Design of a high-resolution and dynamic soil organic carbon monitoring system for agricultural land

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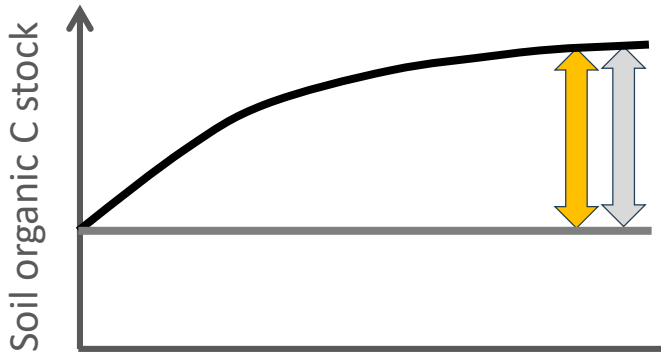
1- INRAE, France
2- ILVO, Belgium
3- Thunen Institute, Germany
4- Wageningen Research, The Netherlands
5- Aarhus University, Denmark

Expected outcome?

More Soil Organic Carbon for GHG mitigation & for soil health

a)

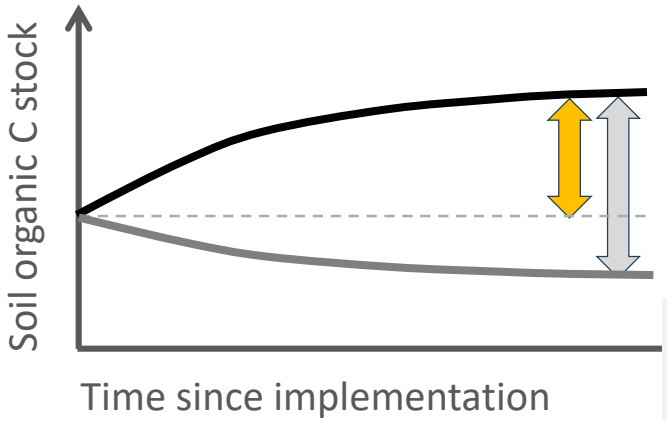


✓ SOC stock accrual
✓ C sequestration
✓ Net C removal

SOC stock accrual | C sequestration in soil

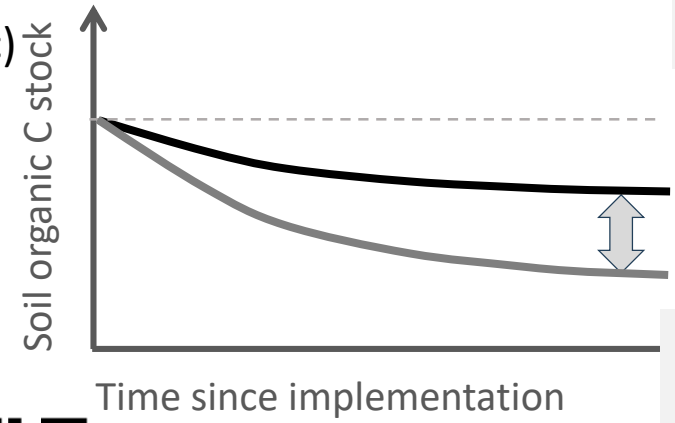
Need to quantify SOC stocks at:
➜ Time 0
➜ Business as usual scenario

b)



✓ SOC stock accrual
✓ SOC loss mitigation
✓ C sequestration
✓ Net C removal

c)



✓ SOC stock accrual
✓ SOC loss mitigation
✗ C sequestration
✗ Net C removal

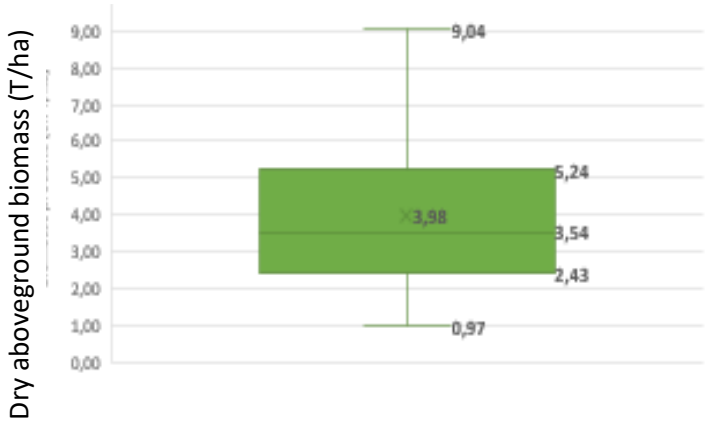
A.Don et al. 2023 GCB

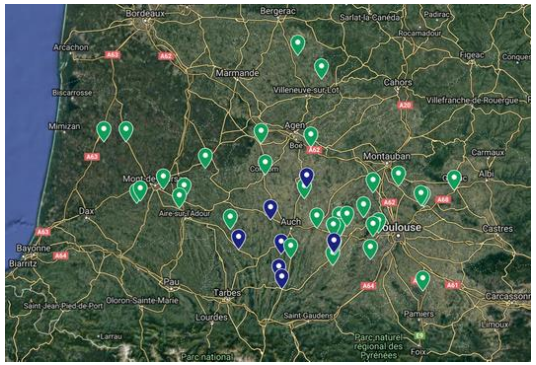
CARBOSEQ

Why a results-based MRV system ?

Because additional SOC storage of a given measure depends on pedoclimatic conditions & management

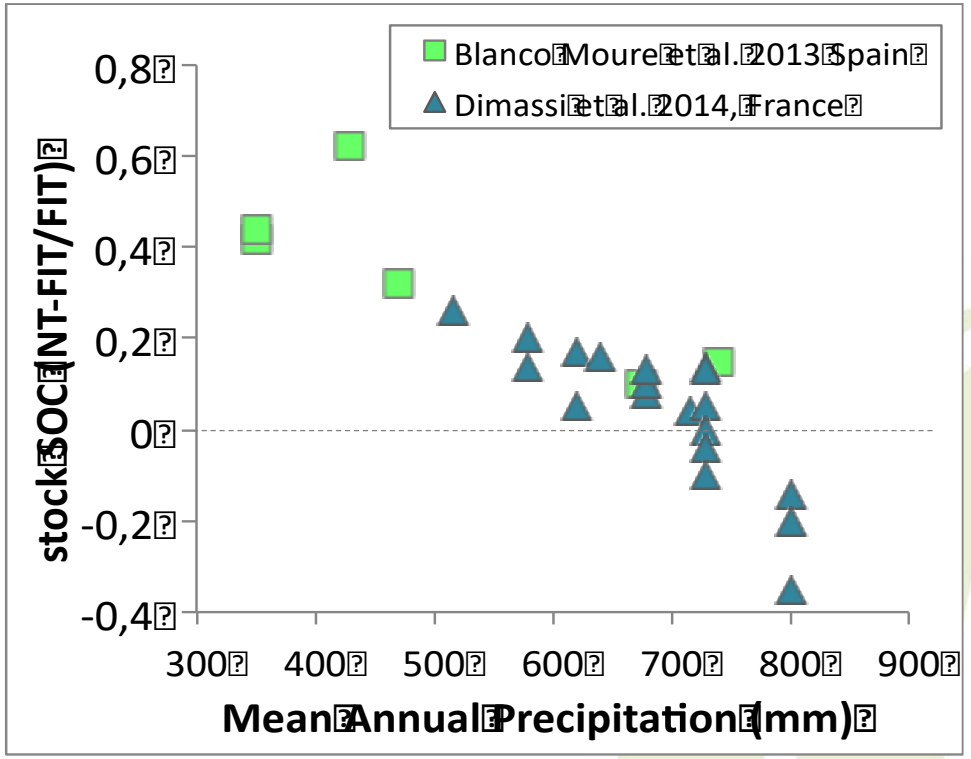
Cover crops:





Inter-crop spatial variability : In-situ cover crop biomass measurements at 57 plots in South West France (©E. Cescia, INRAE)

No-tillage:

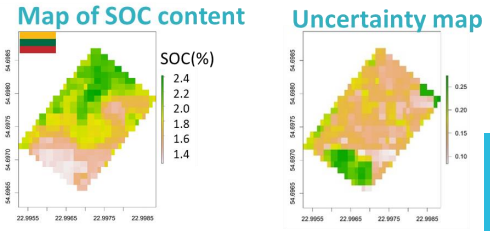


Measuring, modelling ? Why a “hybrid” MRV system ?

Direct soil sampling and SOC measurement ?

- Sensitivity :
  - Small Δ over large stocks
  - Slow changes
  - Spatial variability

=> High costs!



Castaldi et al., 2023

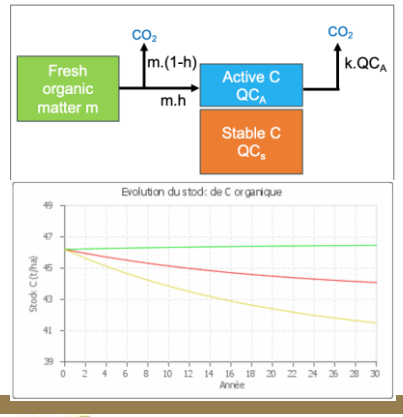
Direct SOC measurement via remote sensing?

- Accuracy and uncertainty
- C contents not stocks

=> Not mature yet for SOC !

Modelling?

- Detailed input parameters needed
  - Soil texture, type
  - Initial SOC
  - Management (e.g, rotation, tillage, fertilisation, etc)



⇒ High administrative burden!

⇒ Explore other info sources..

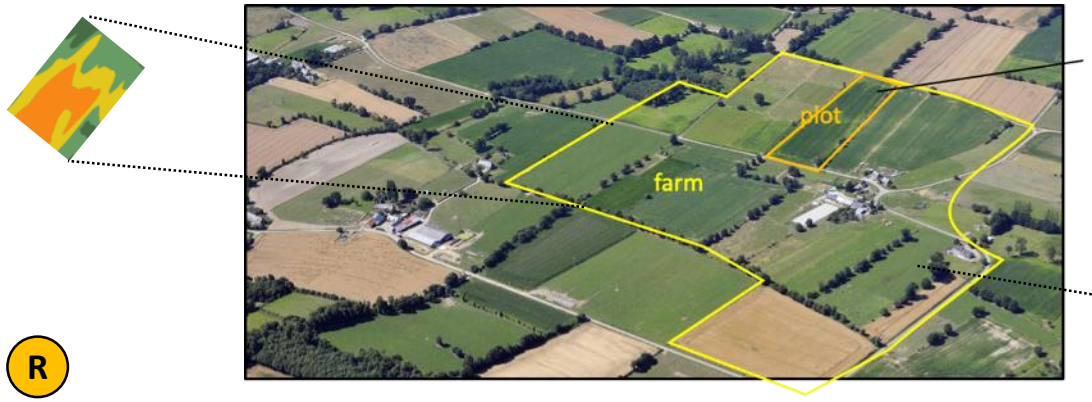
Example of Soil C Monitoring, Reporting and Verification approach

MARVIC
MRV for carbon farming
Funded by the European Union

A FARM DATA M R

G BENCHMARK SITES M

B REMOTE SENSING M R V



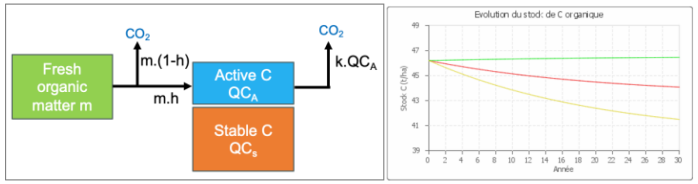
F SAMPLING ALGORITHMS

E SOIL SAMPLING & MAPPING M V

C DATASOURCES M R

D CROP-SOIL MODELS

Evolution of SOC stocks over time



CIRCASA

Adapted from
Smith et al. 2020, GCB
Ruysschaert et al. 2022

1- Eligibility check

MARVIC
MRV for carbon farming
Funded by the European Union

A FARM DATA

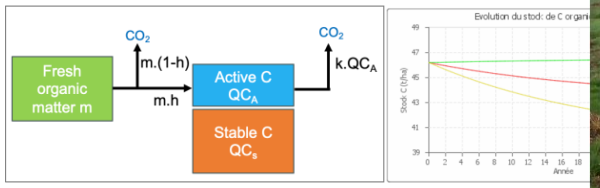
- Field/farm/ IACS data
- Management data

B REMOTE SENSING

- Activity data (crop rotation, harvest, tillage operations etc..)
- Biomass
- Soil properties

C DATASOURCES

D CROP-SOIL MODEI



- Management options envisioned ?
  - Efficiency / SOC accrual?
  - Potential leakage?
  - Environmental & biodiversity potential effects?
  - Additionality?

The issue of organic amendments: no net C removal

Chenu et al. 2019 STILL

2- Quantifying potential SOC accrual & C removal

MARVIC
MRV for carbon farming
Funded by the European Union

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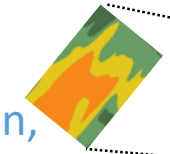
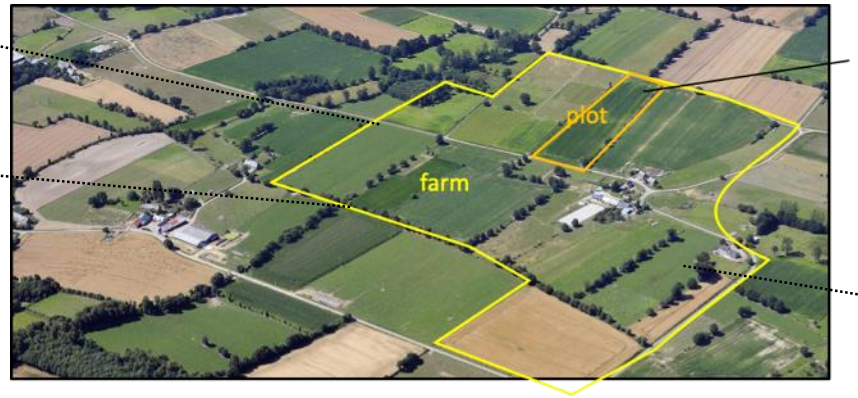




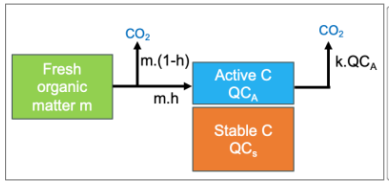
G BENCHMARK SITES M

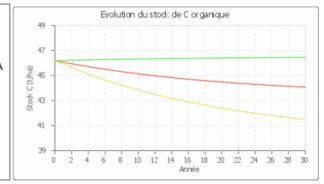
F SAMPLING ALGORITHMS

E SOIL SAMPLING & MAPPING M
- Initial sampling
-

C DATASOURCES M
- climate
- soil
- land cover

D CROP-SOIL MODELS
- Soil models estimating SOC/GHG
- Vegetation models estimating C budget





Evolution of SOC stocks over time

3- Reporting and verifying

MARVIC
MRV for carbon farming
Funded by the European Union

A FARM DATA M R
- Field/farm/ IACS data
- Management data

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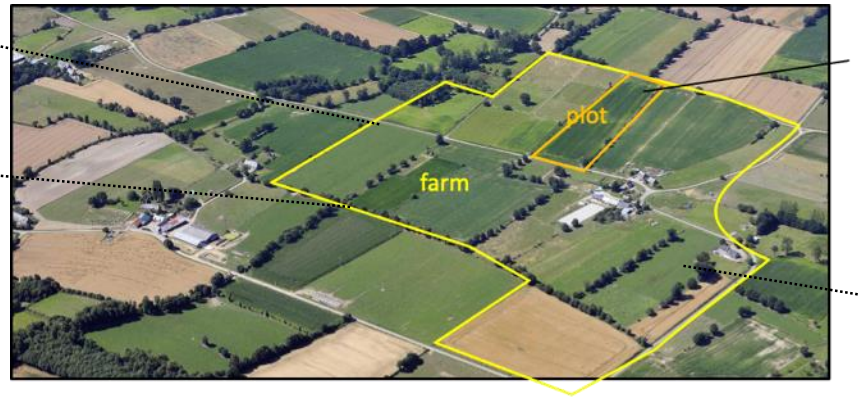
- Activity data (crop rotation, harvest, tillage operations etc..)
- Biomass
- Soil properties

C DATASOURCES M R
- climate
- soil
- land cover



G BENCHMARK SITES M

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Where, how many, when and how to sample

E SOIL SAMPLING & MAPPING
M V
- Initial sampling
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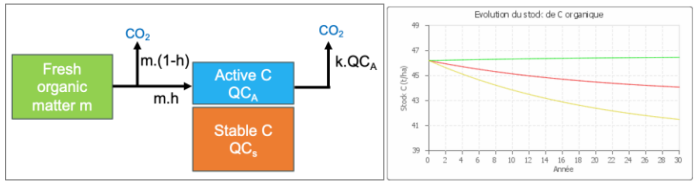
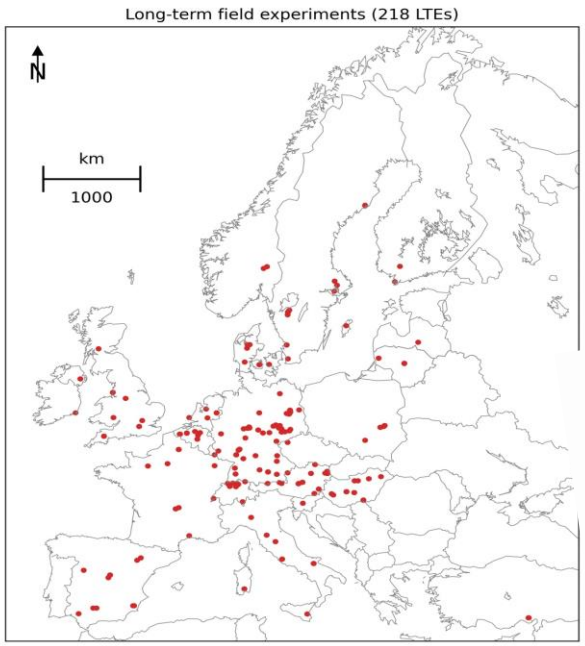


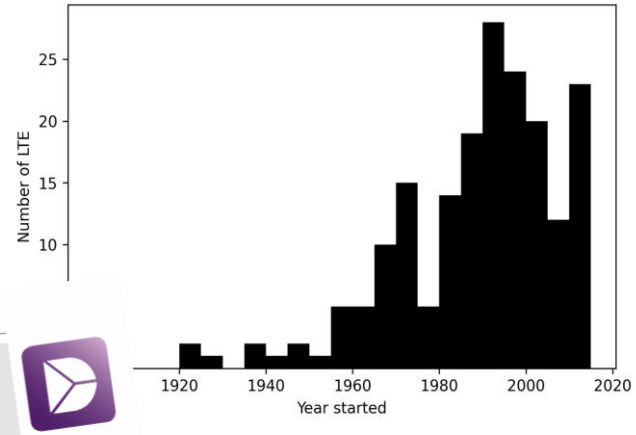
Evolution of SOC stocks over time

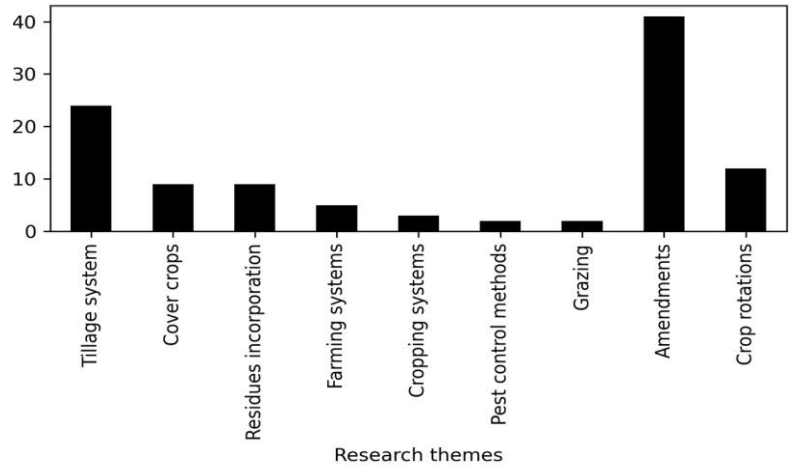
Benchmark sites

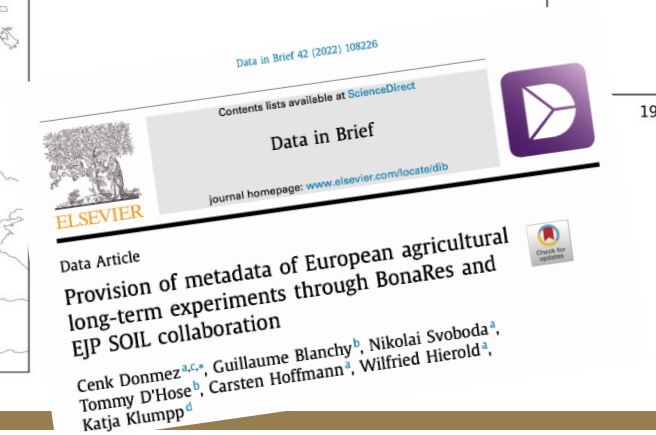
G BENCHMARK SITES M

- Testing C farming practices, EF
- Measuring GHG fluxes
- Developing, calibrating & validating models








Data in Brief 42 (2022) 108226

Contents lists available at ScienceDirect

Data in Brief

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

ELSEVIER

Data Article

Provision of metadata of European agricultural long-term experiments through BonaRes and EJP SOIL collaboration

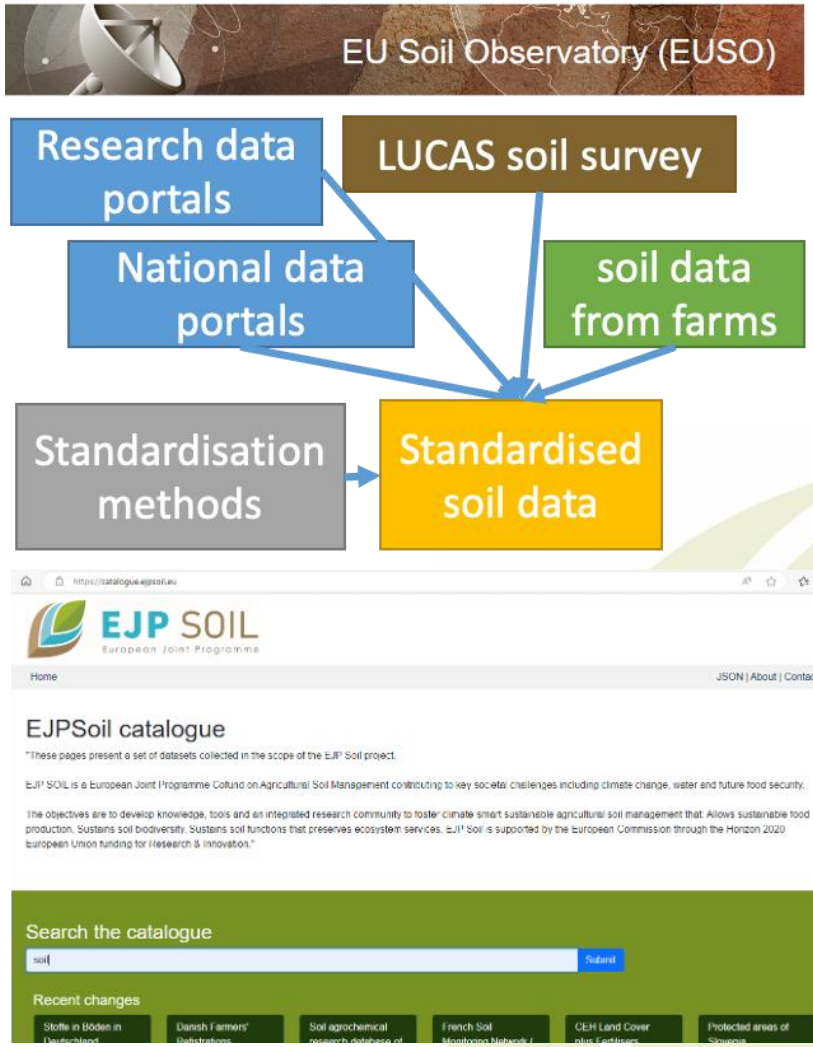
Cenk Donmez[a,c,*], Guillaume Blanchy[b], Nikolai Svoboda[a], Tommy D'Hose[b], Carsten Hoffmann[a], Wilfried Hierold[a], Katja Klumpp[d]

https://lte-eu.bonares.de/experiments

Domnez et al. 2022, Data in Brief

Hybrid, high resolution, dynamic MRV approach

- **Smart assembly** of building blocks (operational processing chains)
- **Automated inputs to models:** as much as possible
  - **Remote sensing**: crop types, carbon inputs, farm activities, soil properties
  - Link with already **publicly available existing data**: e.g. LPIS, GSAA, LUCAS, national databases, research databases
  - Work on **data harmonisation/standardization and interoperability** (e.g. work EJP SOIL WP6, EUSO, Soil Mission, SoilWise etc)
  - Link with **already recorded farm data** (e.g. lab data, harvest machinery, farm management systems) & with **regional data spaces**, e.g. farm data sharing platform https://www.djustconnect.be/en



https://www.ejp.eu

How can such a system comply to the Regulation on Carbon Removals Certification QU.A.L.ITY criteria?

QUANTIFICATION

Carbon removal activities are measured against a baseline and are net of supply-chain emissions

- Time 0 measurements/ soil data
- Modelling of BAU
- GHG emission estimates (emission factor, modelling)

ADDITIONALITY

Carbon removal activities go beyond standard market practices and what is legally required to the operator

- Eligibility step
- Farm data
- Remote sensing/farm practices

LONG-TERM STORAGE

Certificates clearly account for the duration of carbon storage and distinguish permanent storage from temporary storage

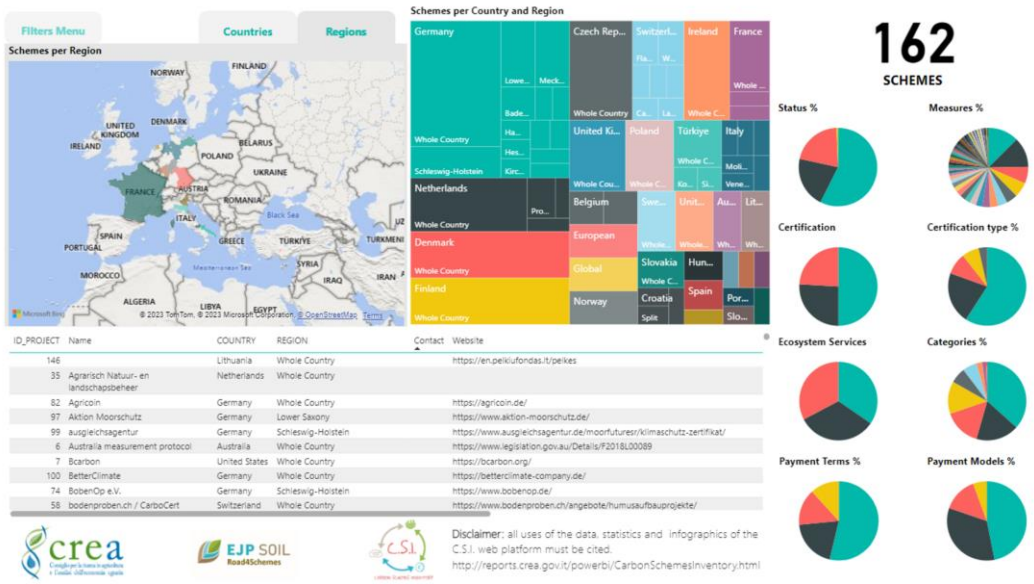
- Remote sensing for C input and activity
- Modelling the effects of climate change on biomass and SOC

SUSTAINABIL**ITY**

Carbon removal activities do not harm the environment or even benefit other environmental objectives such as biodiversity

- Evaluating ecosystem services provision and biodiversity

How can such a system comply to the Regulation on Carbon Removals Certification QU.A.L.ITY criteria?



SUSTAINABILITY

Carbon removal activities do not harm the environment or even benefit other environmental objectives such as biodiversity

- Evaluating ecosystem services provision and biodiversity

EJP SOIL SIREN
Inventory of current indicator systems

EJP SOIL SERENA
Common definitions, thresholds inventory/proposal

EJP SOIL MINOTAUR
Prioritizing biodiversity indicators

EJP SOIL European Joint Programme WP6
WP6: "D6.5 Guidelines for accounting and mapping agricultural soil carbon, fertility and degradation changes at different scales"

Soil Health BENCHMARKS

How can such a system comply to the Regulation on Carbon Removals Certification QU.A.L.ITY criteria?

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✓

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✓

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SUSTAINABIL**ITY**

Carbon removal activities do not harm the environment or even benefit other environmental objectives such as biodiversity

✓ ✗

- Evaluating ecosystem services provision and biodiversity

Design of a high-resolution and dynamic soil organic carbon monitoring system for agricultural land

- Store more C in soils **for ecosystem services and GHG mitigation**. Not only C!
- **"Mixed" carbon farming systems**: practice-based & results-based MRV both needed
- **Adapted to different context of application**
  - National inventories, CAP, agri-food sector insetting, voluntary markets
- **Hybrid MRV systems** : measurements & modelling & realistic biomass estimates through remote sensing
- **Automated, modular, large scale but high resolution, uncertainty analysis and low cost**
- **Issues:**
  - The **references**: time 0, BAU, regional standard baseline
  - **Soil data**: spatial resolution, harmonization
  - **Data assimilation & assemblage**

Several projects working on it now !

MARVIC
MRV for carbon farming

EU Soil Observatory (EUSO)

SoilWise
KNOWLEDGE & DATA FLOWS

MRV4SOC

EU MISSIONS
SOIL DEAL FOR EUROPE

EJP SOIL
European Joint Programme

ORCaSa
Because soil carbon matters

Thank you for your attention

EJP SOIL has received funding from the European Union's Horizon 2020 research and innovation programme: Grant agreement No 862695

www.ejpsoil.eu
claire.chenu@inrae.fr

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Additional slides

EJP SOIL has received funding from the European Union's Horizon 2020 research and innovation programme: Grant agreement No 862695

Example of Soil C Monitoring, Reporting and Verification approach

MARVIC
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Funded by the European Union

A FARM DATA M R
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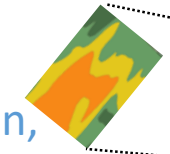
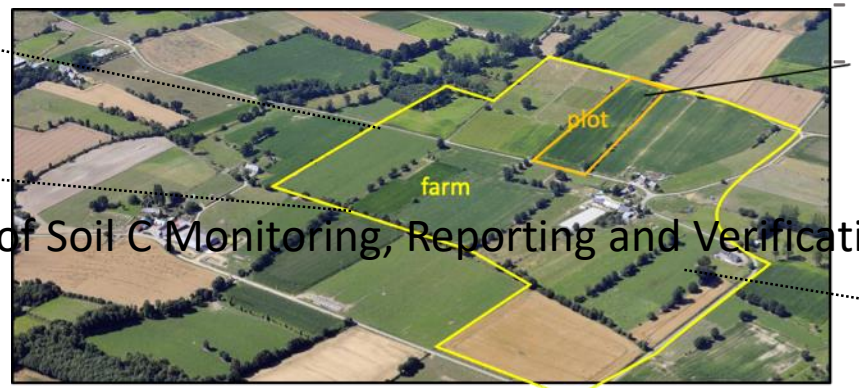
- Biomass
- Soil properties





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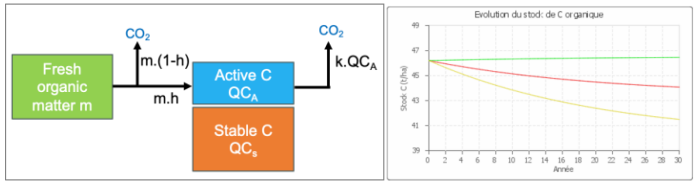


Evolution of SOC stocks over time

G BENCHMARK SITES M
- Testing C farming practices, EF
- Measuring GHG fluxes
- Developing, calibrating & validating models

F SAMPLING ALGORITHMS

Where, how many, when and how to sample

E SOIL SAMPLING & MAPPING

M V
- Initial sampling
- Ground-truthing for V

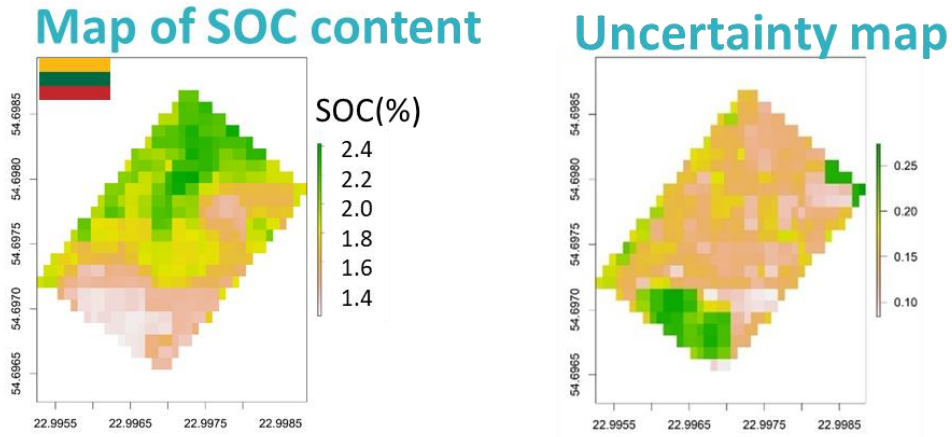
Direct Remote sensing of SOC

For now:

- accuracy / uncertainty of the predicted SOC maps according to several methods and scales is still under investigation
- content considered rather than stock
- spatial uncertainties might be large but most often not provided
- regions with arid/semi-arid climate have intrinsic cumulated scientific locks …under investigation
- need of field samples +agricultural practices

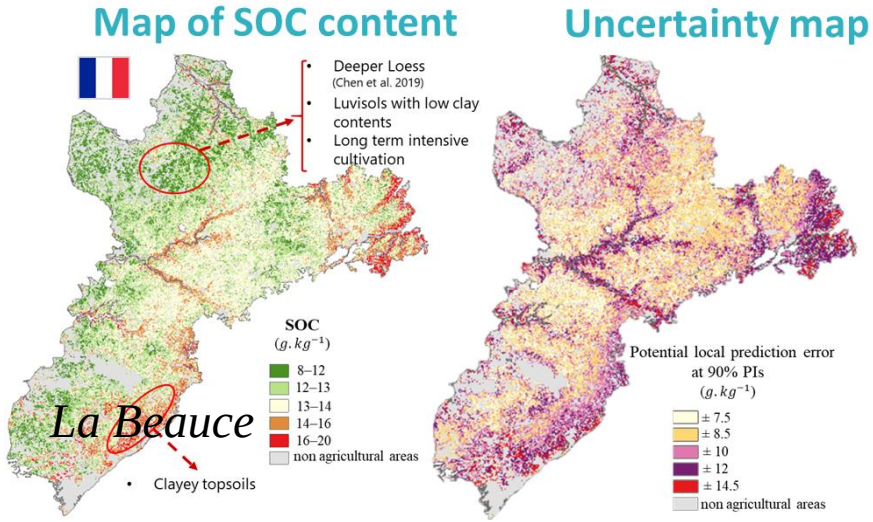
Vaudour et al., 2022 - doi.org/10.3390/rs14122917
Richer-de-Forges et al., 2023 - doi.org/10.3390/rs15123070

local scale
(field 2.8 ha)



Castaldi et al., 2023 - doi.org/10.1016/j.isprsjprs.2023.03.016

regional scale
(4838 km²)

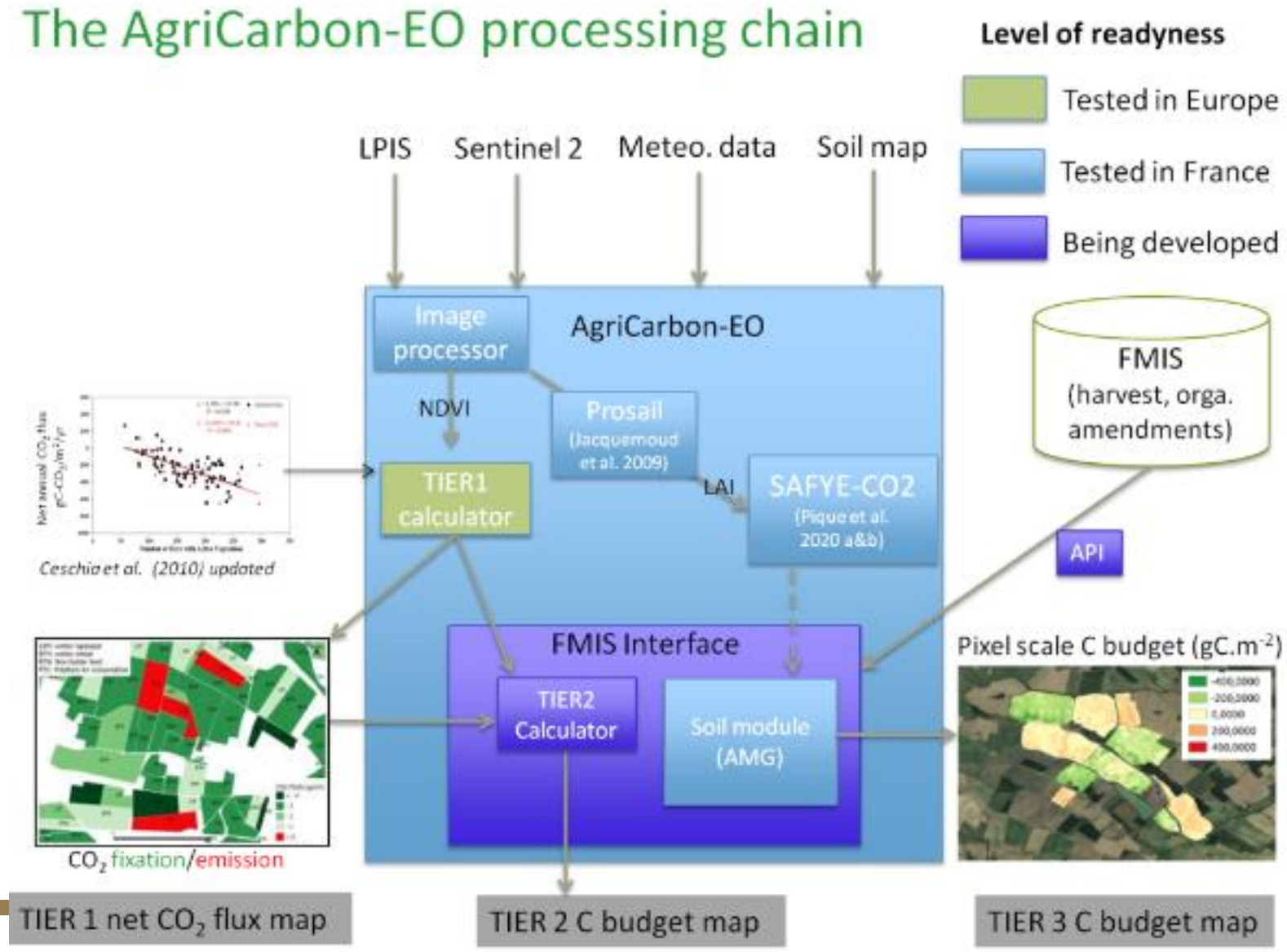


Urbina-Salazar et al., 2023 - doi.org/10.3390/rs15092410

Not mature enough to be used as direct input in C balance modelling approach
➔ keep on using in situ data or derived maps for model initialisation + use as input for smart sampling strategies

EJP SOIL
European Joint Programme

Example of MRV operational processing chain



Source: Eric Ceshia, INRAE, FR