Baseline in agriculture for quantifying SOC stock changes: lesson learned from Marvic

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Greet Ruysschaert, Hui Xu (ILVO),

Lorette Lorand, Edouard Lanckriet (Agrosolution)

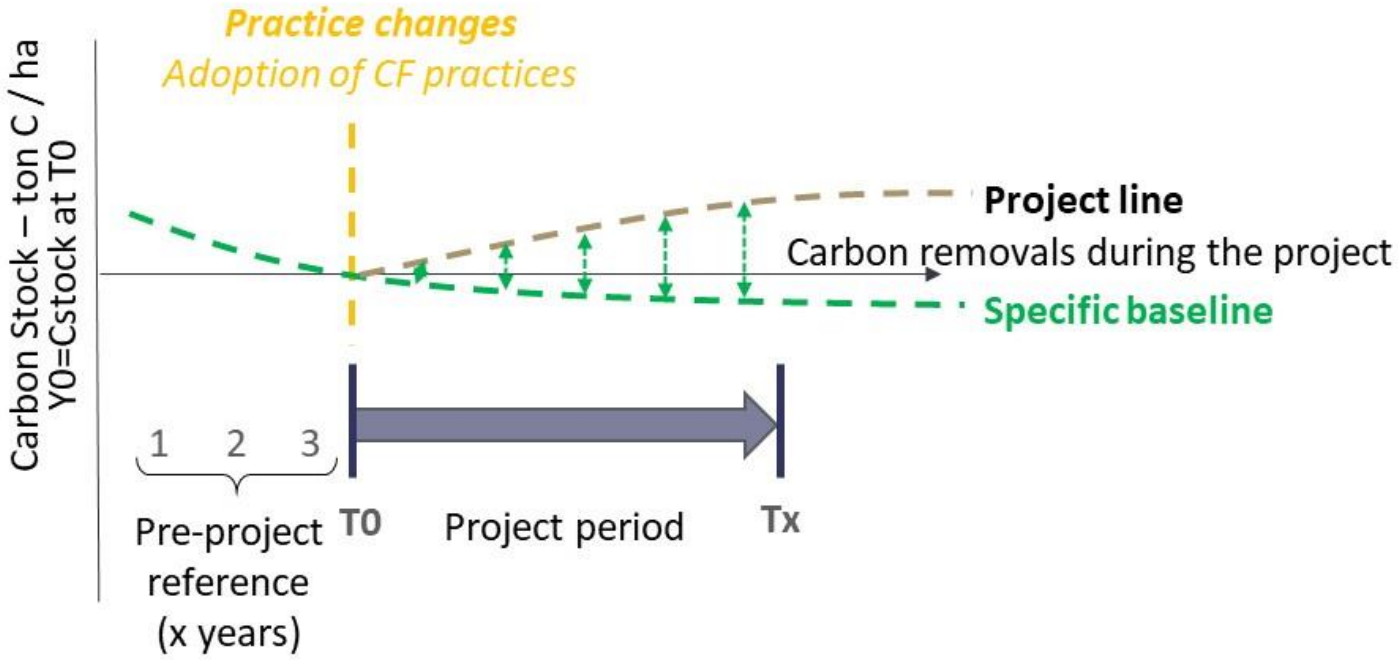
BOG3 Data needs in Support of baseline definition
Chairs: Mirco Migliavacca (JRC), Lucia Perugini (EEA)

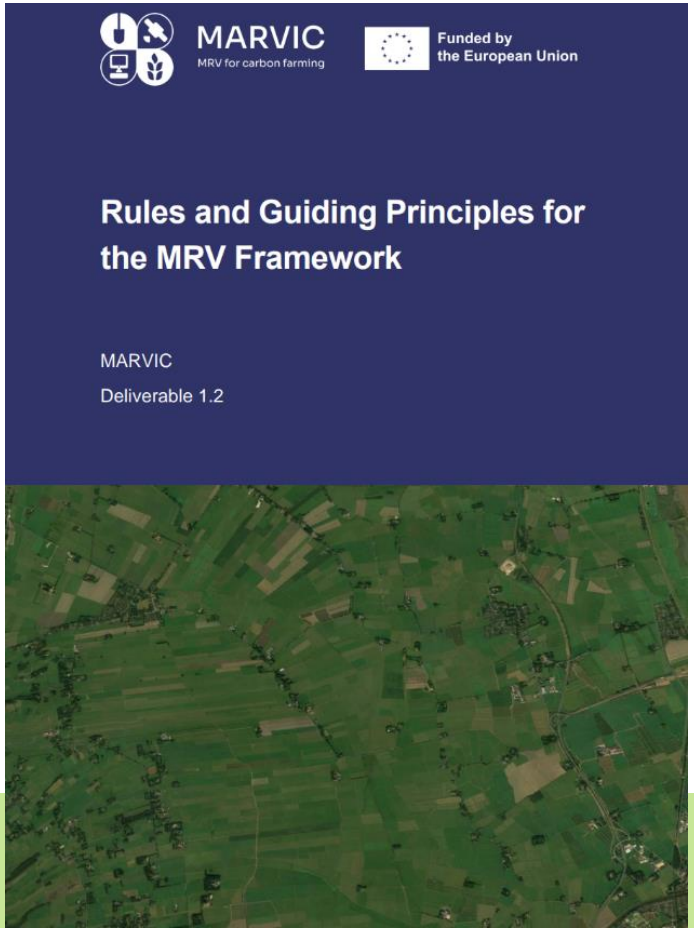
EO Conference on MRV of Carbon Removals, 8-11 October 2024, Copenhagen

Baselines

Baseline = evolution of carbon stocks under business as usual management practices

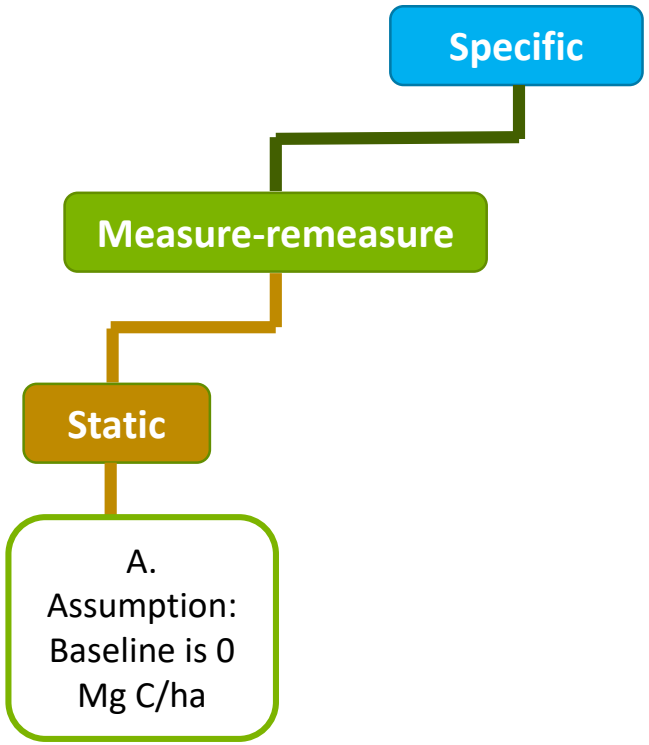
<u>Specific</u> baseline: using data specifically characterizing the farm or field engaged in the carbon farming project

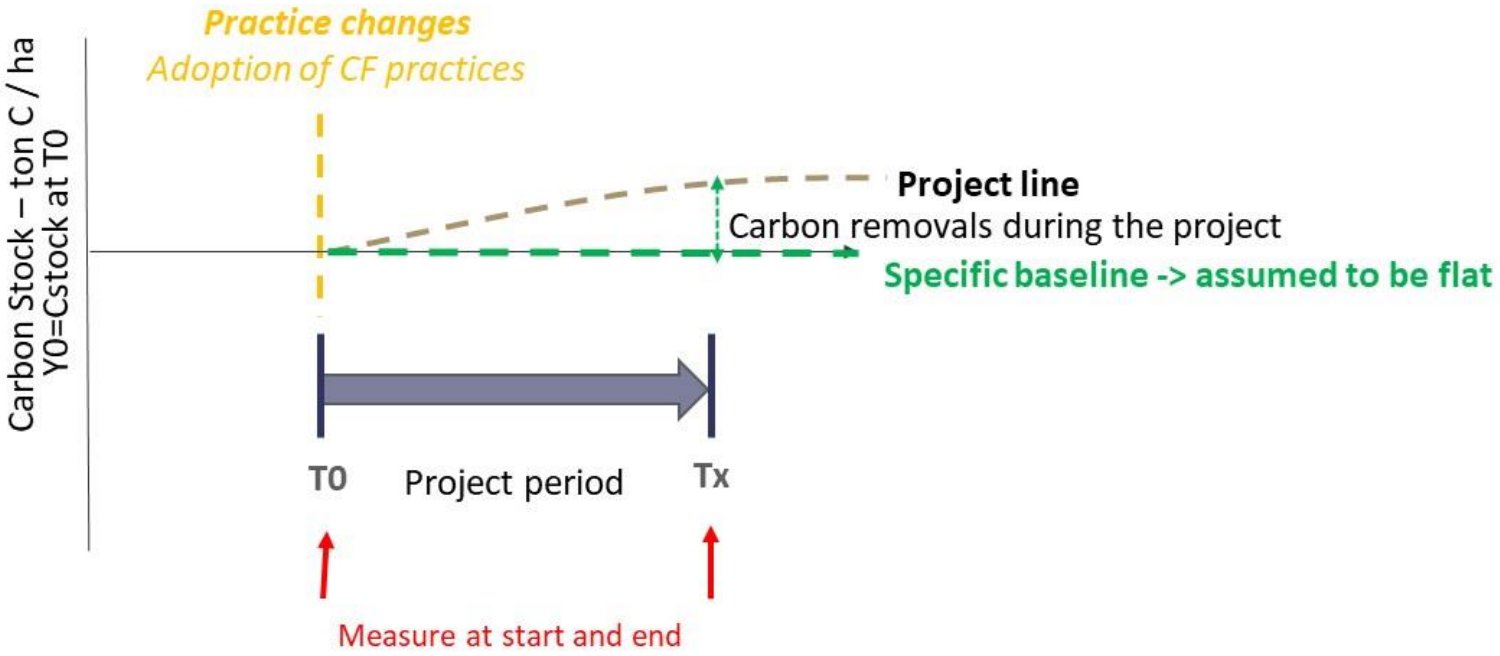




Baseline options

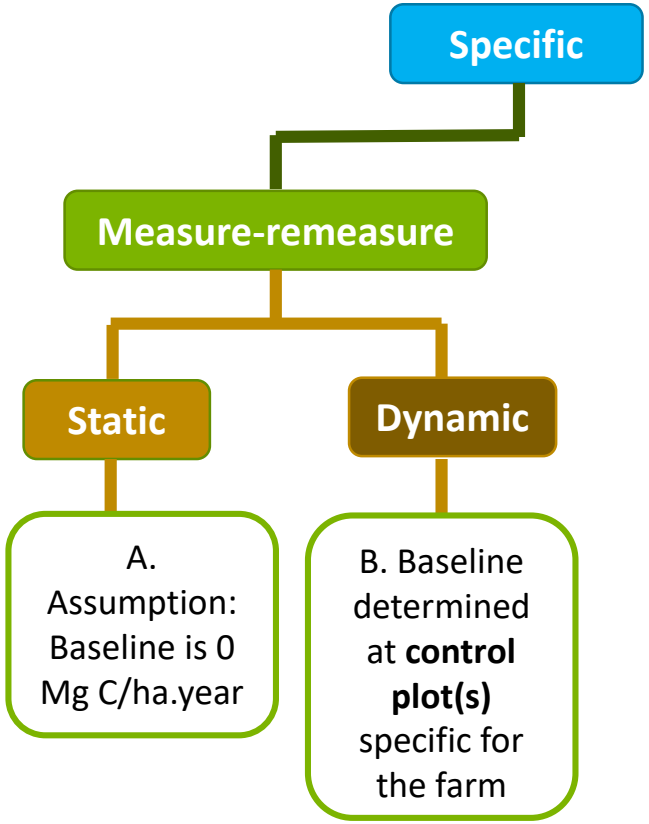
Static: a baseline that is calculated only once, at the beginning of the project





Baseline options

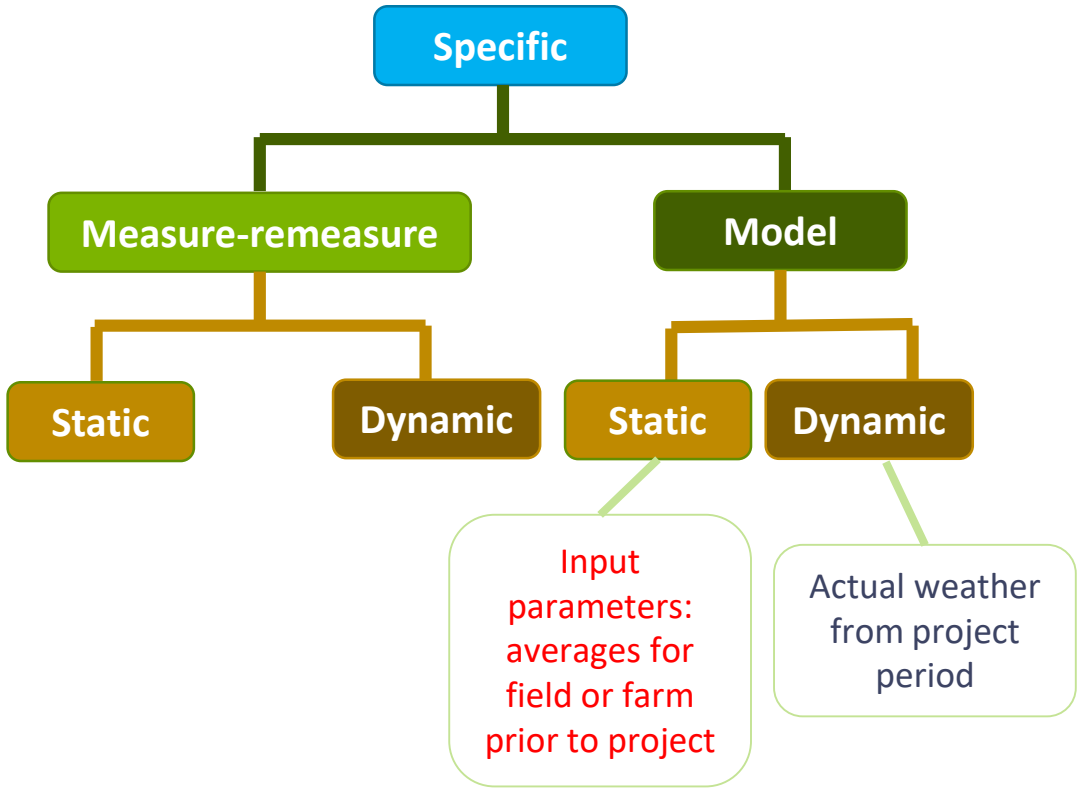
Dynamic: a baseline that is recalculated during the lifetime of project, or at the end – taking into account actual conditions

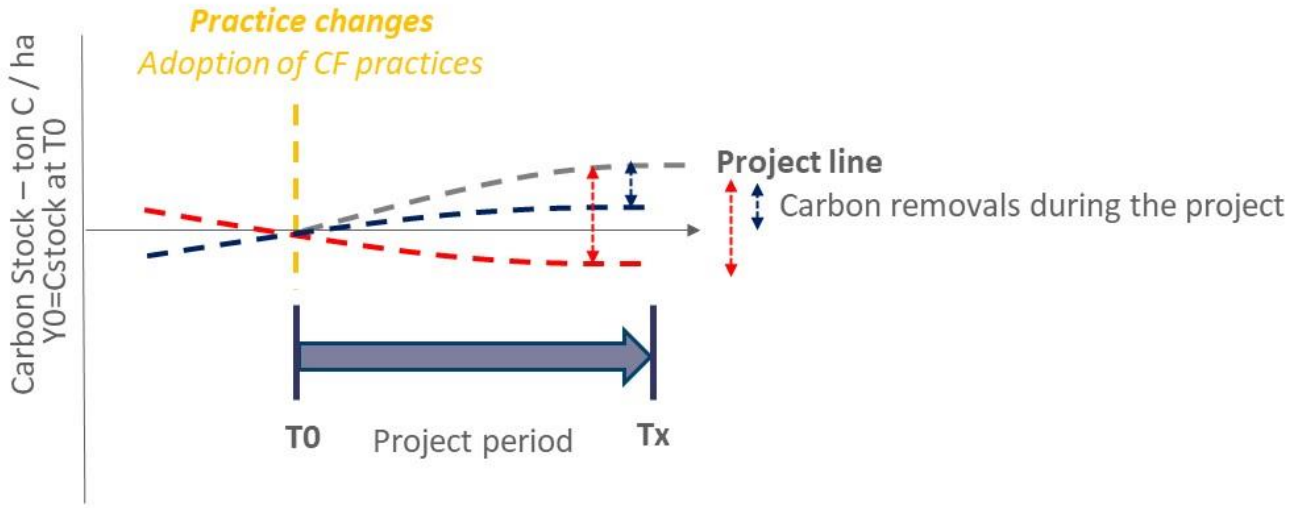


Baseline options

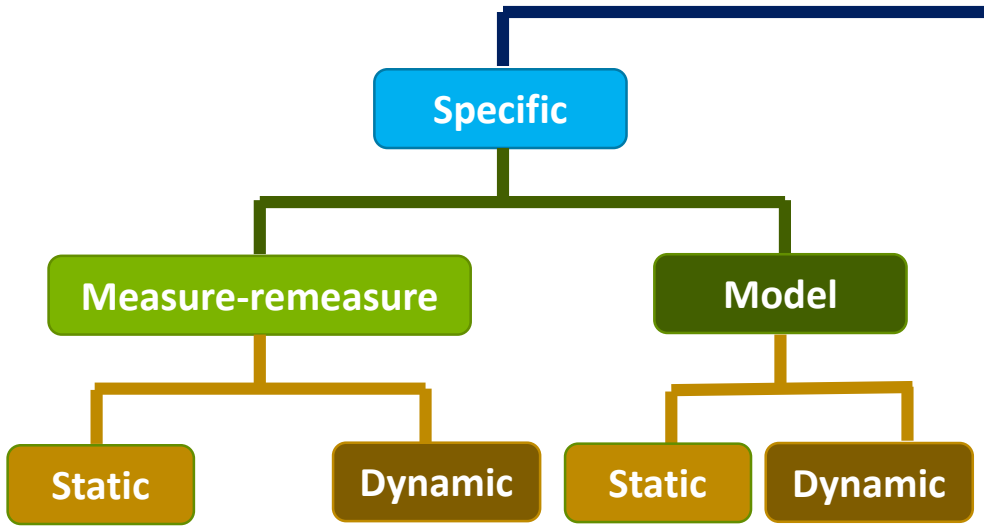
Modeling the evolution in soil carbon stocks (ton C/ha.year)

= f (soil, weather/climate, management practices, biomass input to soils)





Baseline options



EU Carbon Removal Certification framework (CRCF)

Standardised

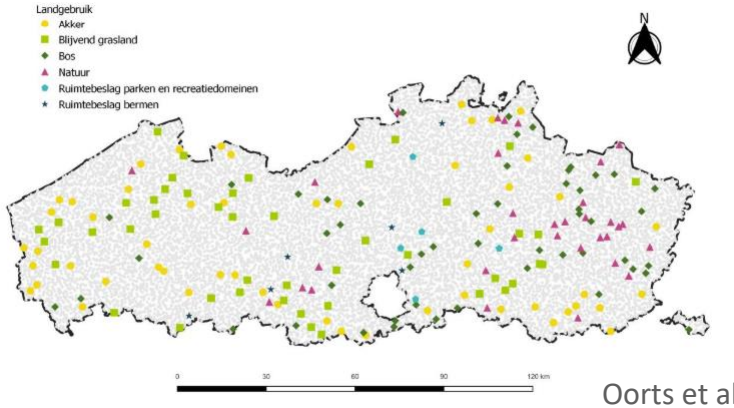
Definition: *Representative of the standard performance of comparable practices and processes in similar social, economic, environmental and technological circumstances and take into account the geographical context, including local pedo-climatic and regulatory conditions.*

\+ ensures objectivity
\+ minimises costs
\+ Incentivise first movers

Baseline options

- **Specific**
  - **Measure-remeasure**
    - Static
    - Dynamic
  - **Model**
    - Static
    - Dynamic
- **Standardised**
  - **Model**
    - Static
    - Dynamic
  - **Measure-remeasure**
    - Static
      - C. Regional monitorng network – based on results prior to project
    - Dynamic
      - D. Regional monitorng network – based on results during project time

Emission factors per land use type



Oorts et al. 2023

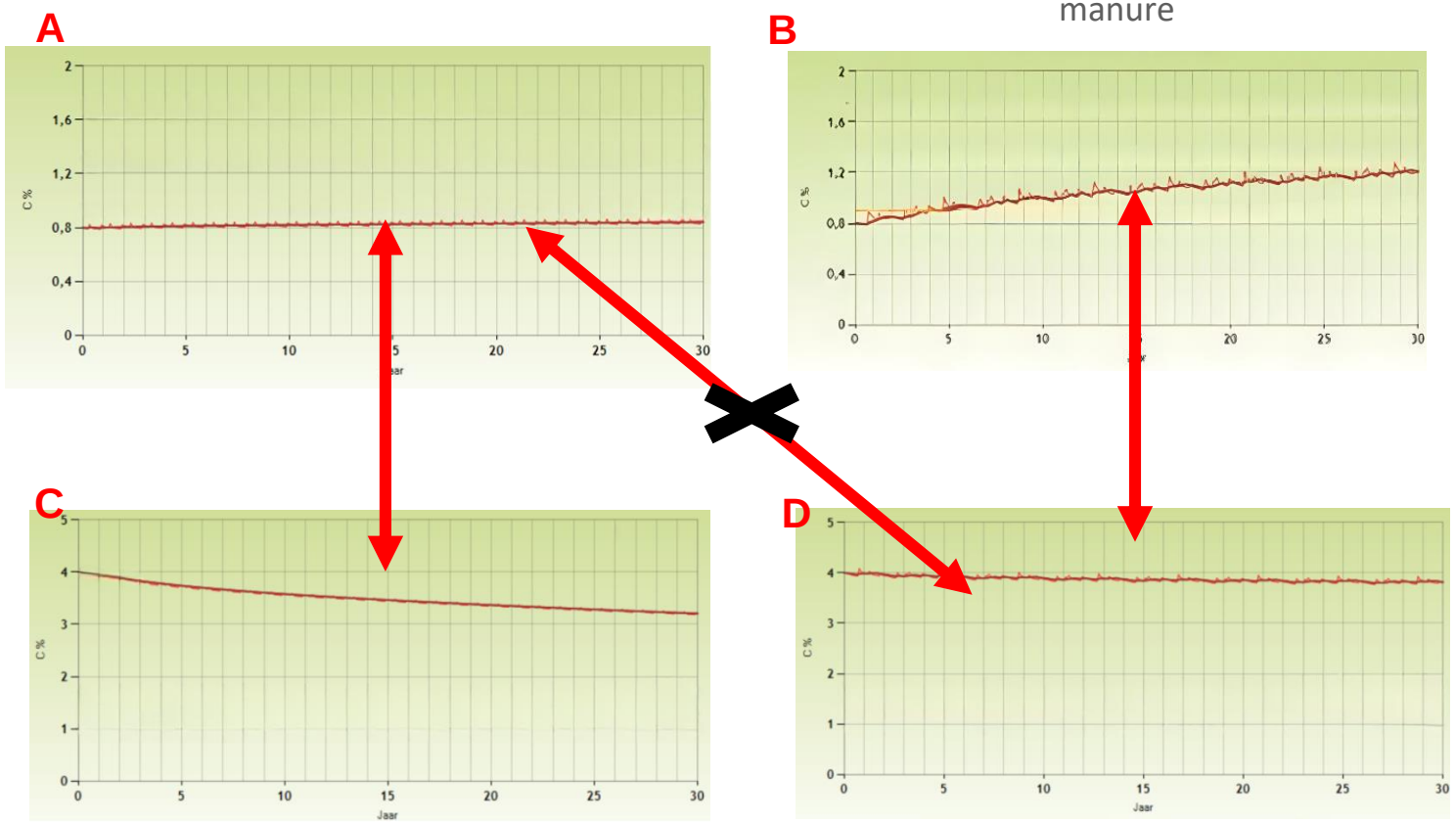
Impact of initial soil C

Standardised management
Monoculture silage maize, some slurry

Carbon farming management
Crop rotation with cereals, cover crops, potato and sugar beet, slurry and farmyard manure

Low initial %SOC: **0.8%**

High initial %SOC: **4%**

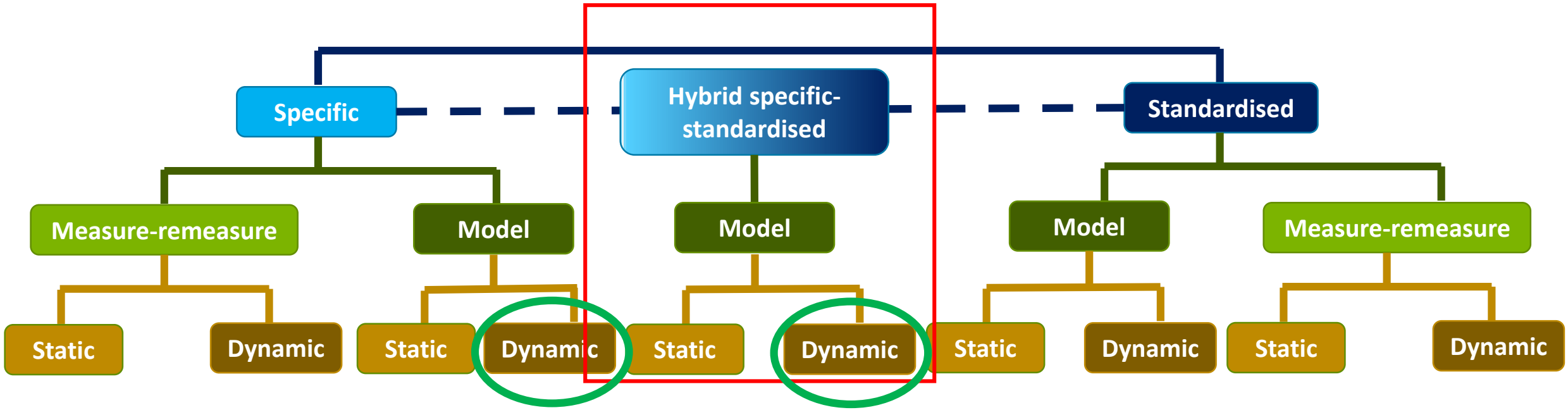


SOC simulation – RothC based model

- **Initial SOC has large impact on SOC trends** (A vs C; B vs D)
- **Baseline and project line should be calculated with same initial SOC!**

+ ensures first movers are incentivised
+ maintaining high C stocks incentivised *(usually requires better management than average)*

Baseline options



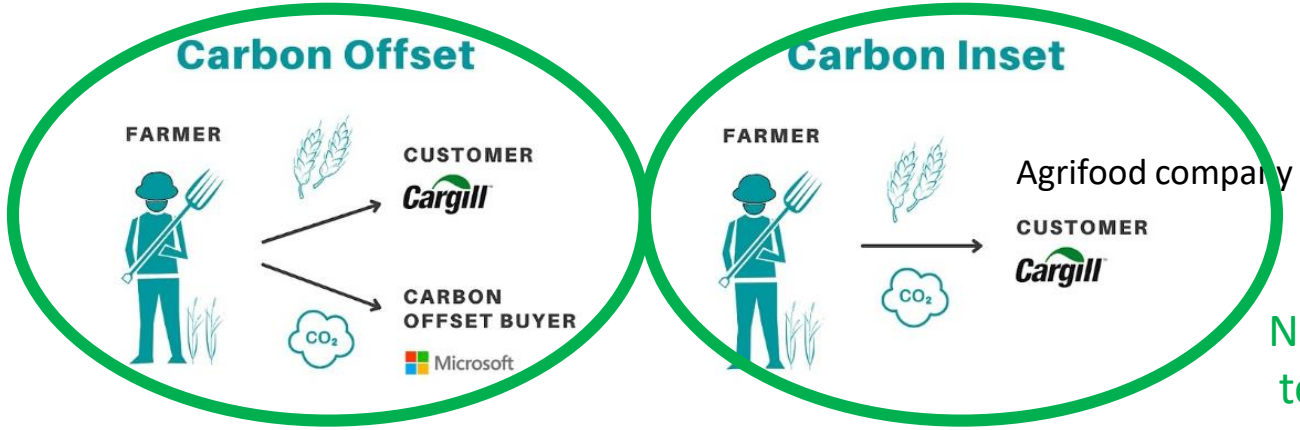
Evolution in soil carbon stocks (ton C/ha.year) = f (soil, weather/climate, management practices, biomass input to soils)

specific **standardised**

+ ensures first movers are incentivised
+ maintaining high C stocks incentivised *(usually requires better management than average)*

Different context of MRV the SOC stock changes

- National inventories; Nationally Determined Contributions (NDCs) under the Paris agreement,
- Common Agricultural Policy: but operational methods are still missing for the current one
- Carbon offset programs (voluntary Carbon market) emerging in agriculture ex. LABEL BAS CARBONE
- Insetting programs are developing fast,



Regional modeling in South West France

Nataïs popcorn company test case

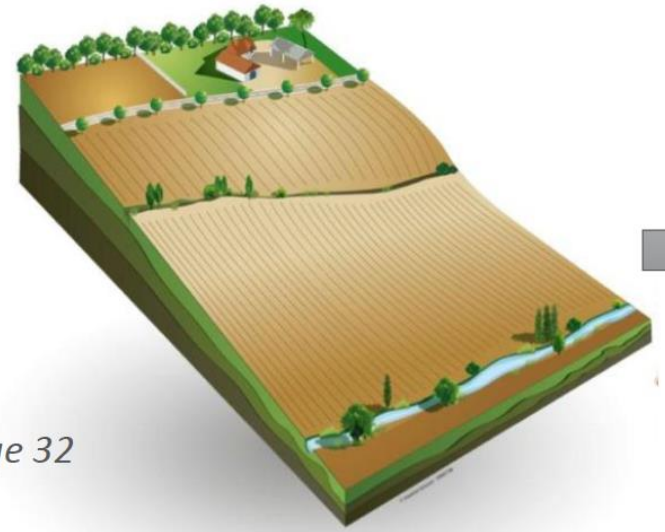
Each context of application has its specificities/requirements and the 3 last ones (CAP, ofsetting, insetting) require dedicated baseline approaches

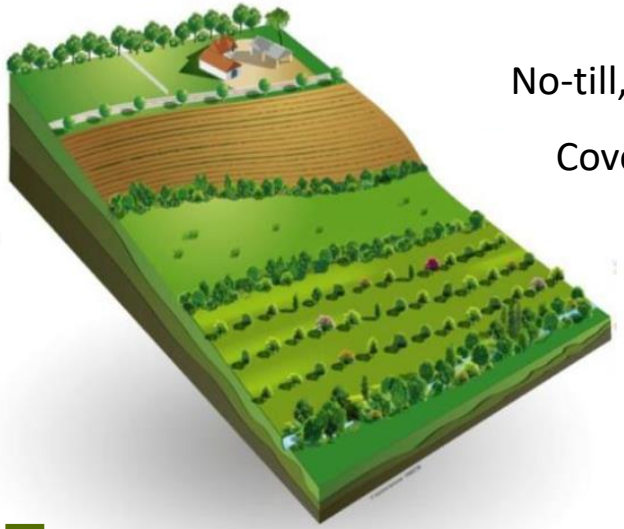
Context & challenges

Transition from conventional towards agroecological practices

Conventional agriculture

Carbon farming practices





No-till, crop diversification

Cover crops

Straw management

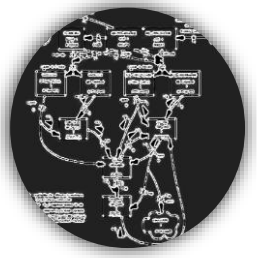
C storage ?

Illustrations:
Arbre et Paysage 32

How to assess the effects of C farming practices in terms of CO_2 emissions/soil organic carbon (SOC) stock changes at the plot scale but over large areas? How to produce meaningful & accurate baselines to assess the effect of the C farming practices in the different context of MRV ?

➔ **Need for a new generation of tools providing an exhaustive/objective vision of the effect of management, climate, soil properties on SOC stock changes applicable to different contexts of MRV**

Limits of current methods for monitoring soil carbon



Models

25-75 samples /ha !!!

AI

4PER1000

CIRCASA

NIVA

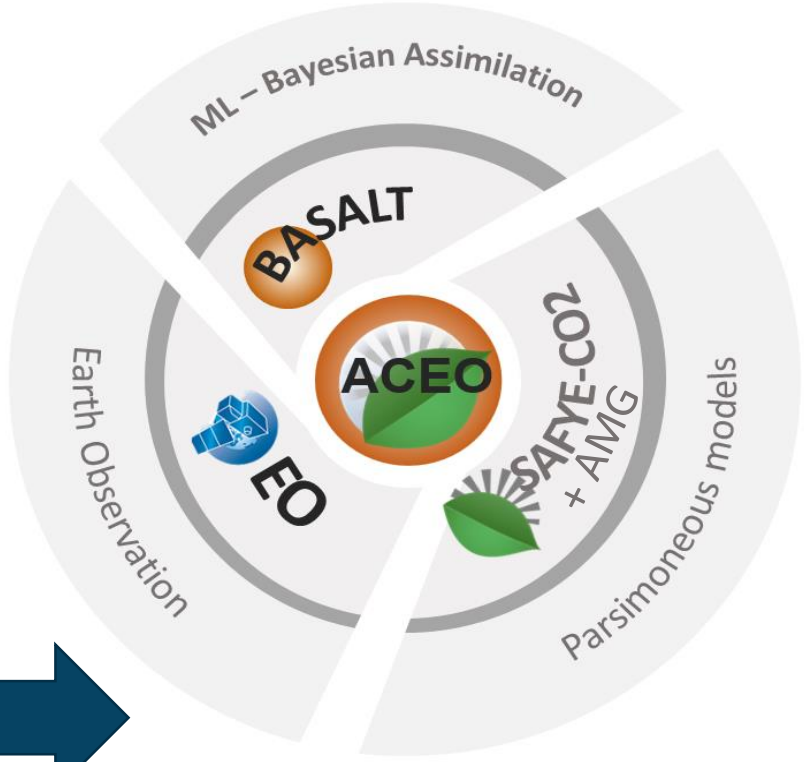
ClieNFarms
Climate Neutral Farms

ORCaSa

MARVIC
MRV for carbon farming

MyEasy Biomass

esa



AgriCarbon-EO

A hybrid method combining parcimonious process based modelling, remote sensing data assimilation and Machin Learning + In-situ data for cal/val

➔ Strong focus on assessing the effect of biomass input to the soil on SOC stock changes

https://www.cesbio.cnrs.fr/agricarboneo/agricarbon-eo/

The AgriCarbon-EO processing chain

A pre-operational multi-context end-to-end processing chain.

Geoscientific Model Development

Wijmer et al. (2024)

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, Ahmad Al Bitar, Ludovic Arnaud, Rémy Fieuzal, and Eric Ceschia

Agri-food, EO & MRV companies:

Toulouse Tech Transfer INNOVATIVE IMPACT

netcarbon

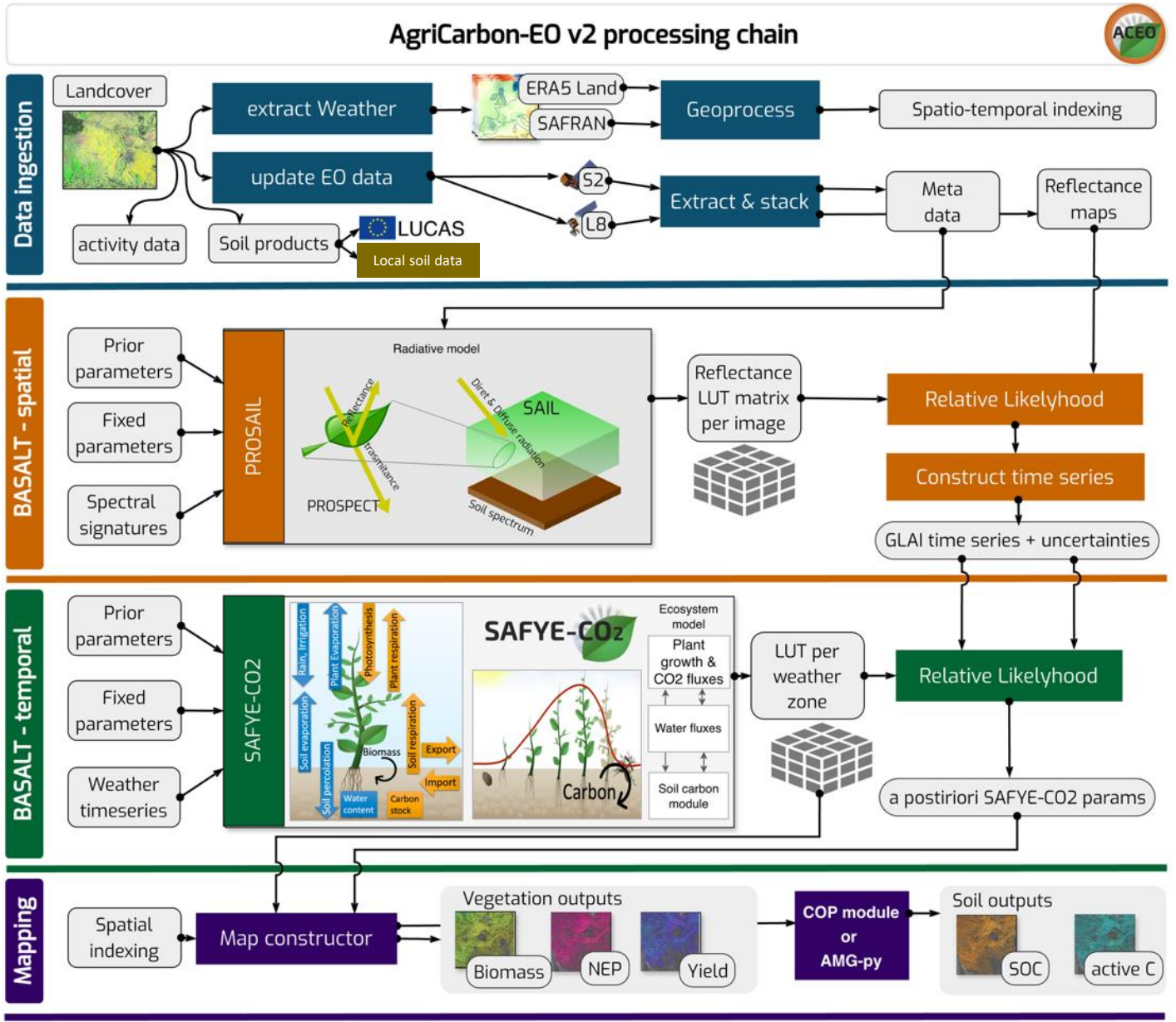
AIRBUS

KERMAP

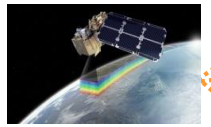
EarthDaily agro

natais

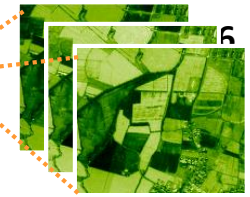
MyEasy Farm



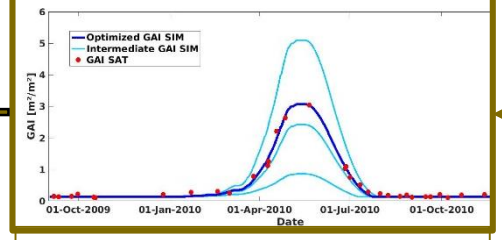
The SAFYE-CO2 model



Sentinel-2, Landsat 8



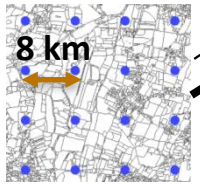
Dynamic mapping of leaf area index



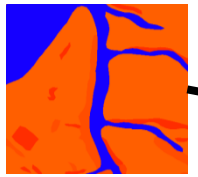
Calibration of model parameters (phenology & photosynthesis efficiency)

Crop map (LPIS…)

climatic data (e.g. ERA5)



soil property maps (e.g. SoilGrids)



Need very little management data!!

Farmer's management data

Crop parameters

T°C, radiation

Texture, OM…

Orga. Amendement,

Straw or CC export

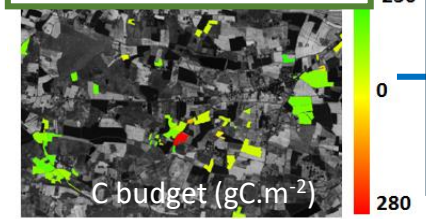
SAFYE-CO_2
(Pique et al. 2020a et b)

LAI

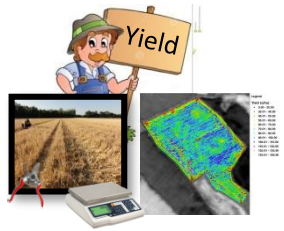
Fluxes CO_2 & water,

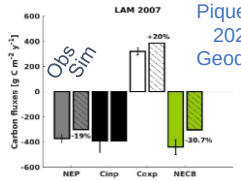
Biomass, Yield,

AMG soil model
(Clivot et al. 2009)



Validation



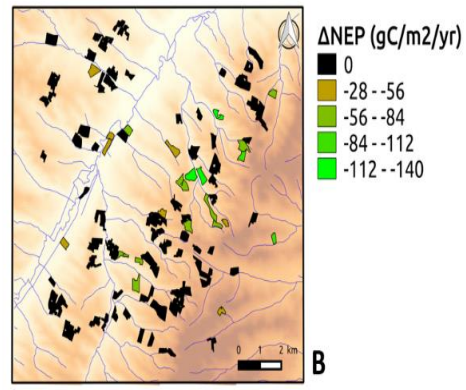


Pique et al 2020a, Geoderma

Started 10 years ago

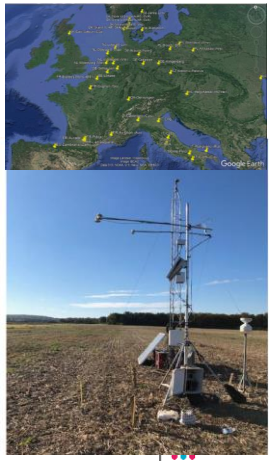
Objective : To force the crop model (SAFYE-CO2) to reproduce at plot level the dynamics and development intensity of the crop/cover crops as seen by satellite ➔ more precise and objective biomass estimates, implicit consideration of stress (N, water, etc.) and of some practices.

Automatic detection of cover crops, spontaneous regrowth /weeds and their impact on CO_2 fluxes/SOC ➔ only possible with EO

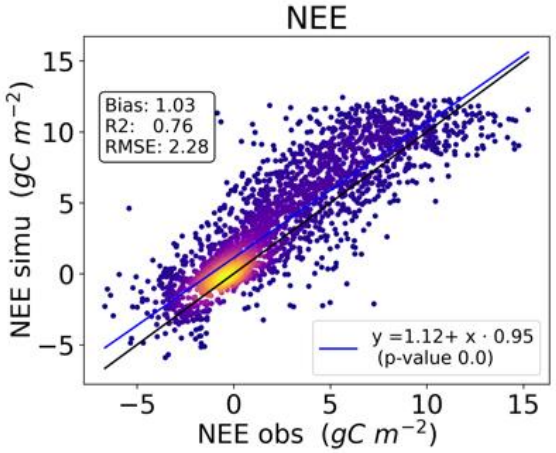


Pique et al (2020c) https://doi.org/10.3390/ecas2020-08141

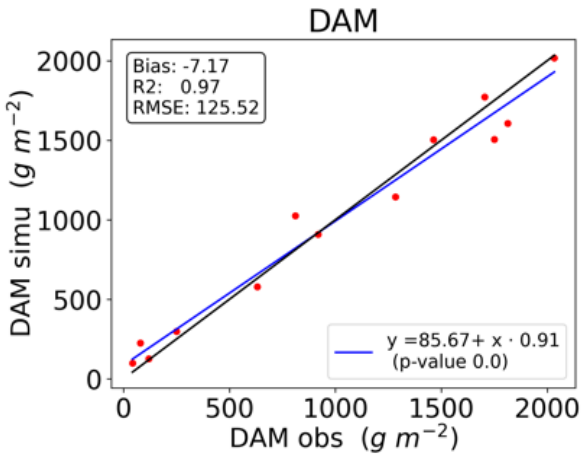
Validation exercises for the C budget components



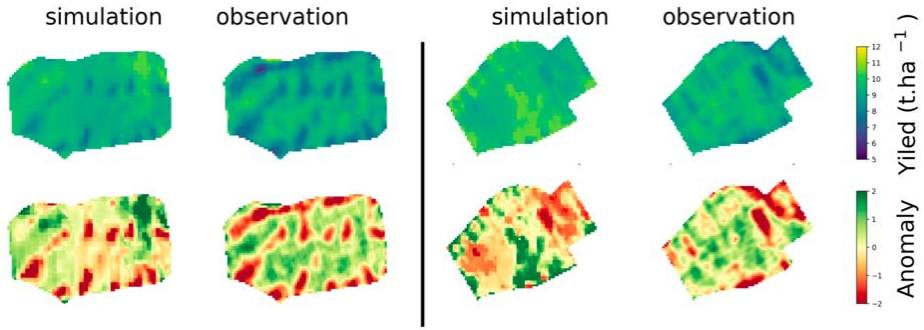
ICOS Integrated Carbon Observation System



Net CO_2 flux for wheat in Europe at ICOS sites

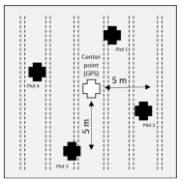


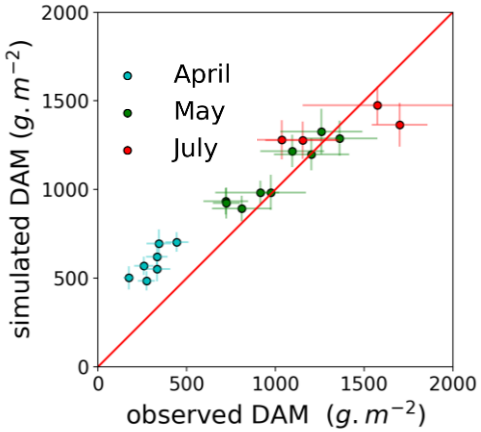
Biomass for wheat in Europe at ICOS sites



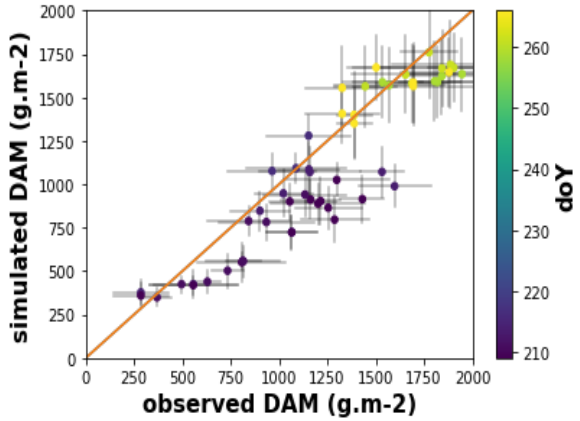
Winter wheat yield maps

Biomass with ESU protocol

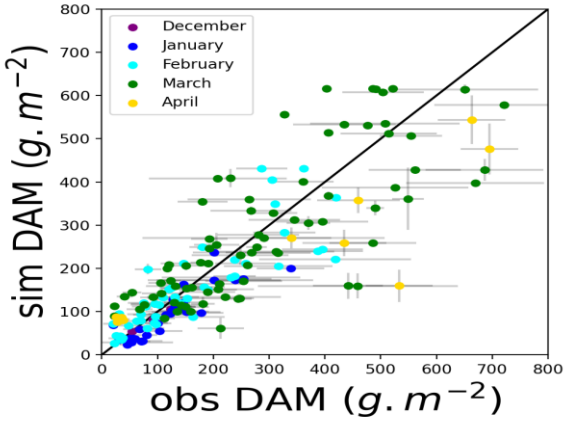




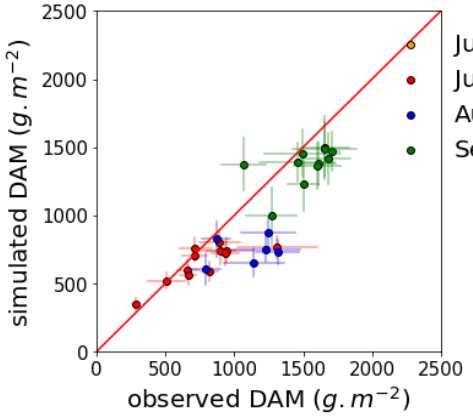
Biomass for Wheat in France



Biomass for Maize in France



Cover crops (Fava bean) in France



Tomato in Italy

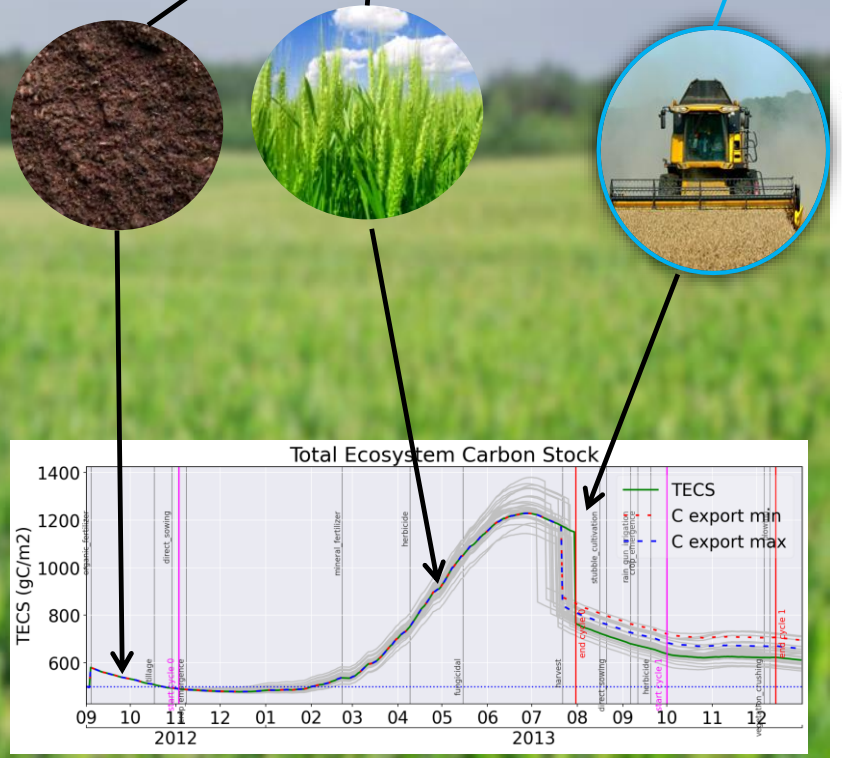
More crops to come but no validation against ΔSOC stock changes yet because data with measures and re-measures since Sentinel 2 data were launched are not missing

Straw cereals near Toulouse in 2019:
scenario with straw restitution and no organic amendment

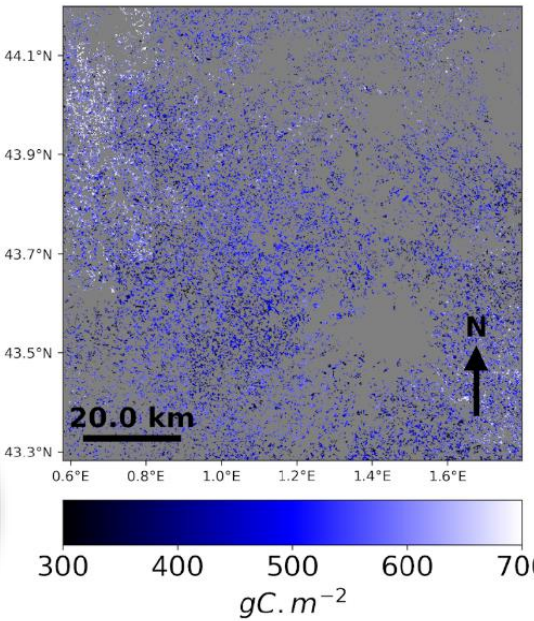
Activity data provided by the farmer

Annual carbon budget components

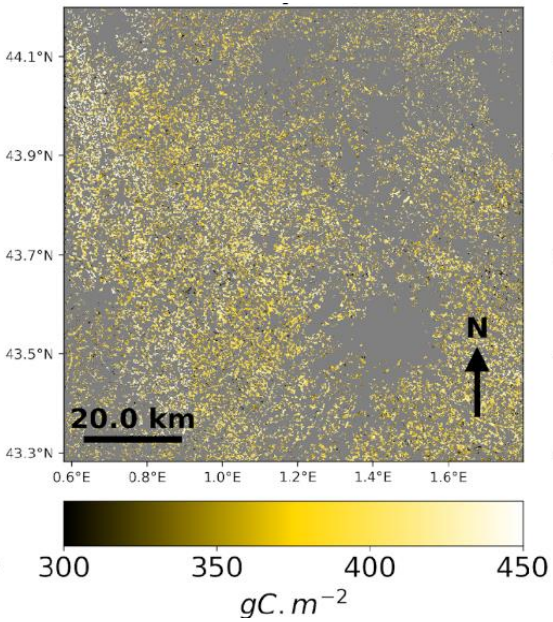
$\Delta SOCstock = Net\ CO_2\ flux + C_{import} - C_{export}$



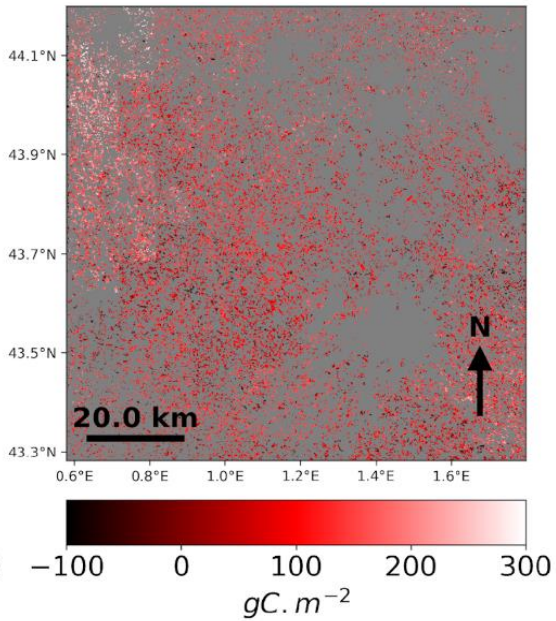
Net annual CO_2 flux (NEP)



C exported at harvest

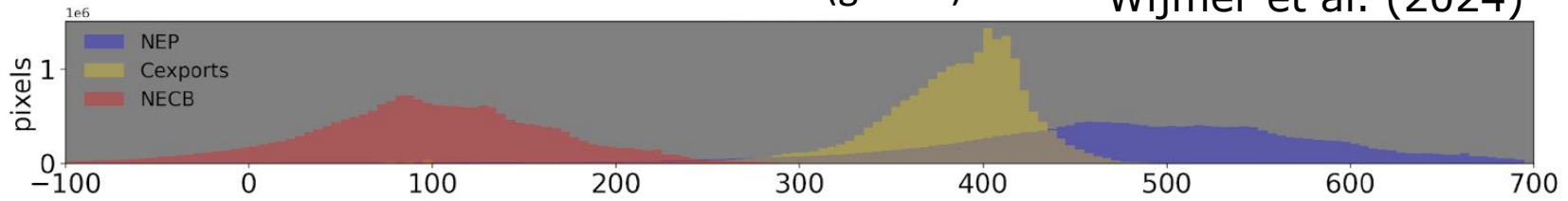


Annual C budget (NECB)

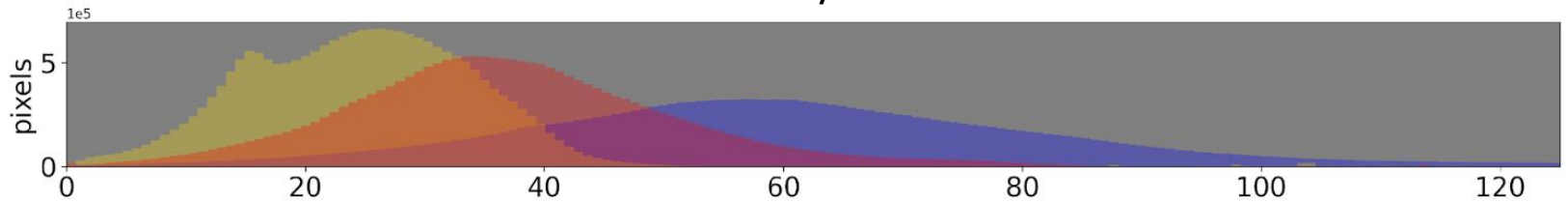


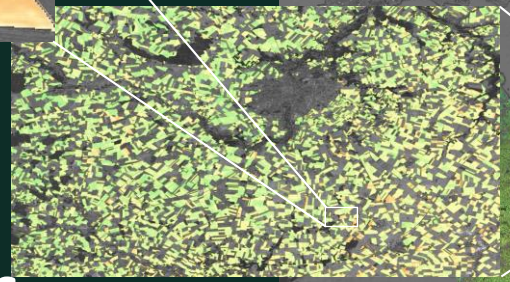
Mean value ($gC.m^{-2}$)

Wijmer et al. (2024)

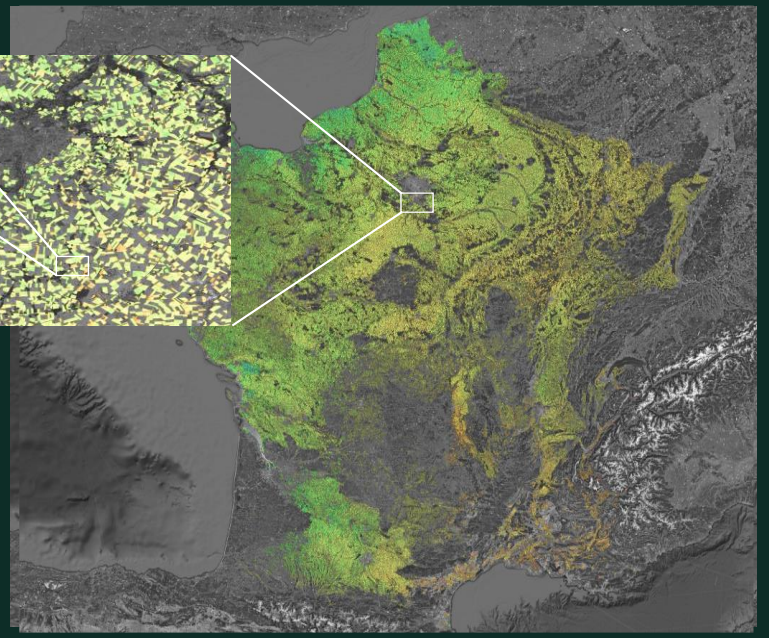


Uncertainty estimates

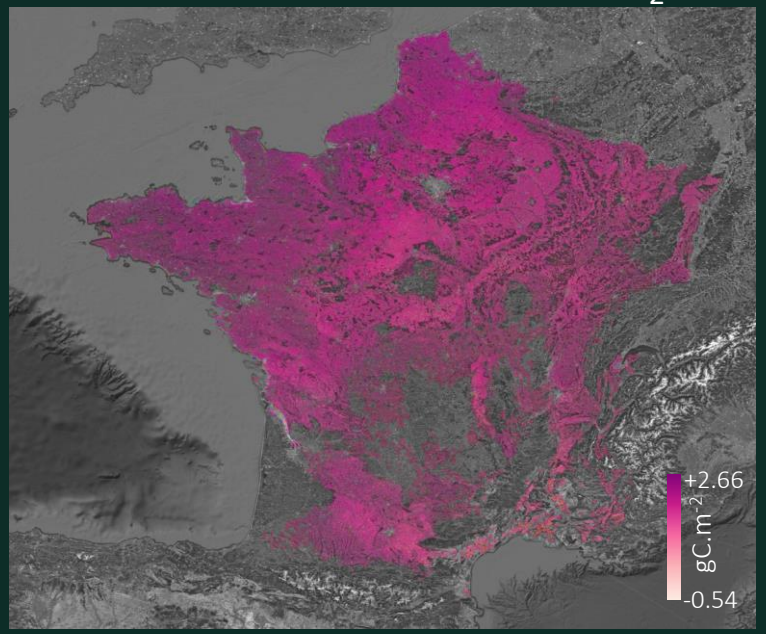




Dry Above ground biomass



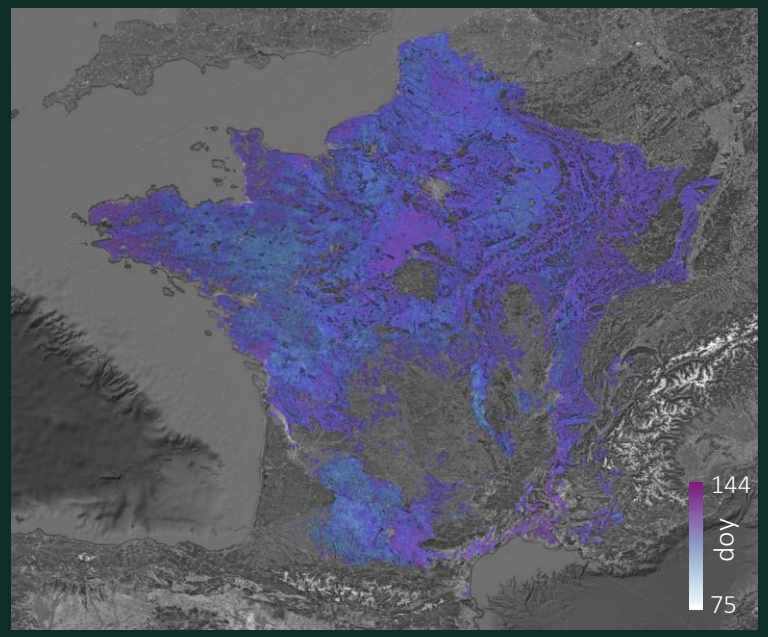
Net annual CO_2 flux



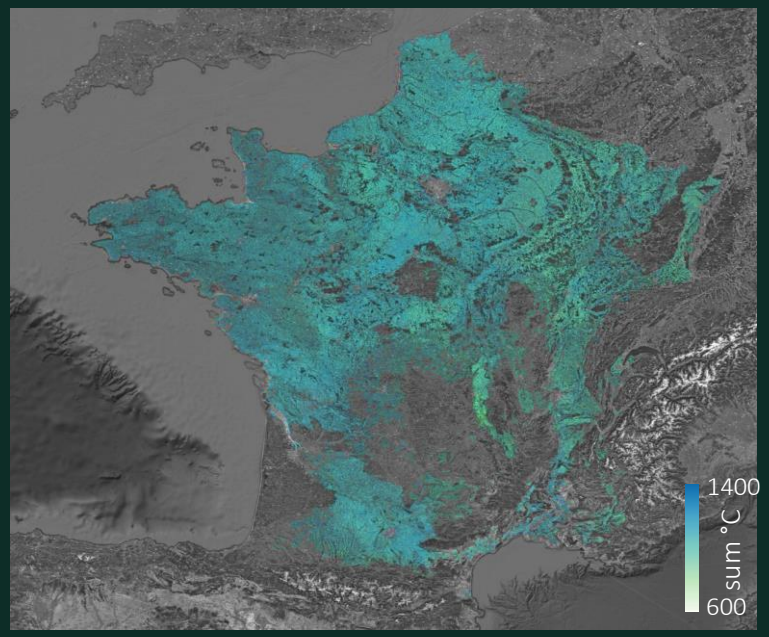
Coherent-set of agri-environmental variables

Produced with support of

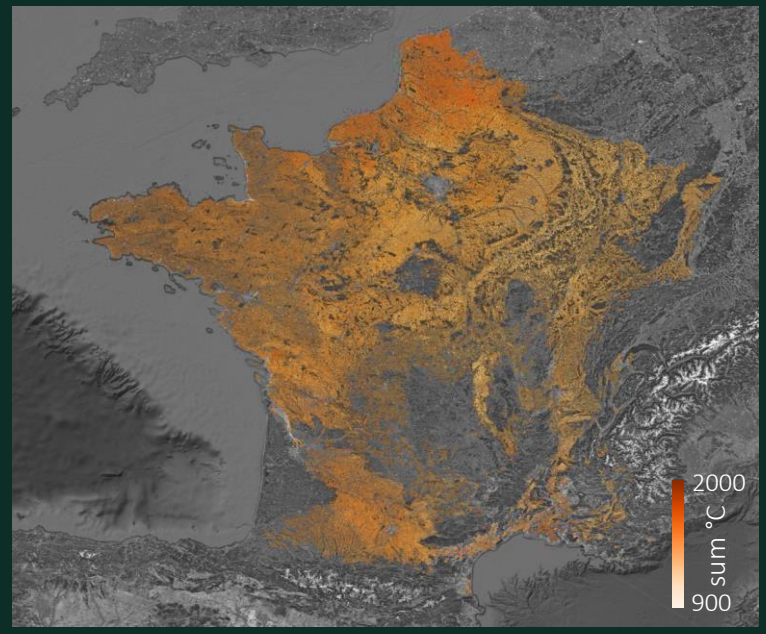
Realisation: A. Al Bitar, V. Antonenko, L. Arnaud



Day of emergence



Maturation phase

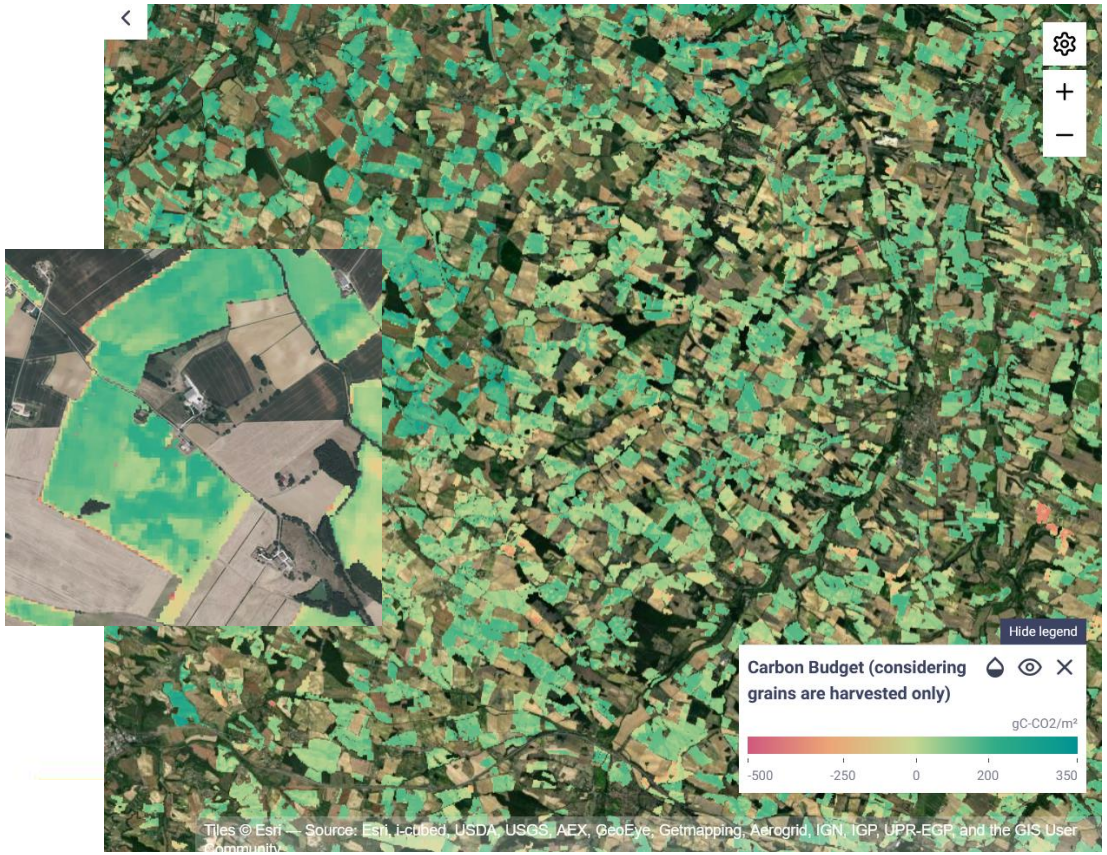


Senescent phase

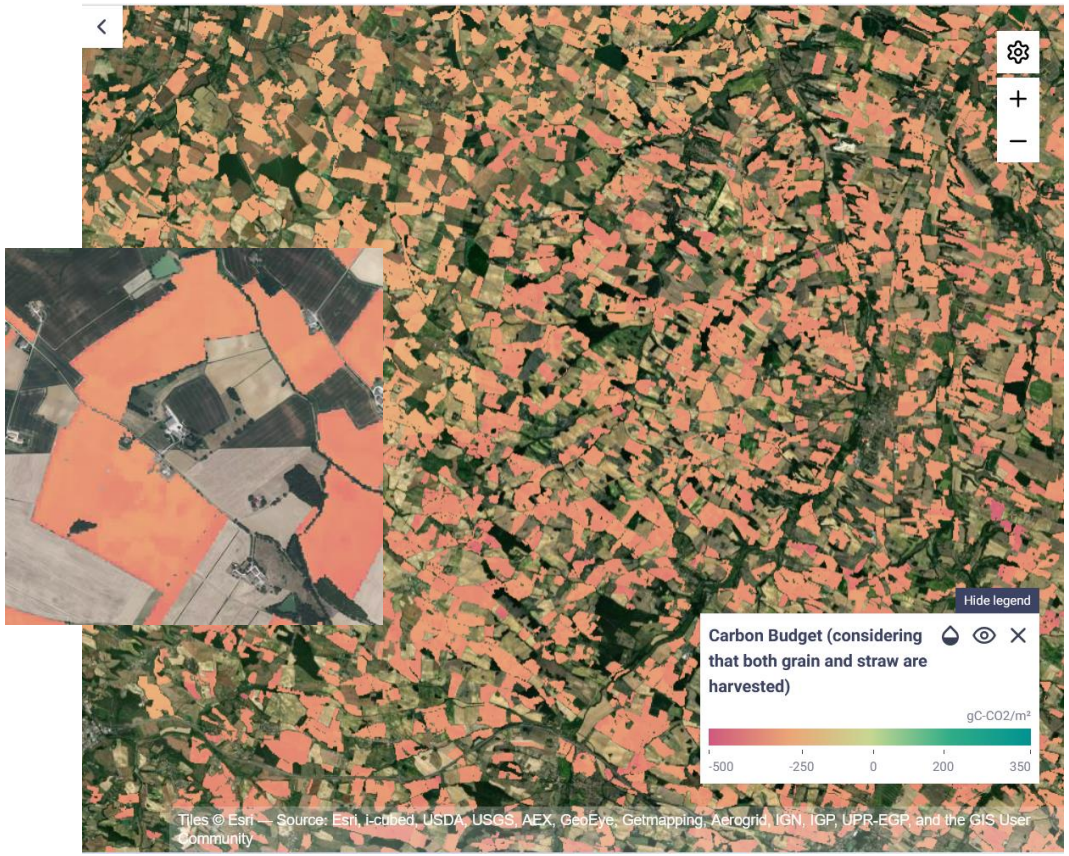
Hybrid standardised baseline: effect of straw management on the annual SOC stock changes for straw cereals

Regional simulation exercices near Toulouse (France) in 2019 : soil specific + standardised management

Scenario 1: only grains are harvested and no organic amendment applied



Scenario 2: grains + straw are harvested and no organic amendment applied



Realistic & objective assessment of the spatial variability of C inputs to the soil from biomass in the baseline calculation accounting for soil, management and climatic effects

Realisation A. Al Bitar

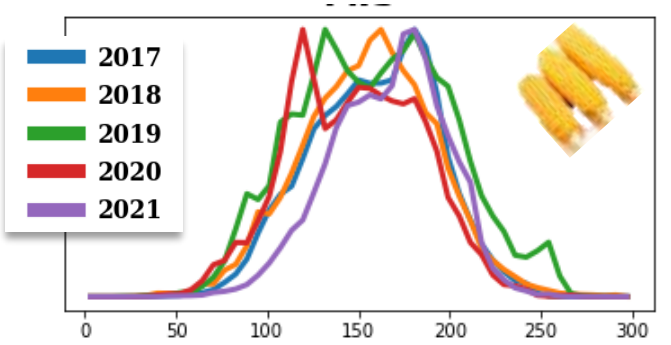
Soil Organic C Stock Changes over 5 years

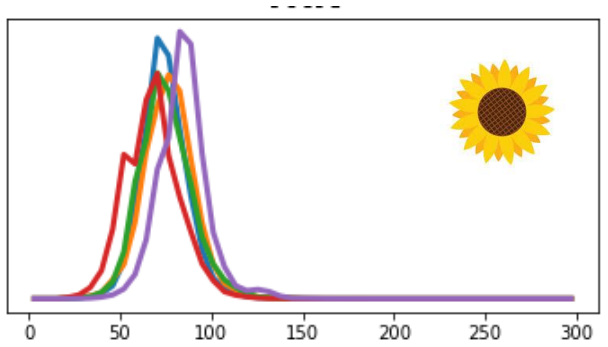
Biomass (SAFYE-CO2)

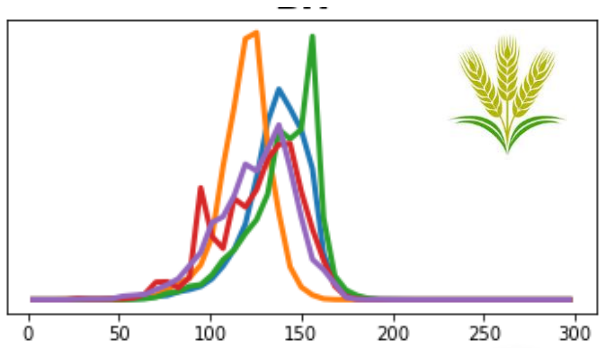
Earth Observation + weather data

Root biomass + (1-exports) x ABG

Humified C in AMG (gC/m2)





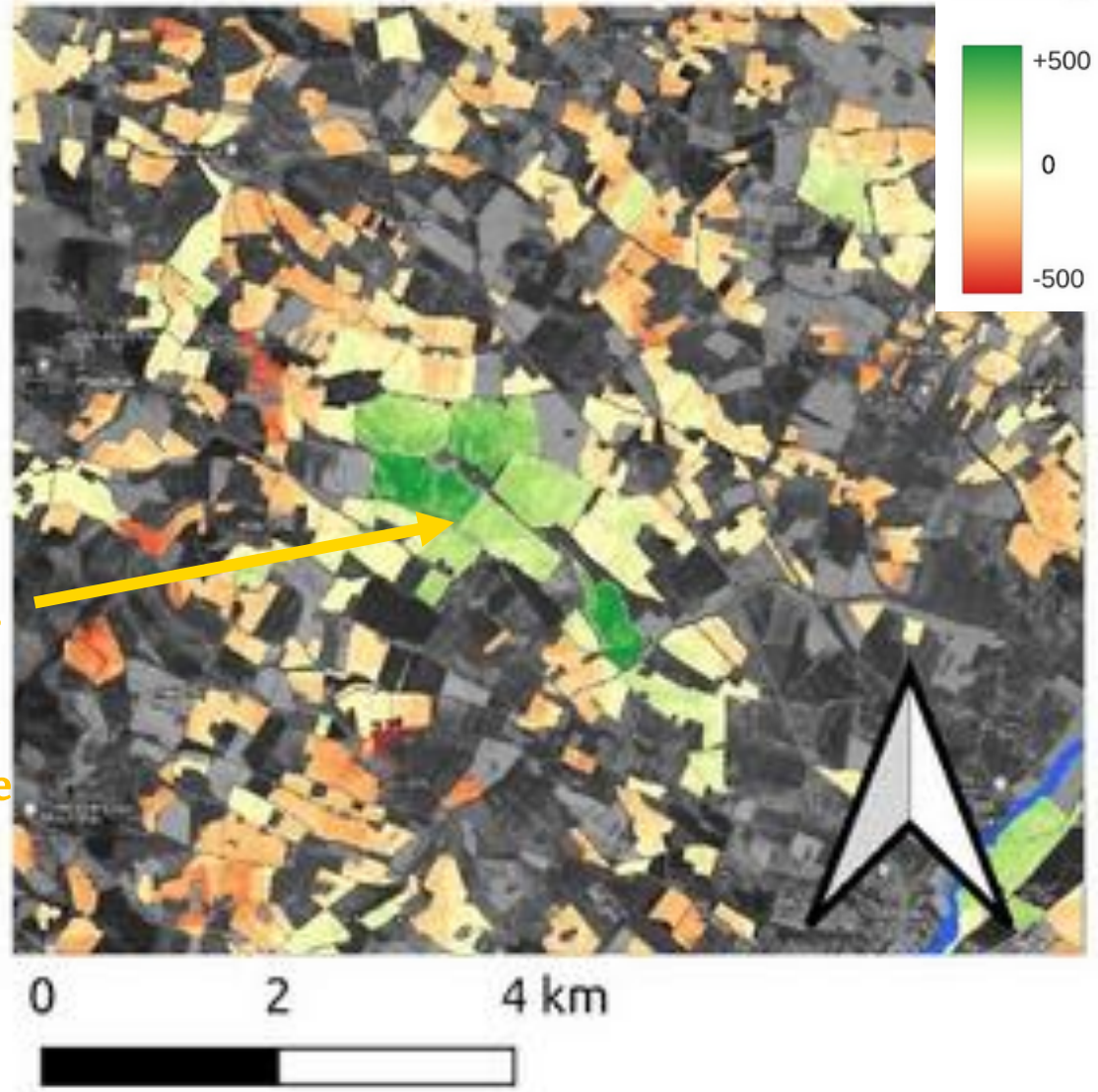


+ covercrops

ESDAC
EUSO
LUCAS
Data for SOC initialisation

Cover crops every second year ➔ C storage while neighbors loose C

Zoom on the villeneuve farm

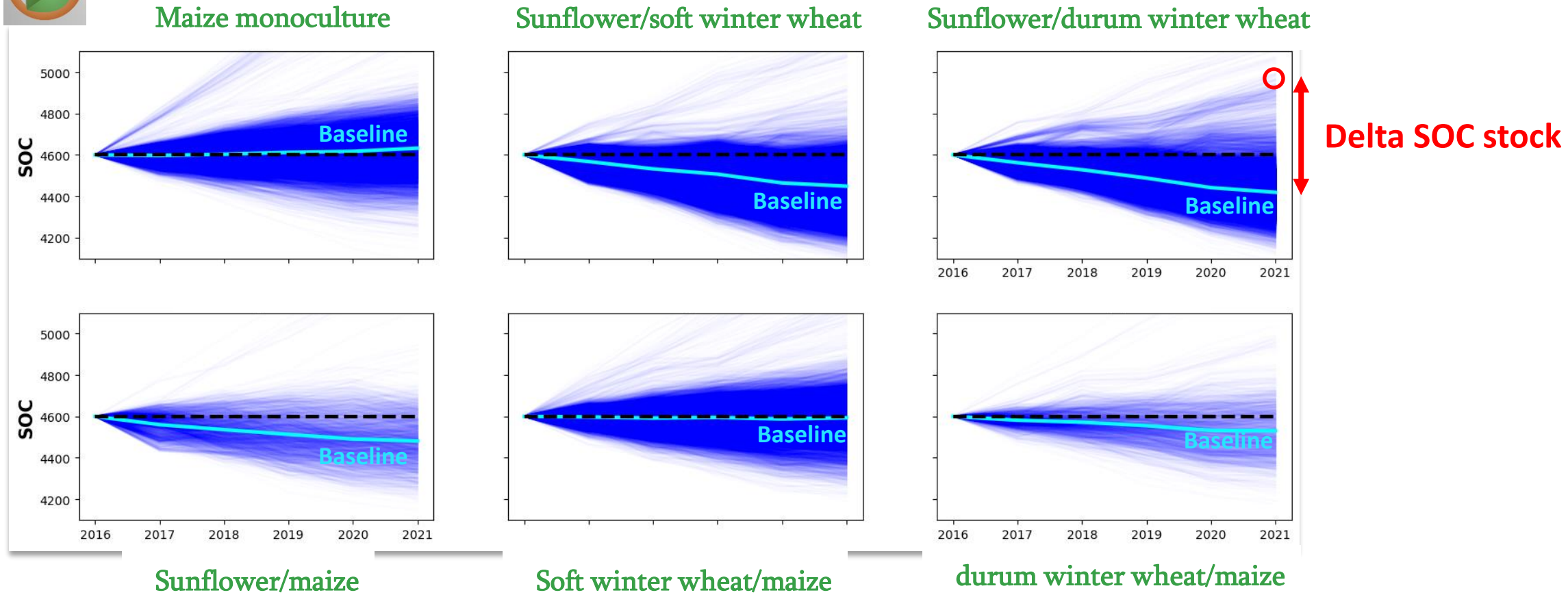


(Wijmer, 2024)

Hybrid standardised baseline: effect of crop rotations and cover crops

Regional simulation exercices near Toulouse (France) in 2019 : soil specific + standardised management (no organic amendment, straw left)

Simulations of ΔSOC per crop rotations for each plot (gC/m2)

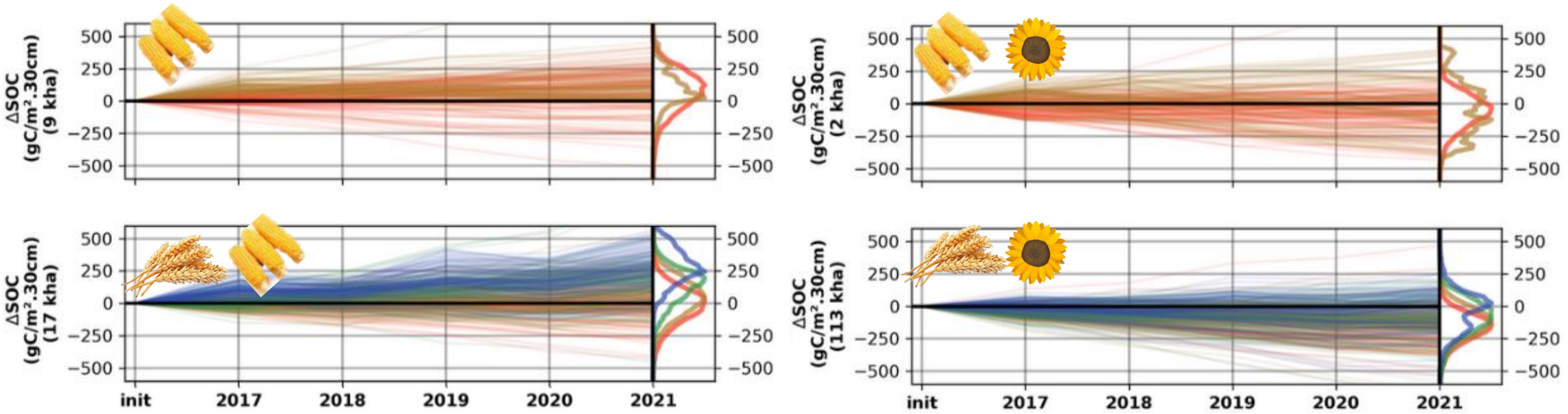


Realistic & objective assessment of the spatial variability of C inputs to the soil from biomass in the standardised baseline calculation accounting for soil, management and climatic effects

Hybrid standardised /specific baseline: effect of crop rotations and cover crops

Regional simulation exercices near Toulouse (France) in 2019 : soil specific + partly standardised (no organic amendment, straw left) and specific (cover crop) management

ΔSOC per crop rotations for each plot and frequency of cover crops



0 cover crop 1 cover crop 2 cover crops 3 cover crops

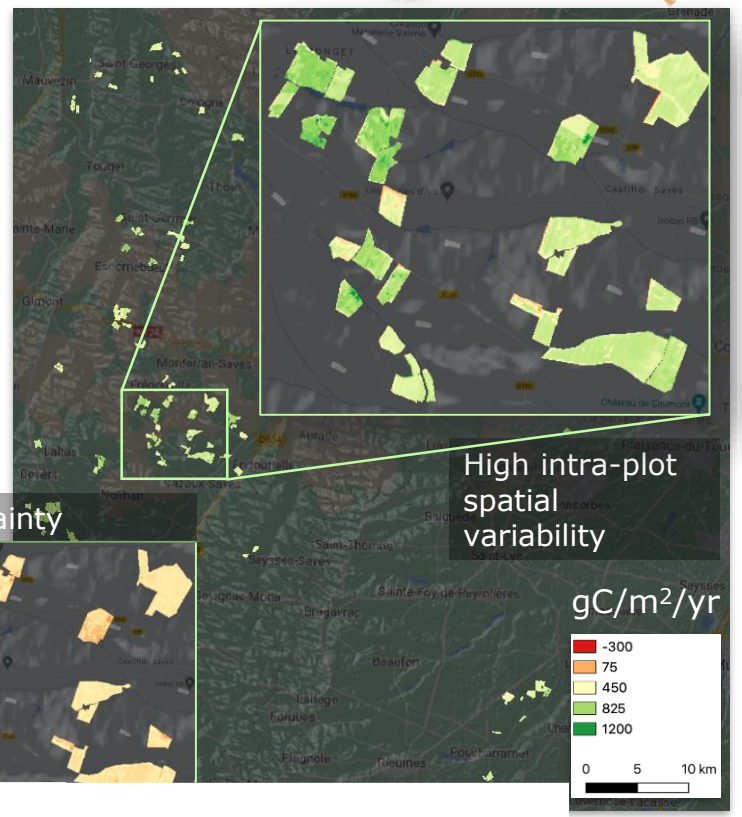
Realistic & objective assessment of the spatial variability of C inputs to the soil from biomass (crop + cover crop) in the standardised baseline calculation accounting for soil, other management and climatic effects

Specific baseline : Effect of cover crops on the net annual C budget

Over the double simulation exercice in an **insetting context**: farmers receive premium from the natais company (popcorn) according to how much C they store in the soil **yearly** with cover crops (Naturellement popcorn project)

Reality

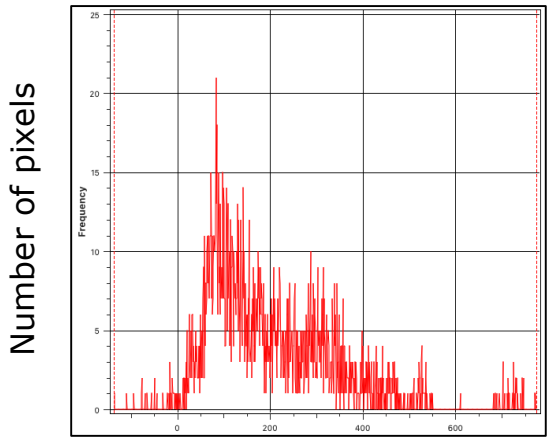
Cover crop + Maize



Uncertainty

Realisation A. Al Bitar

Distribution of the differences between the 2 simulations

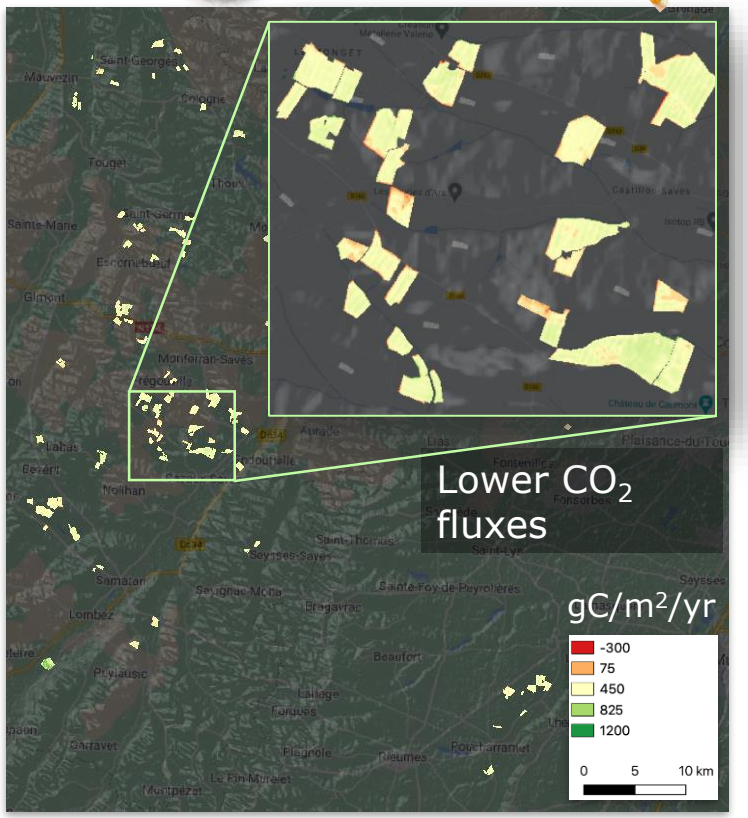


Difference between simulations

On average 200gC of Dry Mass/ha/yr or approx 0,3 t C/ha stored/yr thanks to the cover crops

Ignoring cover crop = baseline

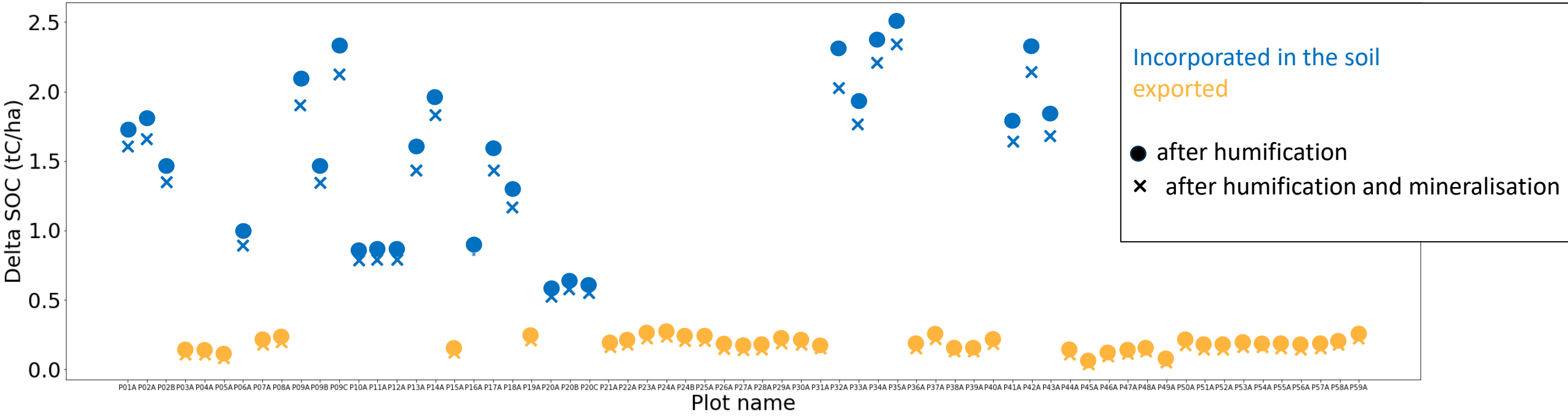
Bare soil + Maize



Possible to produce plot/farm specific baselines of the effect of cover crop on ΔSOC

Specific baseline: Effect of cover crops burial or exportation on SOC stocks changes

Quantica projects (financed by cnes CENTRE NATIONAL D'ÉTUDES SPATIALES) SCO SPACE CLIMATE OBSERVATORY ➔ assessing the effect of cover crop biomass production on SOC stock changes



Harvesting cover crop aboveground biomass to feed cattle reduces a lot their C storage effect

Possible to produce both plot specific baseline or to apply regional scenario of cover crop fate with very realistic assessment of biomass input effect on SOC in order to produce regional baseline

Data limitations to develop EO based MRV approaches

- **Limited to a few crops and cover crops** ➔ **progressive acquisition of new in-situ datasets for CAL/VAL in Europe (e.g. at ICOS sites) but we lack of ABG biomass data with ESU protocols for more crop/cover crop species (collab with companies & cooperatives…) and of co-located AGB biomass/ΔSOC/activity data !!!!**

ICOS flux tower network

We need a EU scale coordinated action

- Building on LUCAS ?
- Building on the JECAM network ?
- Others ?

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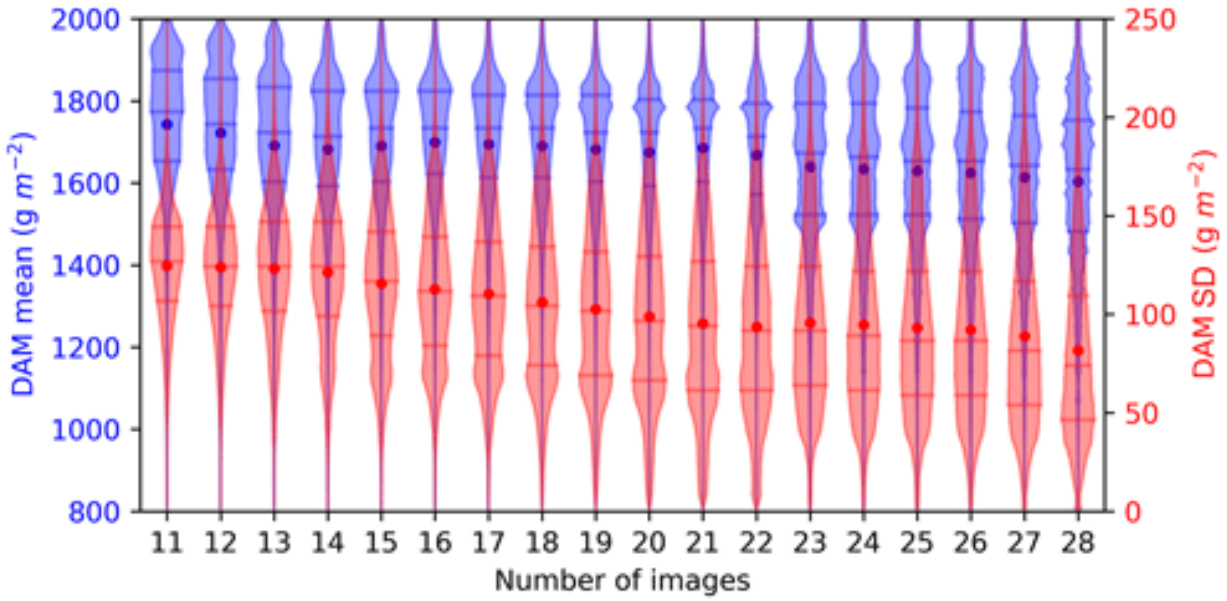
- **Use of HR optical remote sensing data only (S2, L8, Planet…) can be limiting for operational applications (long cloudy periods)** ➔ **combining optical SAR (Sentinel 1) satellite data assimilation will allow to overcome this issue (PhD A. Géraud in collab with Netcarbon)** ➔ **need for gapfilled LAI and/or proxy of biomass**



The reduction in the number of clear images (S2 + Landsat8) during the wheat cycle had little impact on the precision of the estimate of ABG biomass (left axis) but it increased the uncertainties (right axis)

(Wijmer et al., 2024)

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- **Quality, accessibility and spatial resolution of the soil data/products (e.g. initial SOC stock, texture) ➔ 1) use high resolution remote sensing data for digital soil mapping (collab with E. Vaudour) for regional applications and 2) use local soil data (e.g. soil samples, plot level maps) when relevant (e.g. VCM)**

- **Access to reliable management data on straw management and organic amendments is currently the strongest limitation for all modelling approaches at plot scale (to build specific baseline and to quantify ΔSOC stocks) ➔ the use of API to access FMIS is not enough, management data must be verified first (agricultural advisor)**

- **Yet to build standardised baselines, regional statistics on management is probably good enough.**

Thanks for your attention!!

More about our work: https://www.cesbio.cnrs.fr/agricarboneo/

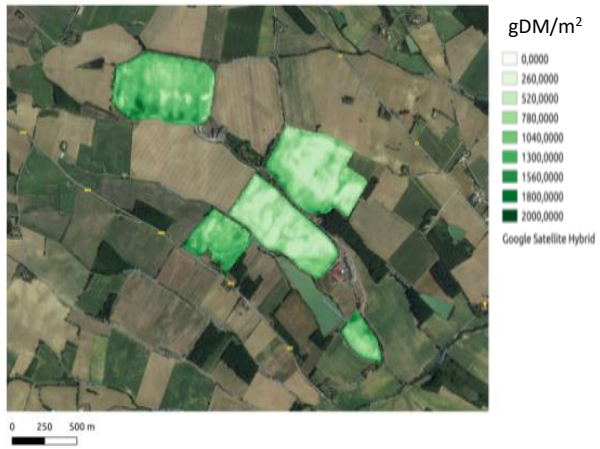
Contact : eric.ceschia@inrae.fr

High resolution C budget maps with ACEO

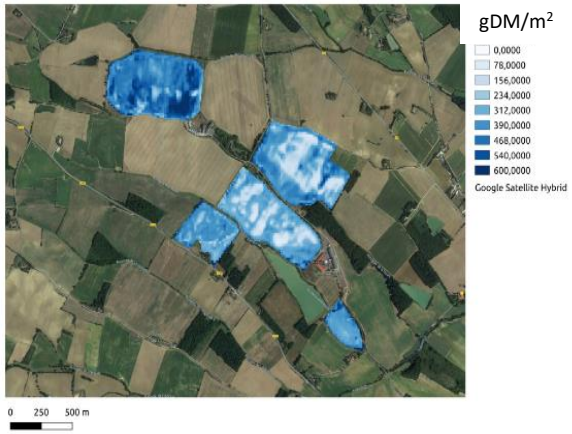
Naturellement popcorn project (insetting) ➔ farmers can receive a premium from the natais company depending on the amount of C they store in the soil thanks to cover crops biomass inputs

Realisation
T. Wijmer

Crop biomass + Uncertainties



Cover crop biomass + Uncertainties

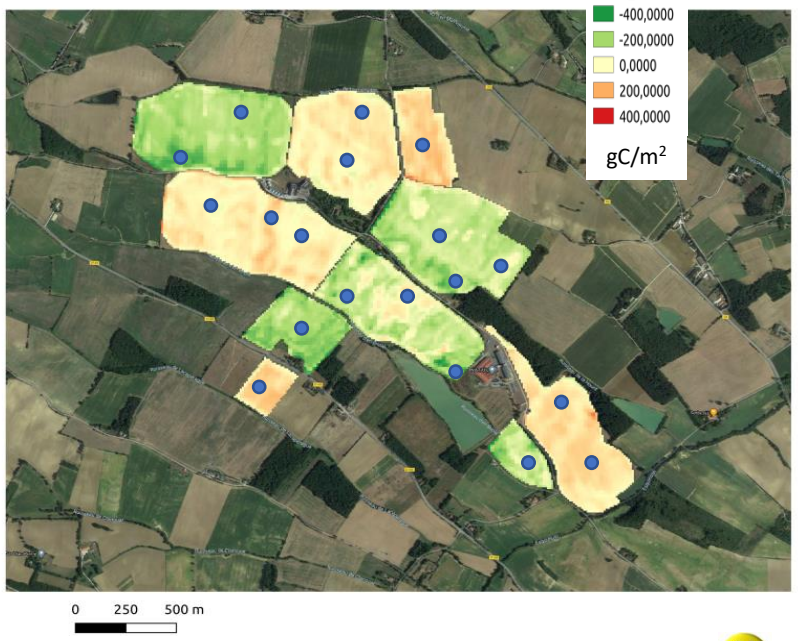


+ farmers data and the AMG soil model

10m resolution maps make it possible:

- to define an optimal cost/accuracy soil sampling scheme for verification of delta SOC stocks at plot/farm level
- to detect faster SOC stock changes by sampling areas with contrasted dynamics

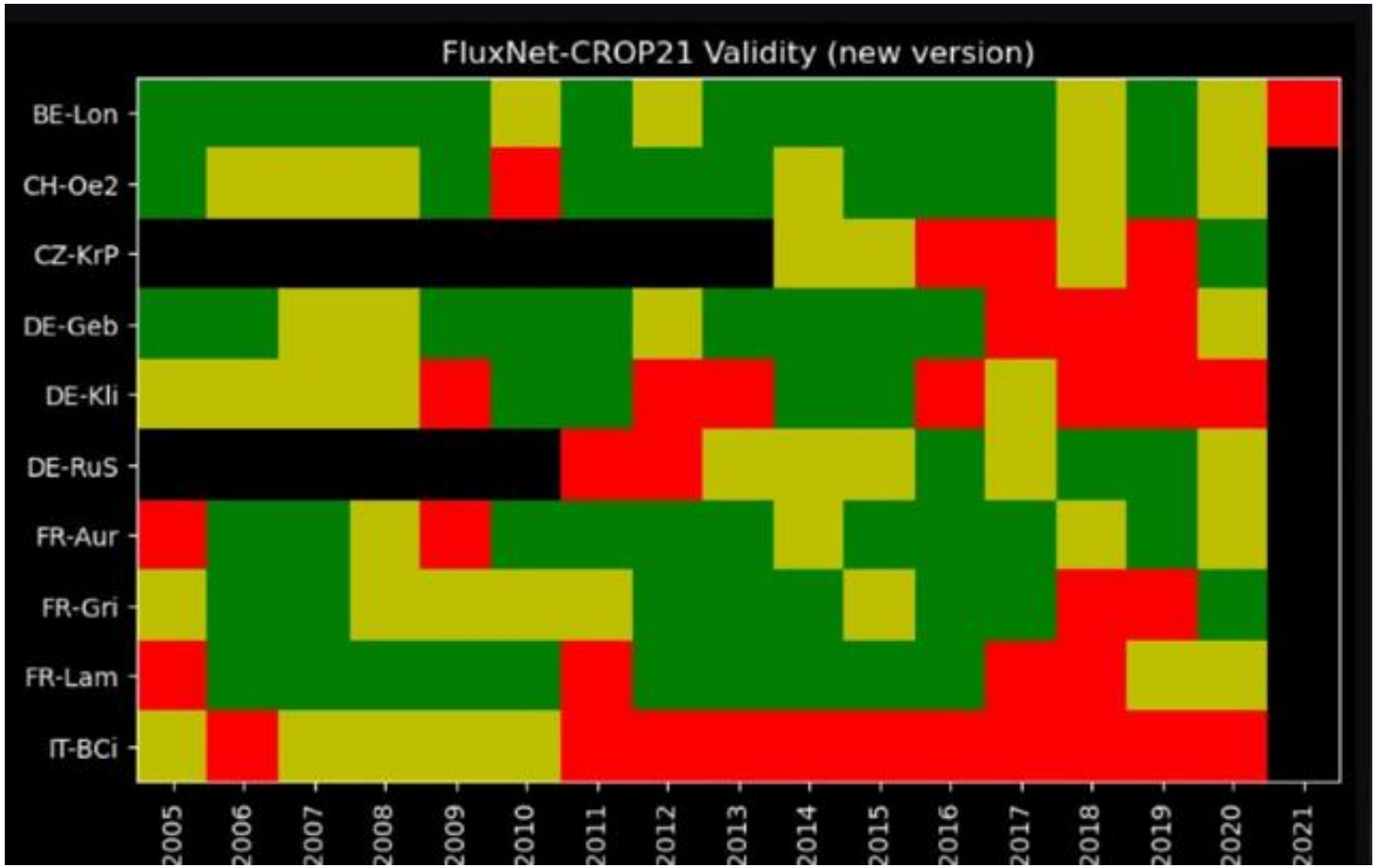
First C budget map at 10m resolution in 2019, for rotation cover crop/corn/wheat (Villeneuve farm, Bézéril, France)



C storage by the soil

C losses by the soil

Assessment of the data quality of the CROP21 dataset for our study

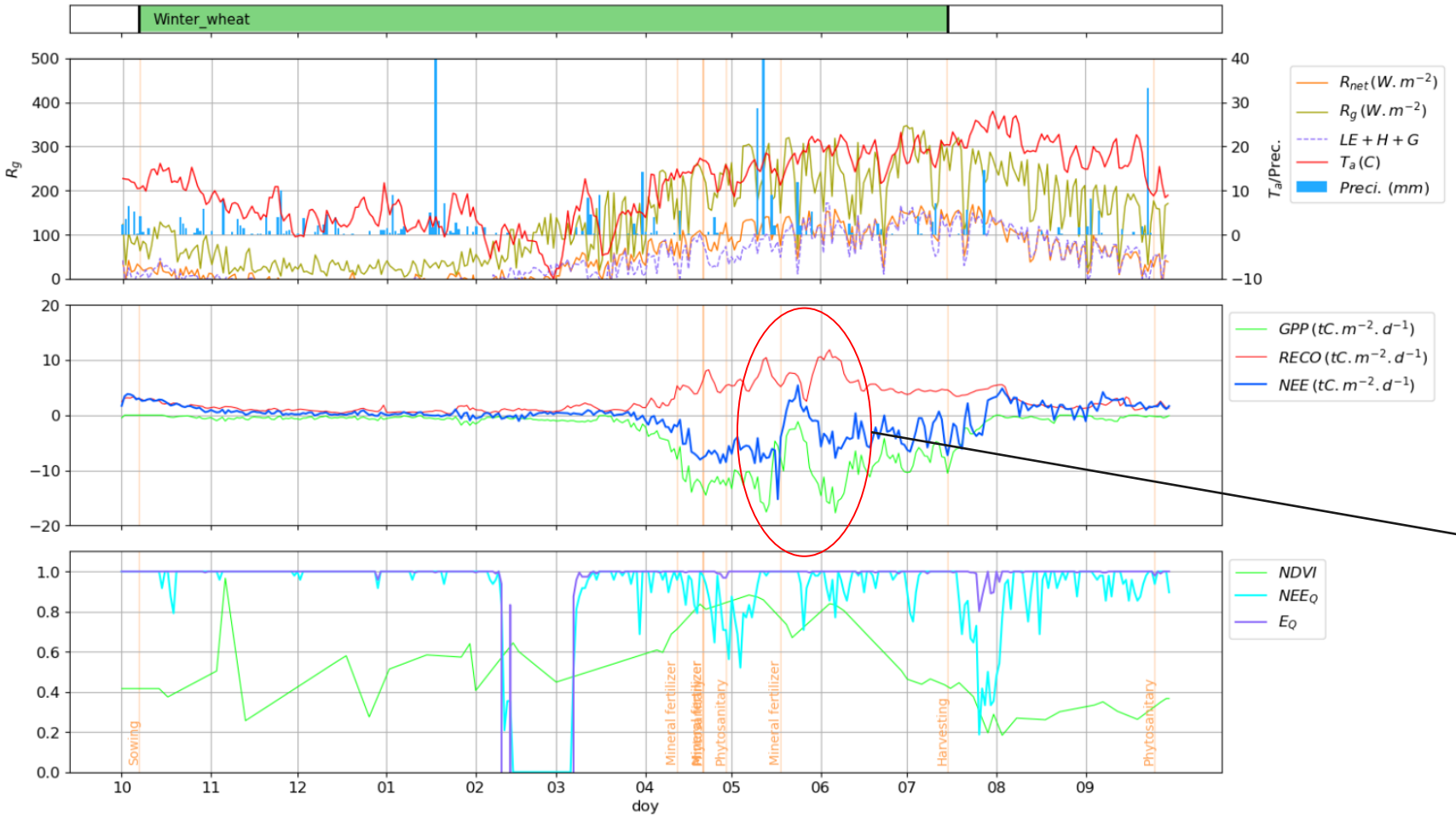


Unexploitable

OK

Good

DE-Geb en 2018 - Blé d'hiver

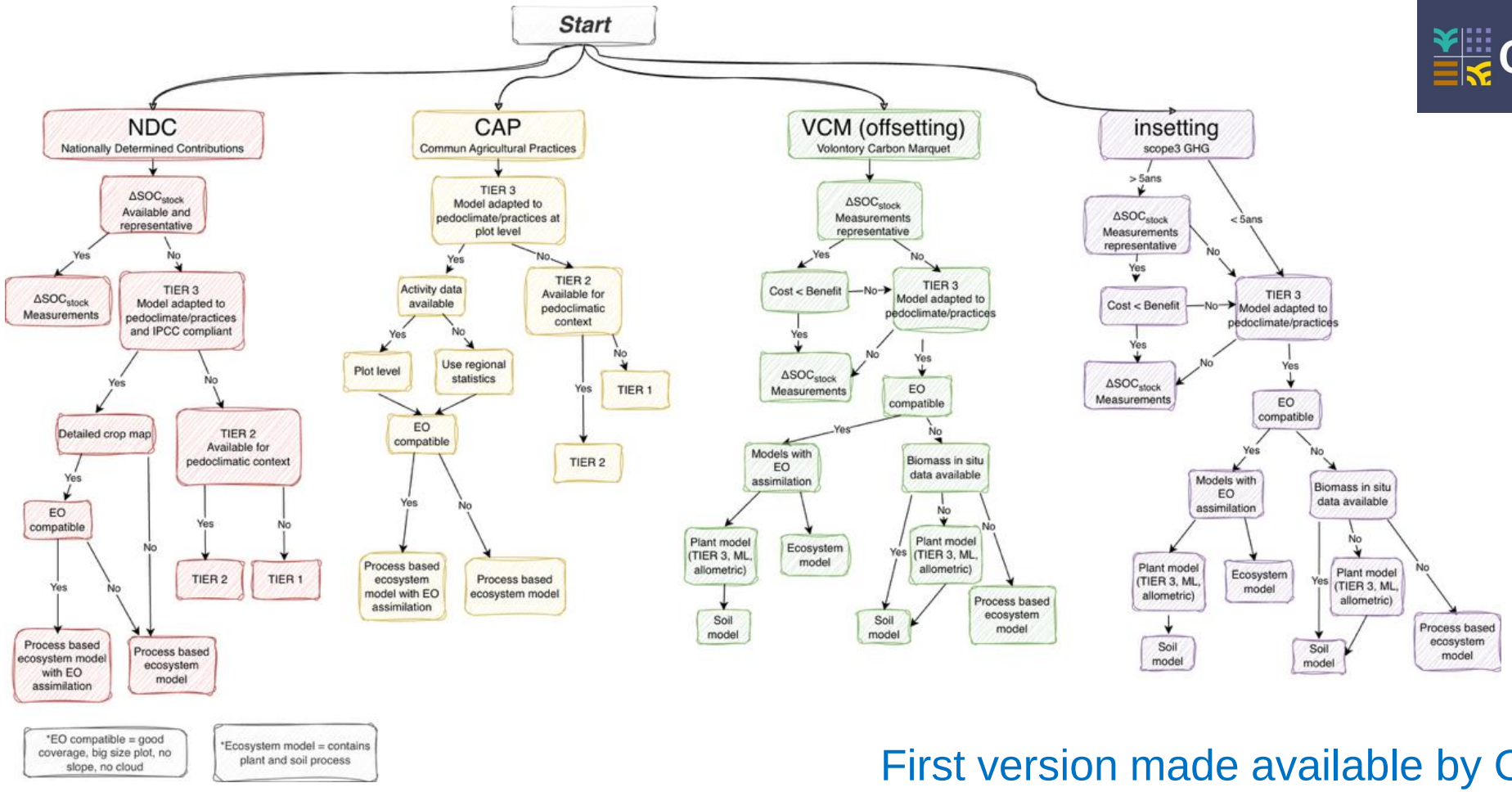


⇒ La chute de GPP correspond à la récolte de la moitié de la parcelle

⬭ Tour à flux

Contour de parcelle déclaré sur ICOS

Decision tree to choose the Monitoring approach tailored to the local context



First version made available by ORCASA at the end of the