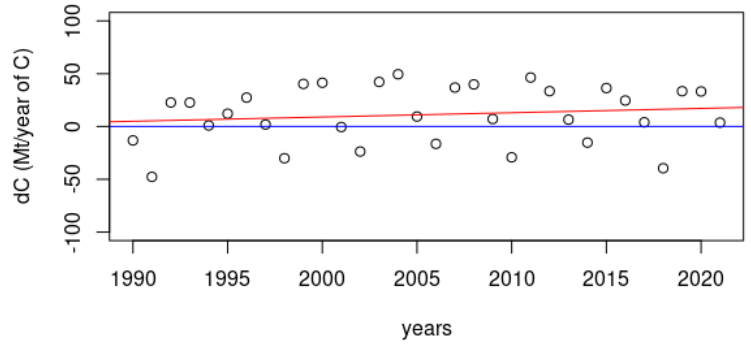
Farm Field Survey
2010-2016

Scenario without management

dC=5.3 Mt yr^{-1} average loss



dC=11.9 Mt yr^{-1} average loss



Lugato E. *et al., Nature Climate Change* **8**, 219–223 (2018)
Lugato E. *et al., Science Advances* **4 (11)**, 2018
Lugato E. *et al., GCB,* **20 (11)**, 2014

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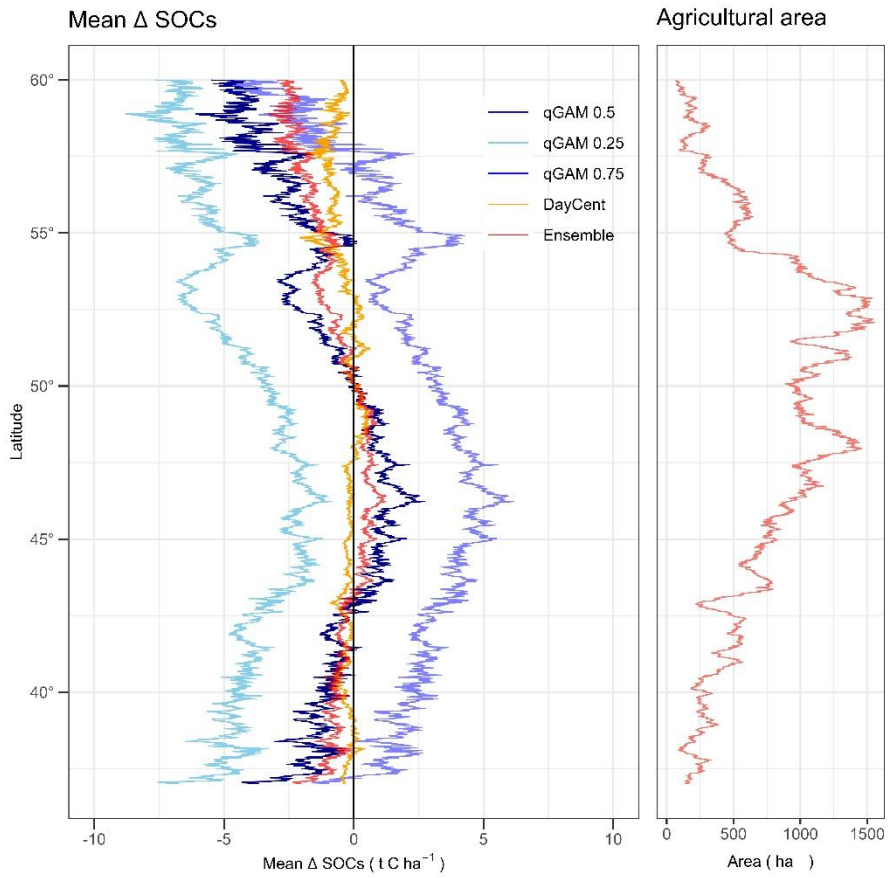
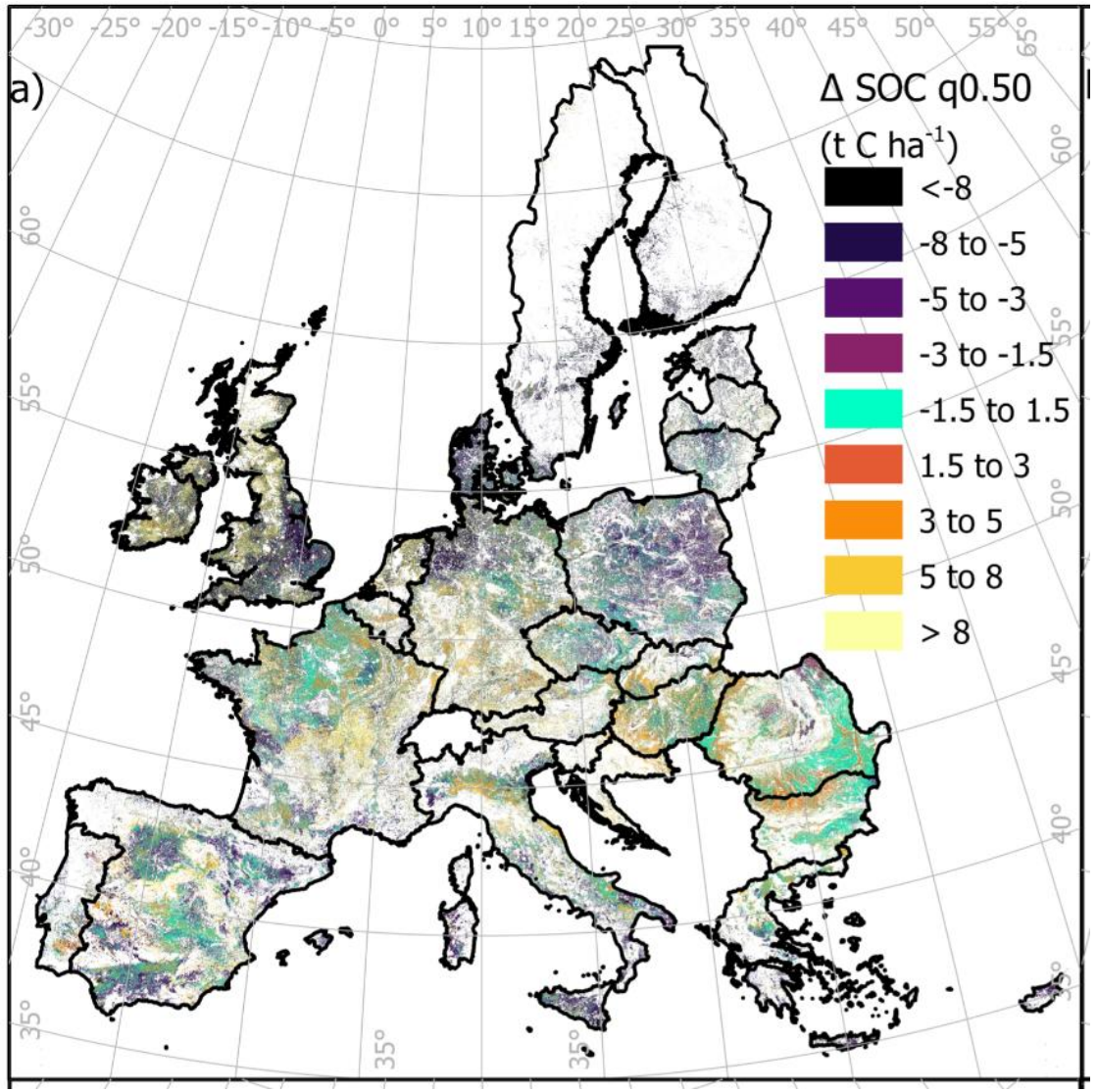
SOC, how much have we lost in the past decade?

-0.75% between 2009 and 2018
~ 70 Mt C (0-0.2m depth) =
28 $MtCO_2e$ per year





De Rosa et al. 2024. Global Change Biology

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Novel assessments on SOC

nature communications

Article

https://doi.org/10.1038/s41467-025-57355-y

Revisiting the soil carbon saturation concept to inform a risk index in European agricultural soils

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The form in which soil organic carbon (SOC) is stored determines its capacity and stability, commonly described by separating bulk SOC into its particulate- (POC) and mineral-associated (MAOC) constituents. MAOC is more persistent, but the association with mineral surfaces imposes a maximum MAOC capacity for a given fine fraction content. Here, we leverage SOC fraction data and spectroscopy to investigate POC/MAOC distribution, together with SOC changes data over 2009–2018 period, across pedo-climatic zones in the European Union and the UK. We find that rather than a universal mineralogy-dependent maximum MAOC capacity, an emergent effective MAOC capacity can be identified across pedo-climatic zones. These findings led us to propose the SOC risk index, combining SOC changes and effective MAOC capacity. We find that between 43 and 83 Mha of agricultural soils are classified as high risk, mostly constrained to cool and humid regions. The index provides a synthetic information to decision makers for preserving and accruing POC and MAOC.

The pathway to climate neutrality foresees the contribution of the land to offset the residual sectorial greenhouse gas emissions by 2050, incrementing the carbon (C) removal from vegetation and soil. In the European Union (EU), operative policy instruments to increase the land C sink are atmospheric carbon dioxide (CO_2) removal targets in the land use, land use change and forestry (LULUCF) regulation[1] as well as the recent Carbon Removal Certification regulation[2], including carbon farming. Agricultural soils in the EU, in particular, are depleted in soil organic carbon (SOC) as compared to other land uses[3]. Furthermore, the majority of EU agricultural soils are far from saturation of the stable mineral-associated organic carbon (MAOC) fraction[4,5], allowing the storage of additional C by changing to appropriate management practices[6,7]. However, a recent data-driven study estimated a relative SOC loss of 0.75% for the period 2009–2018 in European agricultural soils[8]. These SOC losses occurred despite the introduction of both mandatory and voluntary schemes in 2013, aiming at increasing agricultural sustainability[9].

Assessing current bulk SOC content and its change over time (ΔSOC), while fundamental, does not provide enough information for effective SOC sequestration interventions. In the last decades, a new conceptual framework has highlighted the advantage to separate bulk SOC in two fractions that underlie prevailing mechanisms of SOC formation and stabilization, namely the MAOC and the particulate organic carbon (POC)[10]. MAOC is mostly composed of plant and microbial derived compounds low in molecular weight, which can be stabilized by interaction with the soil matrix via sorption and physical protection[11]. Consequently, MAOC is more resilient to degradation compared to POC, and it has a lower turnover time on average[4] which promotes the long-term accrual of atmospheric CO_2 into soil. However, MAOC has a 'theoretical mineral capacity' due to a finite number of mineral surface binding sites, as postulated and demonstrated by a large body of studies[12–14]. Therefore, the degree of MAOC saturation indicates the proportion of measured MAOC over the theoretical capacity. The theoretical mineral capacity is commonly calculated

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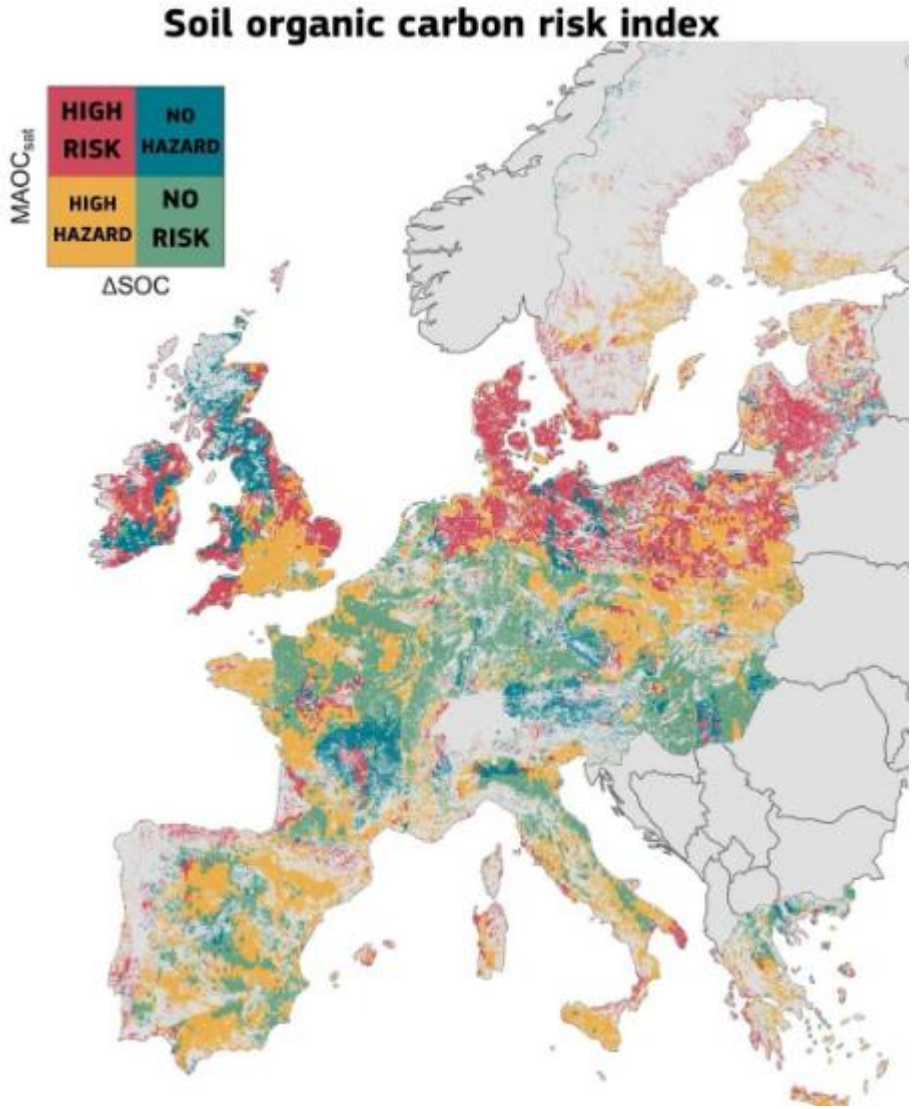
Combination of POC/MAOC distribution with LUCAS Spectra data



43-83 Mha (up to 44%) of EU+UK agricultural land is at risk of losing carbon (in cool and humid regions)

50 Mha could still absorb more, helping mitigate climate change and generate carbon credits.

Important for **sustainable soil management**

Policy relevance:

- *Carbon Removal Certification Framework*
- *Soil Monitoring Law SOC Indicators*

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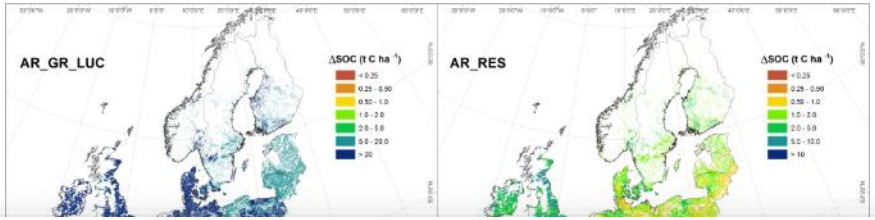
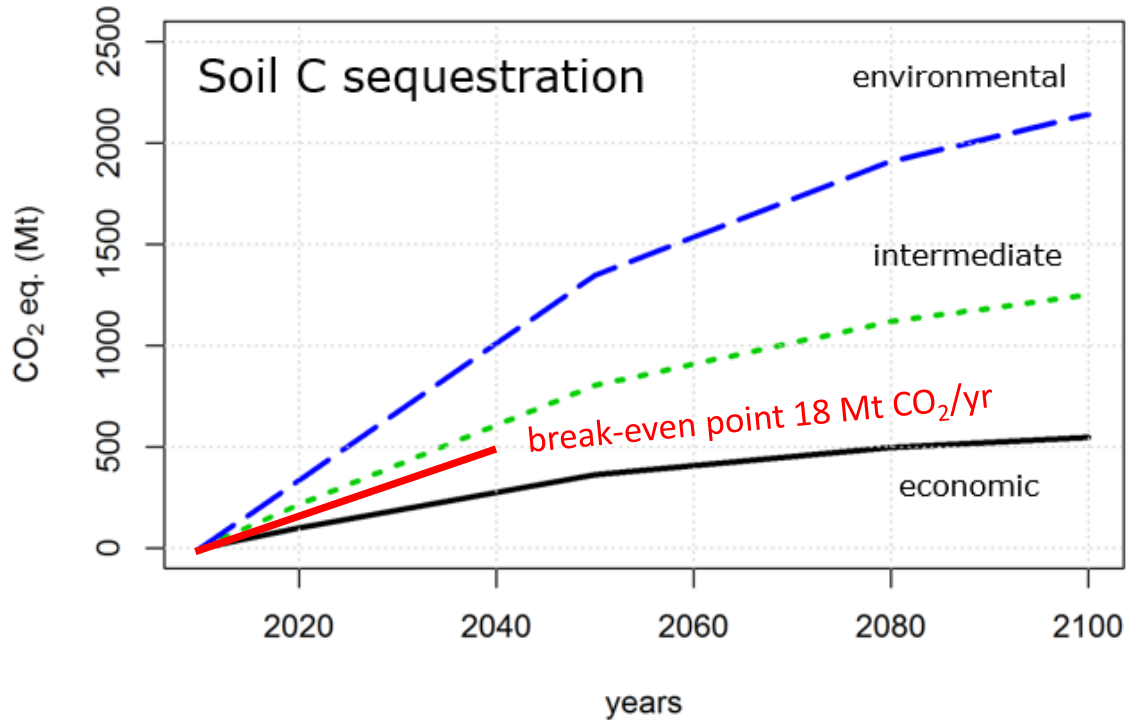
Scenario analysis
(SOC stock changed by 2050)

1) Conversion from arable to grassland (**LUC_AR_GR**);
2) Crop residue management (**AR_RES**);
3) Reduced tillage scenario (**AR_RT**)
4) Combined residue incorporation + reduced tillage (**AR_RET**);
5) Ley in rotation (**AR_LEY**);
6) Cover crop (**AR_CC**);



Arable land allocated to AMP (%)

Scenario	AR_GR_LUC	AR_RES	AR_RT	AR_RET	AR_LEY	AR_CC	Total
Economic	2	2	2	2	2	2	12
Intermediate	5	5	5	5	2	2	24
Environmental	10	2	2	2	5	7	28



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Organic soils: a key “special” issue

EU emissions from organic soils

Source: Annual European Union greenhouse gas inventory 1990–2018

17 Mha -> 95 Mt CO_2

≠

GREIFSWALD MIRE CENTRE

>160 Mt CO_2e

ORGANIC SOILS IN NATIONAL INVENTORY SUBMISSIONS OF EU COUNTRIES

Martin, N. & Couwenberg, J.

Land use subcategory	Area (Kha)	ICECF (tC/ha)	Emissions from Org. Soils. (Kt CO_2)
4A1	12 264	[-2.60; 0.65]	13 631
4A2	407		1 494
4B1	1 242	[-10.01; -1.00]	25 813
4B2	273		5 814
4C1	4 132	[-6.80; 0.25]	42 150
4C2	354	Large uncertainty EF	5 683

85%

The EU emissions from organic soils are at least 4-5 times (7-8 times Greifswald estimates) higher those from croplands

Peatlands as a hotspot of emissions

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How healthy soils may increase EU competitiveness?

5th EUSO Stakeholder Forum

Decarbonization and Competitiveness	Closing Innovation Gap	Reducing Excessive Dependencies and Increasing Security
	Remediation	
Banking & Insurance	Banking & Insurance	
	Biotechnology and Biodiversity	Biotechnology and Biodiversity
	Agritech Solutions	Agritech Solutions
	Biofertilizers & Pesticides	Biofertilizers & Pesticides
Circular Economy	Circular Economy	Circular Economy
Carbon Farming	Carbon Farming	Carbon Farming
	Laboratories	
Regenerative Agriculture	Regenerative Agriculture	Regenerative Agriculture

Main highlights:

The need for acceleration: The current progress in soil health and sustainability is not sufficient to meet the challenges posed by food security, climate change, soil degradation and biodiversity loss.

Carbon Farming is a business model with high economic potential (almost to 13 billion Euros opportunity) involving many actors and can be an attractive for farmers, certificating authorities, auditors

Regenerative agriculture has the potential to transform the agricultural sector and contribute to a more sustainable food system. However, it is in its infancy in the EU due to economic, cultural and structural barriers.

Farmers' profit is very important. However, social benefits and sustainability needs to be also addressed.

AgriTech Solutions – AI and Open Data

https://esdac.jrc.ec.europa.eu/euso/5th-euso-stakeholders-forum

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Thank you

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