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

Claire Chenu, Greet Ruyschaert, Eric Ceschia, Axel Don, Fenny Van Egmond, Antonio Bispo, Martin Thorsoe, Suzanne Reynders, Maria Fantappiè

2nd meeting of the Carbon Removals Expert Group
Carbon Farming: mapping of certification methodologies
21-22 June 2023 Brussels

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

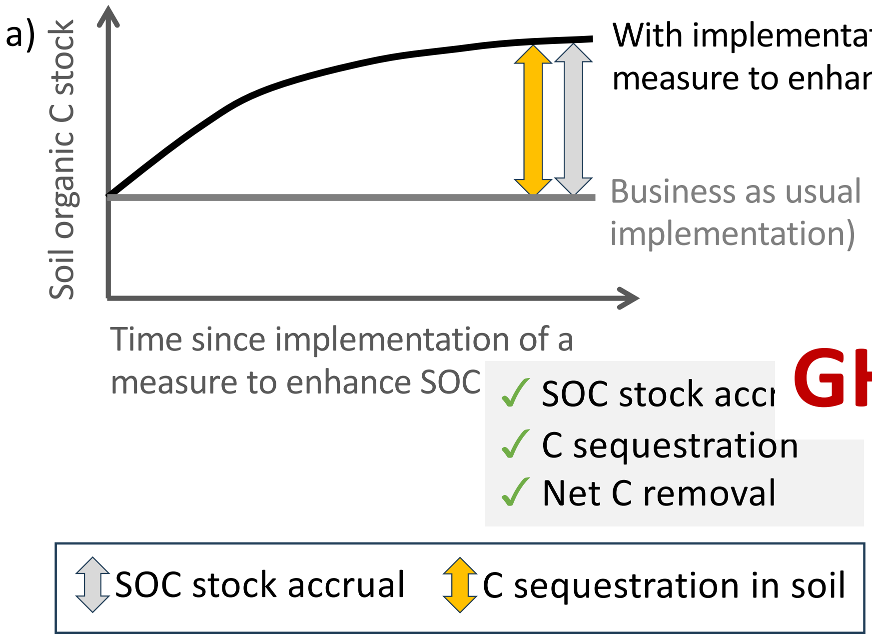
Claire Chenu[1], Greet Ruyschaert[2], Eric Ceschia[1], Axel Don[3], Fenny van Egmond[4], Antonio Bispo[1], Martin Thorsoe[5], Suzanne Reynders[1], Maria Fantappiè[9]

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

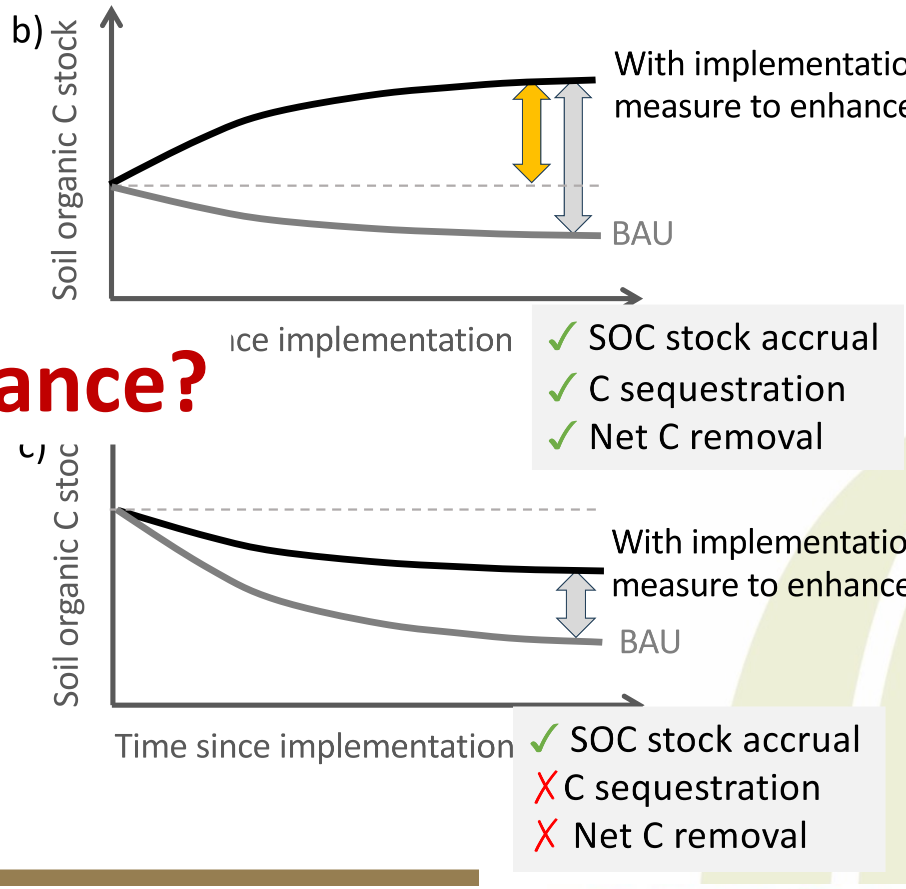
EJP SOIL
European Joint Programme

What is the expected outcome?

More Soil Organic Carbon for GHG mitigation
for soil health improvement



GHG balance?

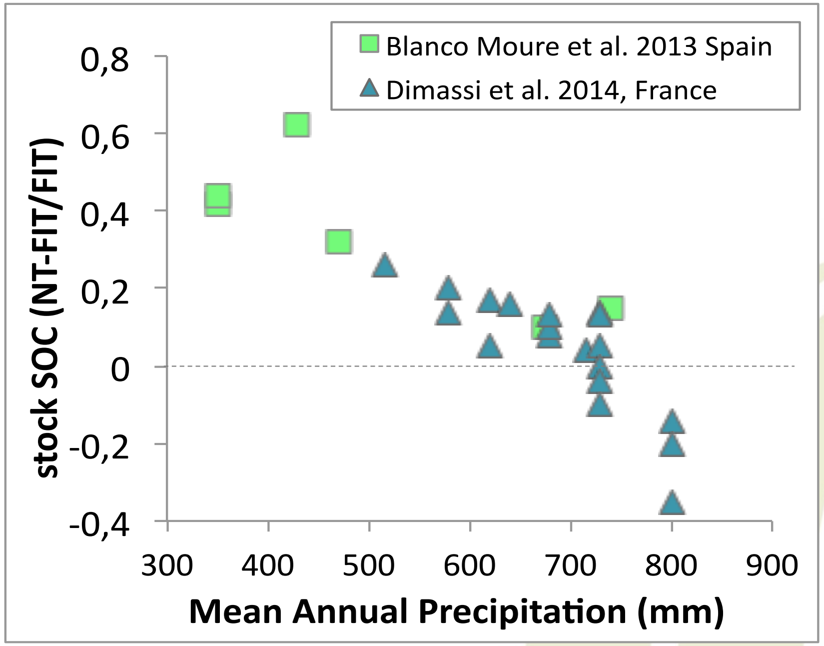


➜ Time 0 SOC stock value
➜ Business as usual scenario

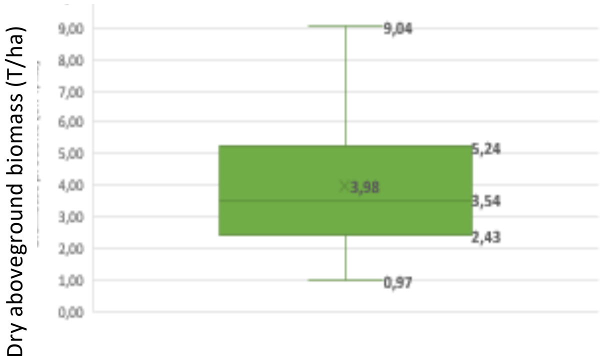
Why a results-based MRV system ?

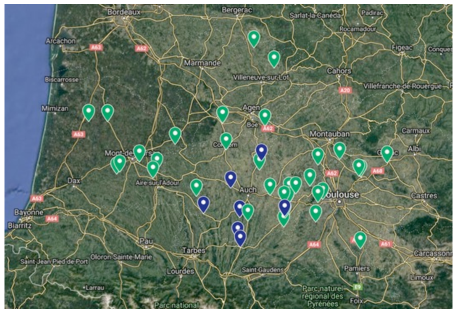
Because additional SOC storage of a given measure depends on the pedoclimatic conditions

No-tillage



Cover crops





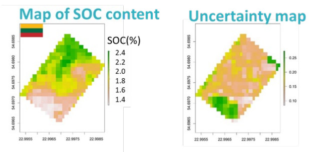
Inter-crop spatial variability : In-situ cover crop biomass measurements at 57 plots in South West France (©E. Cescia, INRAE)

Why a “hybrid” MRV system ?

Direct soil sampling and SOC measurement ?

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

=> High costs!

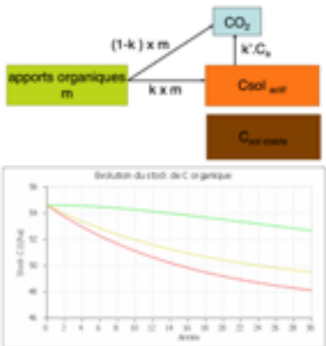


Castaldi et al., 2023

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
  - Details on management (e.g, rotation, tillage, fertilisation, etc)

⇒ High administrative burden!
⇒ Explore other info sources

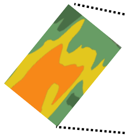
Example of Soil C Monitoring, Reporting and Verification approach

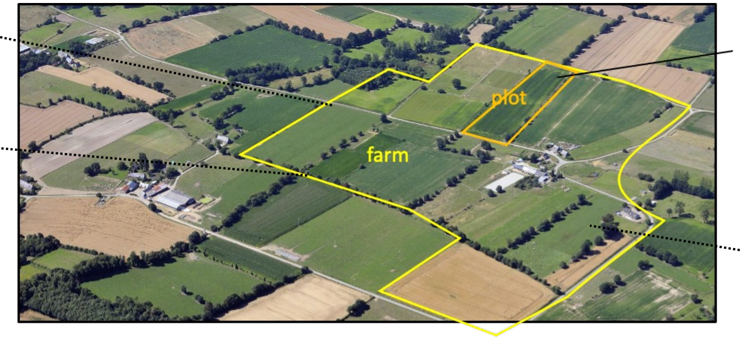
MARVIC
MRV for carbon farming
Funded by the European Union

A FARM DATA (M) (R)

G BENCHMARK SITES (M)

B REMOTE SENSING (M) (R) (V)



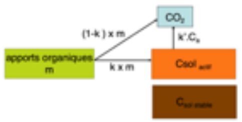


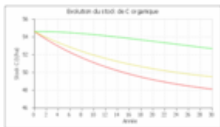
F SAMPLING ALGORITHMS

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 Ruyschaert et al. 2022

APPLY	ENROLL	QUANTIFY	VERIFY/REPORT
Eligibility check	T0, BAU and Cseq potential	Transparent, robust outcomes	Transparent, verifiable outcomes
A B	A C D E	D E	F ⇨ E D

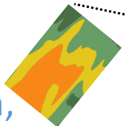
1- Eligibility check

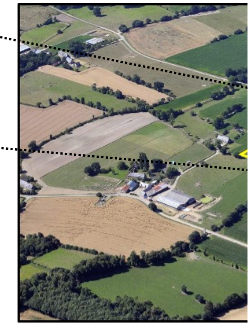
A FARM DATA (M) (R)

- Field/farm/ IACS data
- Management data

B REMOTE SENSING (M) (R) (V)

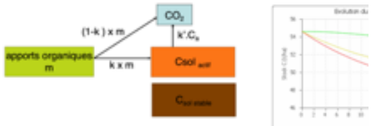
- Activity data (crop rotation, harvest, tillage operations etc..)
- Biomass
- Soil properties





C DATASOURCES (M) (R)

D CROP-SOIL MODEL



APPLY — Eligibility check (A) (B)

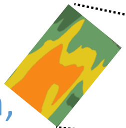
ENROLL — T0, BAU and Cseq potential (A) (C) (D) (E)

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

2- Enroll

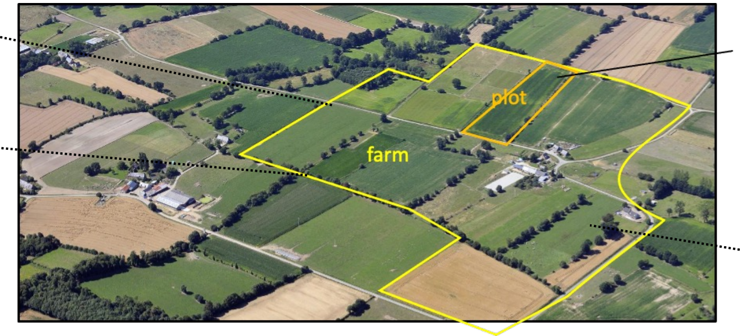
A FARM DATA (M) (R)
- Field/farm/ IACS data
- Management data

B REMOTE SENSING (M) (R) (V)



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

C DATASOURCES (M) (R)
- climate
- soil
- land cover



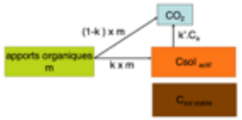
G BENCHMARK SITES (M)

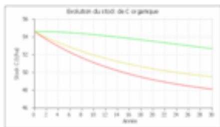
F SAMPLING ALGORITHMS

E SOIL SAMPLING & MAPPING (M) (V)
- Initial sampling
-

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

Evolution of SOC stocks over time





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3- Quantify

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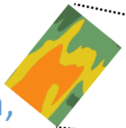
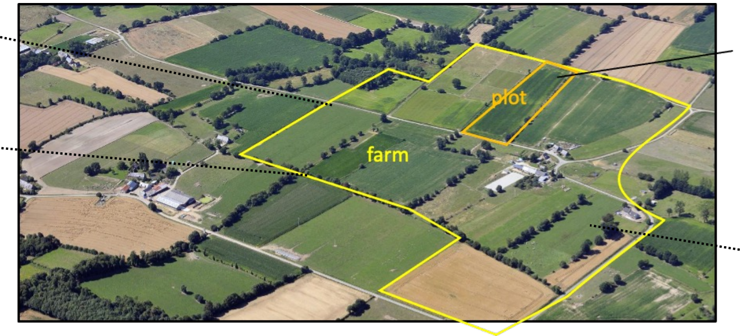
- Soil properties





C DATASOURCES (M) (R)

- climate
- soil
- land cover

G BENCHMARK SITES (M)

F SAMPLING ALGORITHMS

E SOIL SAMPLING & MAPPING

(M) (V)

- Initial sampling
-

D CROP-SOIL MODELS → **Evolution of SOC stocks over time**

- Soil models estimating SOC/GHG
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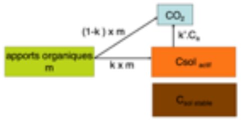

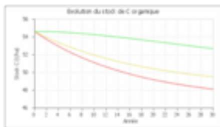

APPLY	ENROLL	QUANTIFY	VERIFY/REPORT
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5- Verify and Report

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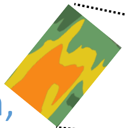

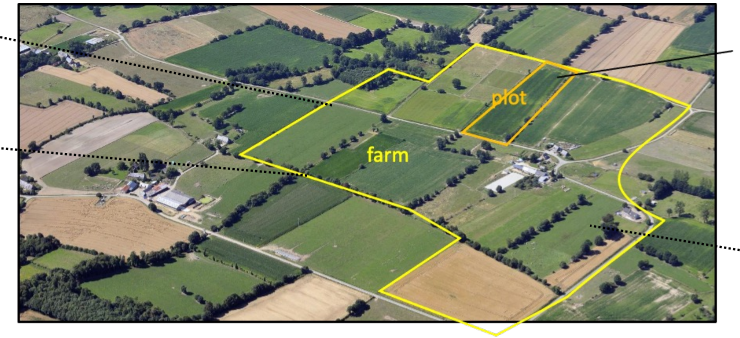

G BENCHMARK SITES (M)

F SAMPLING ALGORITHMS
Where, how many, when and how to sample

E SOIL SAMPLING & MAPPING (M) (V)
- Initial sampling
- Ground-truthing for V

C DATASOURCES (M) (R)
- climate
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- Soil models estimating SOC/GHG
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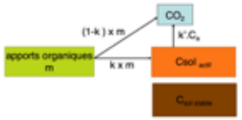

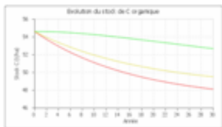

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Develop MRV methodologies

MARVIC MRV for carbon farming
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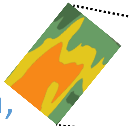

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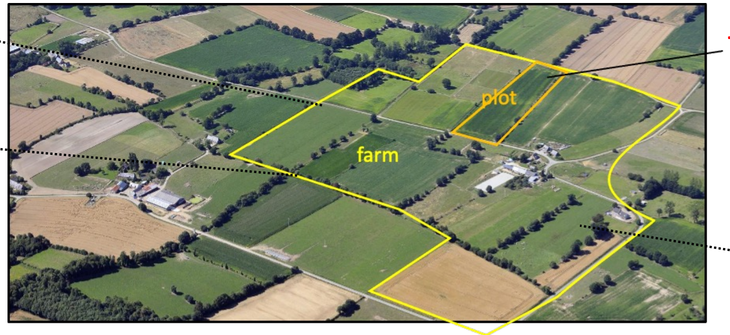

G BENCHMARK SITES M

- Test CF practices
- Measure fluxes
- Develop/refine models

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Where, how many, when and how to sample

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- Precision sampling M

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- Soil models estimating SOC/GHG
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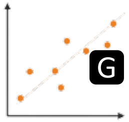
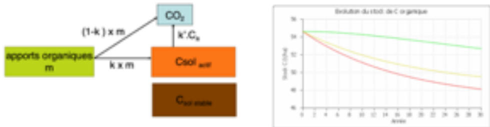
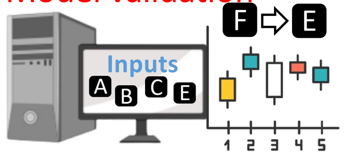
Evolution of SOC stocks over time

Model calibration





Model validation



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

Develop MRV methodologies

Apply MRV in CF schemes

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Example of Soil C Monitoring, Reporting and Verification approach

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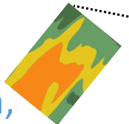

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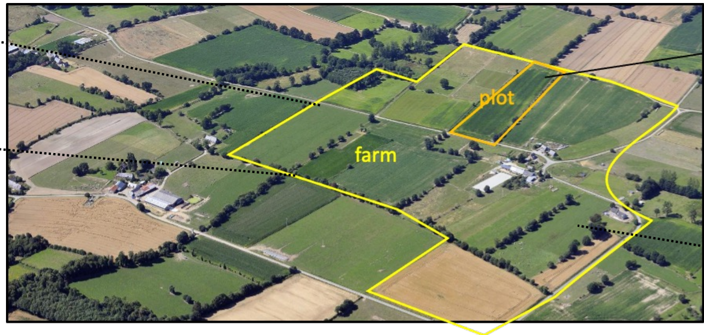

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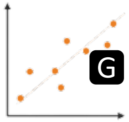
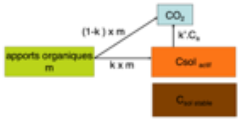
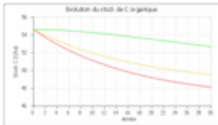
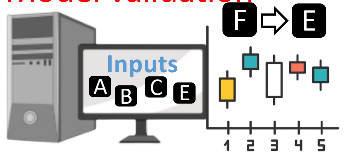






Model validation



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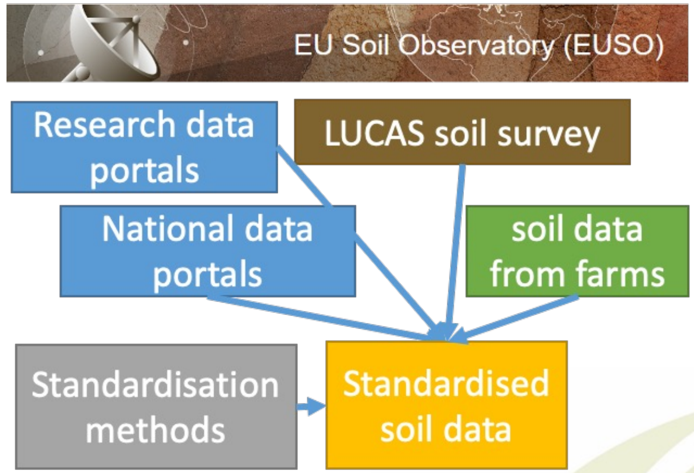
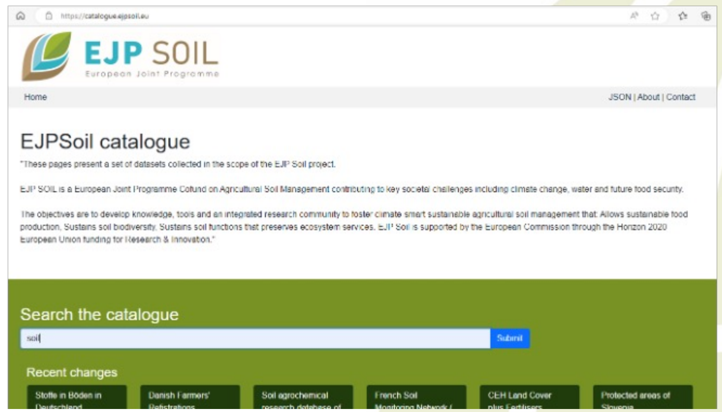
Hybrid, high resolution, dynamic MRV approach

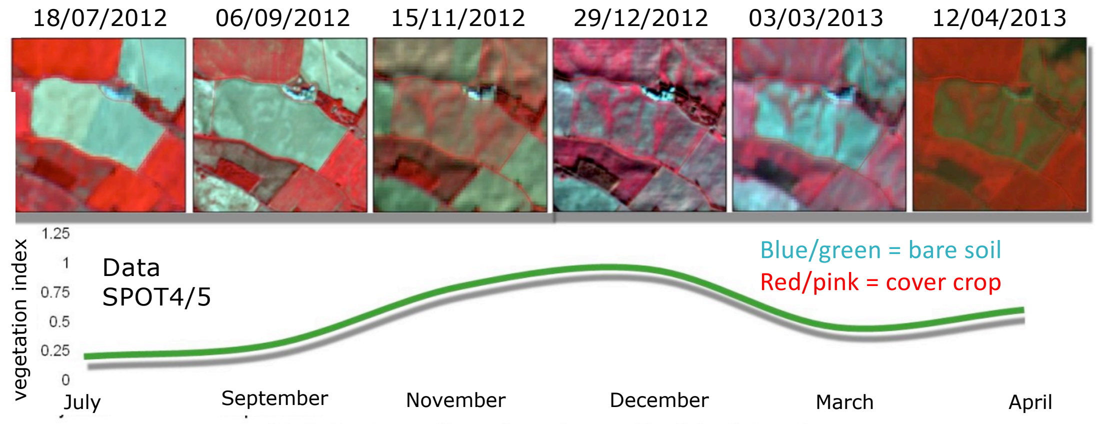
- **Smart assembly** of building blocks (operational processing chains)
- **Automated inputs to models:** as much as possible
  - **Remote sensing**: crop types, carbon inputs, farm activities, soil properties
  - Link with already **publicly available existing data**: e.g. LPIS, GSAA, LUCAS, national databases, research databases (country dependent)
  - 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**, eg farm data sharing platform https://www.djustconnect.be/en





Remote sensing for accurate assessment biomass production and restitution to the soil

High intra plot spatial variability cover crop development
(@E. Cescia, INRAE)



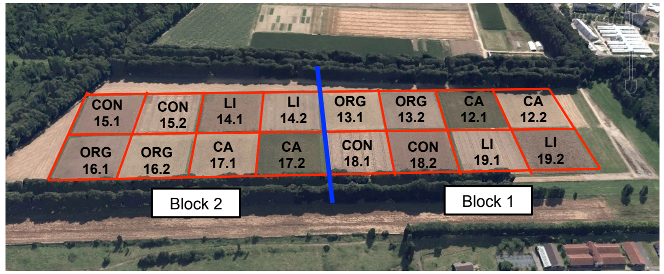
- Classical agronomic models cannot predict spatio-temporal variability in biomass production (& in-situ measurements too expensive) ➔ huge uncertainties on SOC stock changes,
- Previous attempts to assimilate remote sensing data in agronomical models (e.g. STICS, EPIC) failed (too many input data) ➔ not adapted to upscalling

➔Assimilation of remote sensing data in crop models dedicated to upscaling (e.g. SAFYE-CO2) ➔ force the model to estimate accurate biomass production/spatial variability

HYBRID APPROACH NEEDED !

Developing MRV methodologies

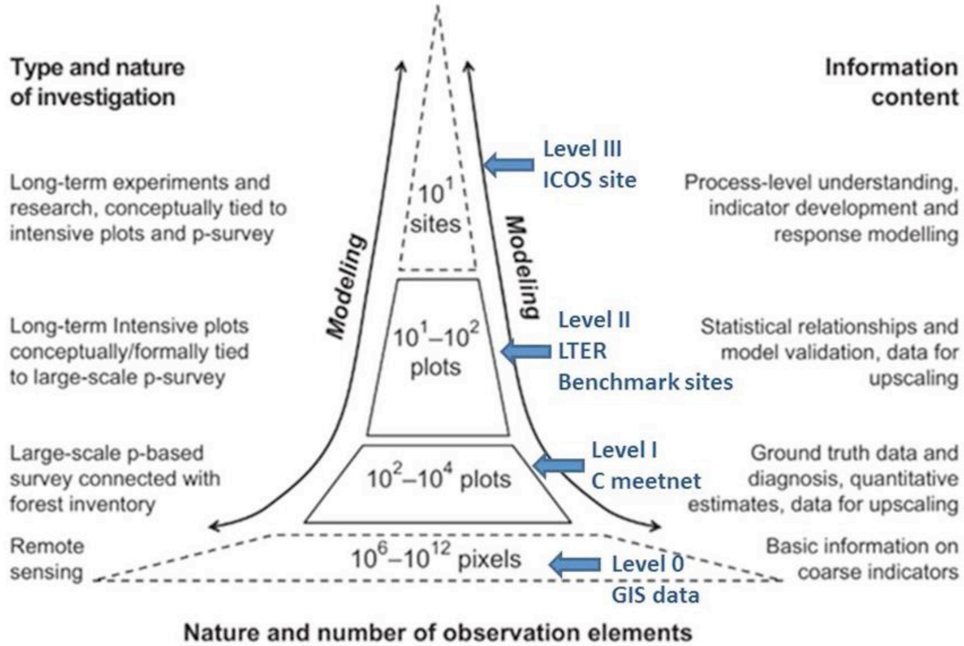
Importance of benchmark sites!



- Test management options

- Develop and test models (calibration/ validation
  - Plant C inputs models (remote sensing)
  - Soil carbon models
  - Direct measurements – detailed monitoring and sampling

- Different complementary networks
  - Level I regional/EU carbon monitoring network
  - Level II LTER benchmark sites
  - Level III ICOS sites



Sleutel et al. 2020 adapted from Ferretti & Fisher 2013

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- Measure...
- De... ...dels

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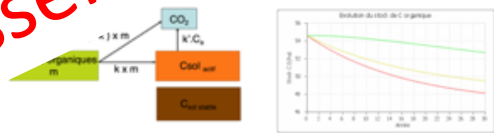
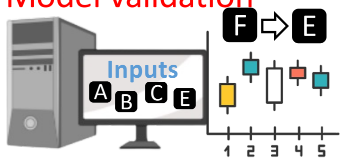
D CR...
- S... ...ing SOC/GHG ...odels estimating C budget

Evolution of SOC stocks over time

Model ca...



Model validation



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

Develop MRV methodologies

Apply MRV in CF sch...

But how to assemble all that in a consistent/efficient way ?

APPLY	ENROLL	QUANTIFY	VERIFY/REPORT
Eligibility check	T0, BAU and Cseq potential	Transparent, robust outcomes	Transparent, verifiable outcomes
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Example of operational processing chain for MRV of SOC stock changes

AgriCarbon-EO [ACEO], an end-to-end pre-operational processing chain dedicated to SOC MRV

BASALT

Bayesian Normalised Importance Sampling using Look-out Table & Bayesian Assimilation Method

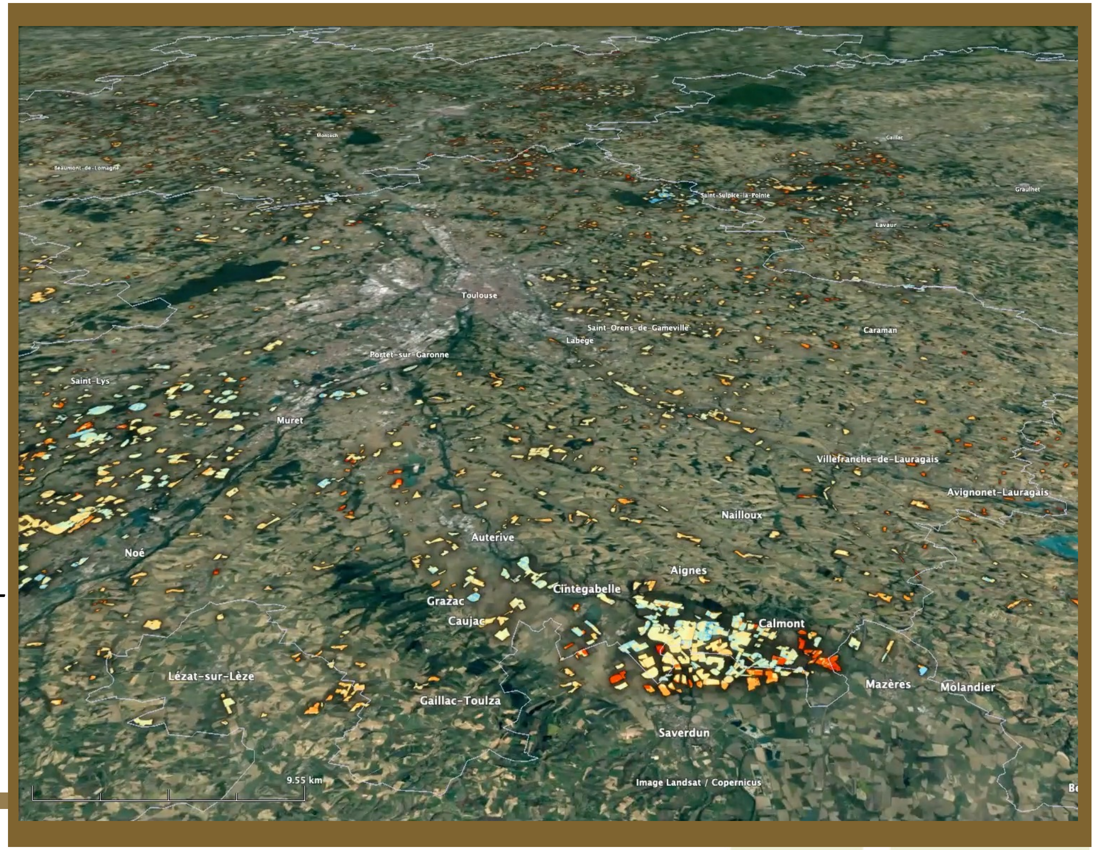
SAFYE-CO2 + AMG

Parsimonious Agronomic + soil model

AgriCarbon-EO v1.0.1: Large Scale and High Resolution Simulation of Carbon Fluxes by Assimilation of Sentinel-2 and Landsat-8 Reflectances using a Bayesian approach

Taeken Wijmer[1,2,*], Ahmad Al Bitar[1,*], Ludovic Arnaud[1], Remy Fieuzal[1], and Eric Ceschia[1]

Net annual CO_2 fluxes for Wheat over 110x110 km at 10m resolution (in France) *simulation takes 4 hours (downloading images takes 1 day)*



https://egusphere.copernicus.org/preprints/2023/egusphere-2023-48/

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

✓

ADDITIONALITY

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

LONG-TERM STORAGE

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

SUSTAINABILITY

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

- Time 0 measurements/ soil data
- Modelling of the business as usual (standard practice)
  - ⇒C sequestration in soil
- GHG emission estimates (emission factor, modelling)
  - ⇒Negative emissions, climate change mitigation

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- Farm data
- Remote sensing
- Eligibility of the practice
  - ⇒ ”additional” management option

Accounting for the pionners ?

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- Remote sensing for C input and activity
- Modelling effects of climate change

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✓ ✗

- 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"

EU MISSIONS SOIL DEAL FOR EUROPE

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
- **Mixed carbon farming systems**: practice-based & results-based MRV
- **Adapted to different context of application**
  - National inventories, CAP, agri-food sector (insetting), voluntary markets
- **Hybrid MRV systems** to predict & validate SOC changes and C budget: measurements & modelling & realistic biomass estimates through remote sensing in crop models
- **Automated**, **modular, large scale but high resolution, uncertainty analysis and low cost**
- **Issues:**
  - The **references**: time 0, BAU simulation, regional standard baseline, specific baselines
  - **Soil data**: spatial resolution, harmonization
  - **Data assimilation & assemblage**

Several projects working on it now !

EU Soil Observatory (EUSO)

MARVIC MRV for carbon farming

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
European Joint Programme

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