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Proposition for a prototype of MRV tool for cropland C stock change assessment at high resolution over large regions

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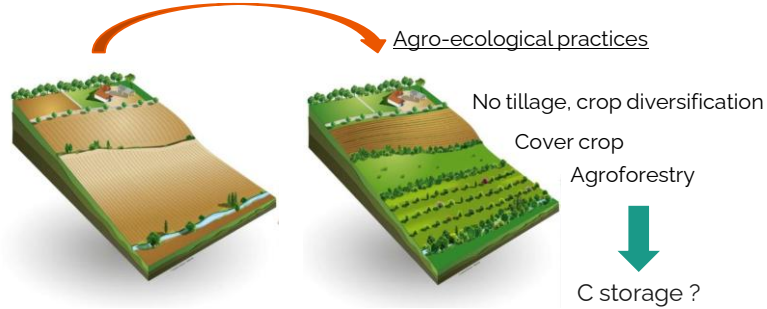
1. CESBIO, Université de Toulouse, CNES/CNRS/INRAE/IRD/UT3, 31400 Toulouse, France;
2. Laboratoire de Géologie, École normale supérieure, CNRS, PSL Univ., IPSL, Paris, France.
3. Catholic University of the Sacred Heart, Piacenza, Italie

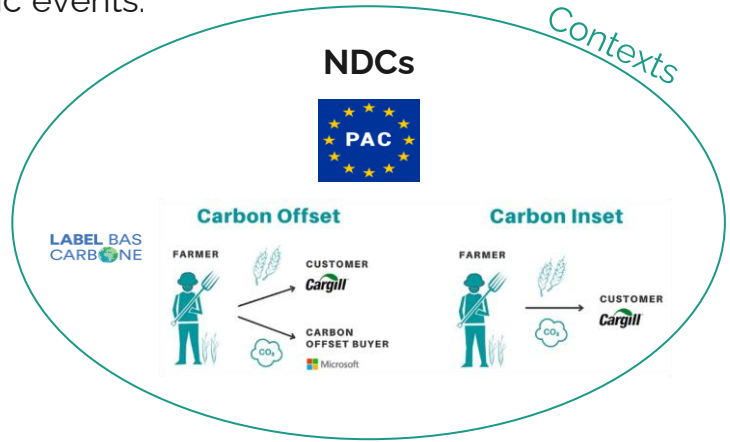
Cropland soil : CO_2 sequestration potential

Environmental and societal challenges

- Climate change mitigation ⇒ remain below 1.5°C of temperature increase by 2100 (COP21, 4p1000 initiative),
- Soil health ⇒ improve soil fertility, water restitution to plant, reduce erosion …
- Food security ⇒ increase crop resilience to extreme climatic events.



Source : Illustrations Arbres et paysages 32



How to assess the impacts of those practices in terms of CO_2 emissions/soil organic carbon storage at the plot scale but over large areas?

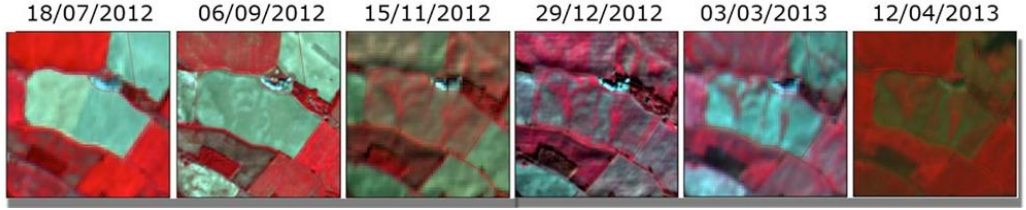
⇒ **Need for a new generation of tools providing an exhaustive/objective vision of the effect of management on SOC stock changes adapted to different contexts of application (CAP, NDCs, carbon market…) ⇒ ORCaSa, ClieNfarms, MARVIC…EU projects**

Monitoring : How to objectively address C budget ?

CIRCASA, K. Paustian et al 2019, P. Smith et al 2020

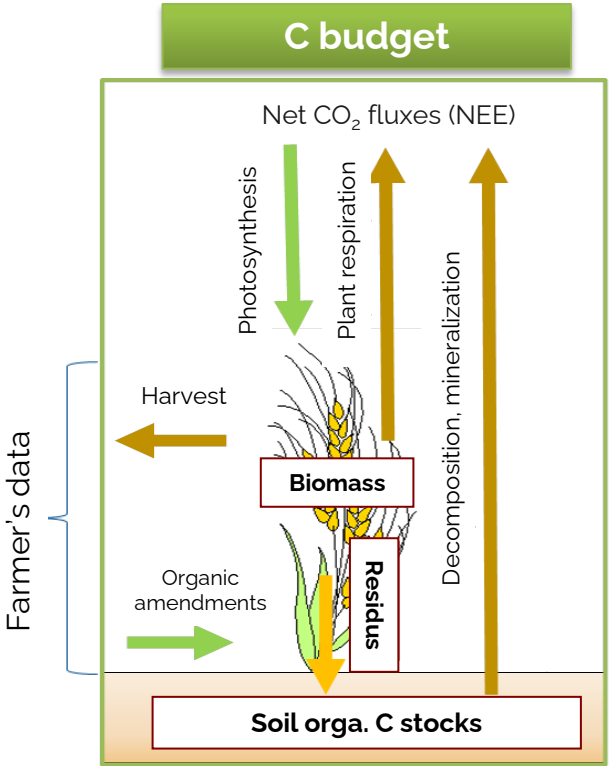
C budget approach ⇒ accounting for C input-output

⇒A global dynamic approach but which requires being able to quantify all C fluxes between the plot and its environment by measurements or via modeling.



SPOT4/5 data

⇒ Remote sensing allows to follow the dynamic and variability of vegetation development.



SAFYE CO_2 : Approach combining satellite and modeling for the spatial estimation of C budget

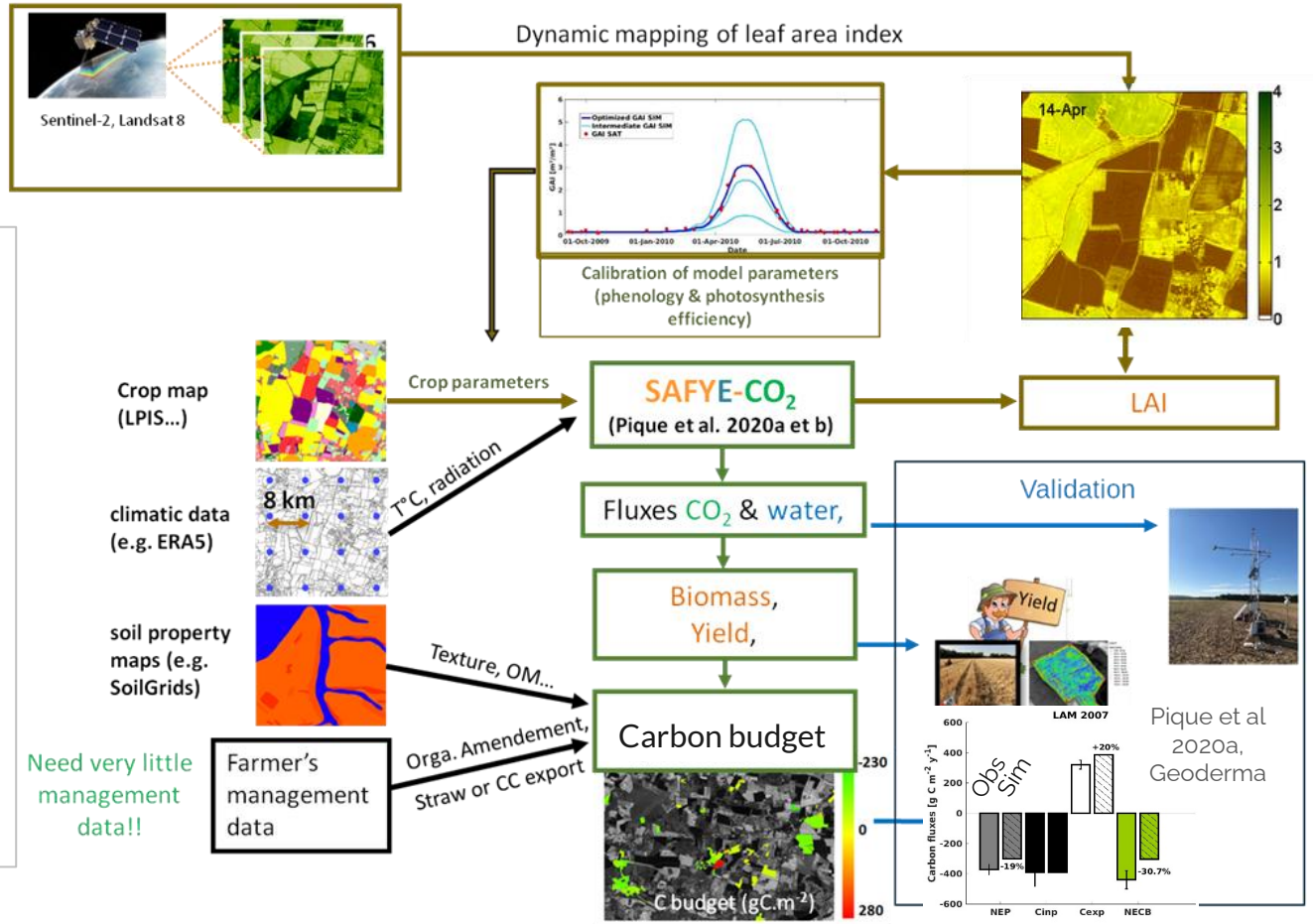
SAFYE-CO2

Satellite observations assimilation :

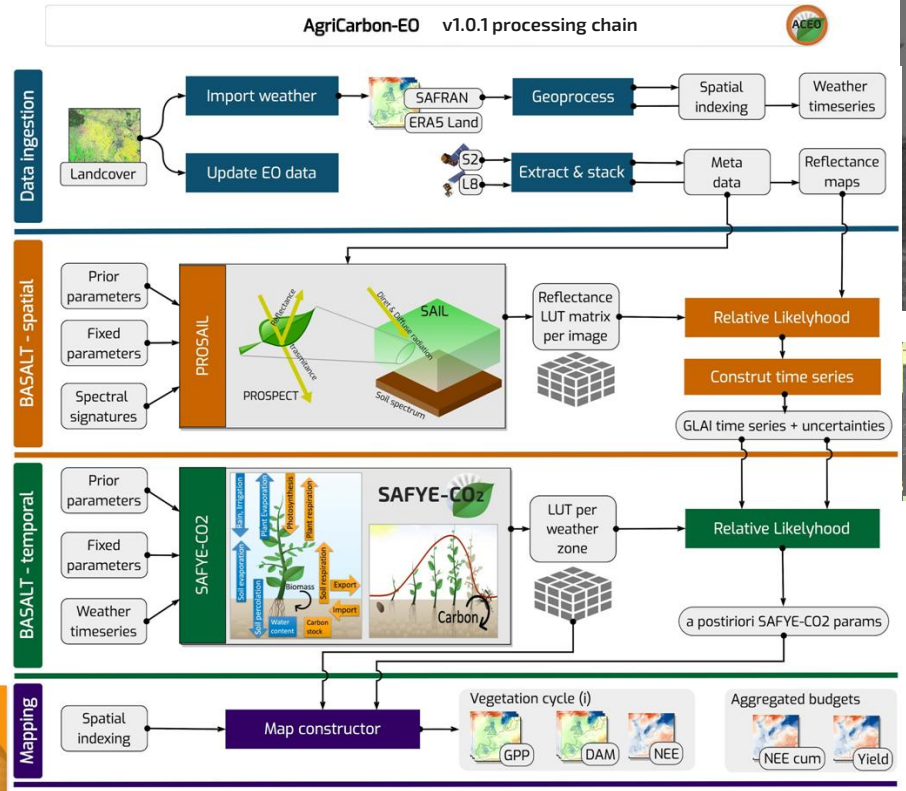
⇒ Reproduce the dynamics and development intensity of vegetation.
⇒ Implicit consideration of stress (N, water, etc), diseases and some practices.

Very simple soil respiration approach :

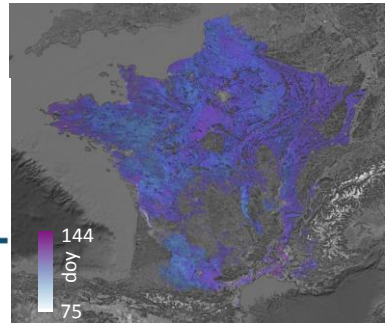
⇒ At first, empirical T(°C) function to overcome the uncertainties of soil products and farmer's data.



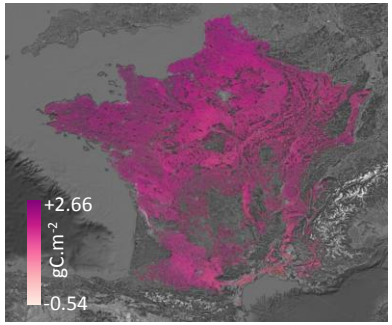
Agricarbon-EO : processing chain with spatialized plant model SAFYE CO_2



Source : T. Wijmer et al 2024

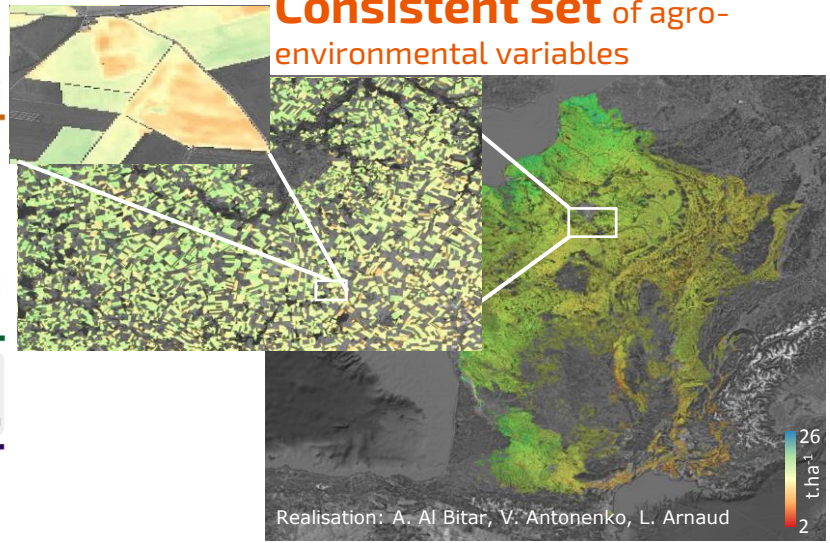


Emergence



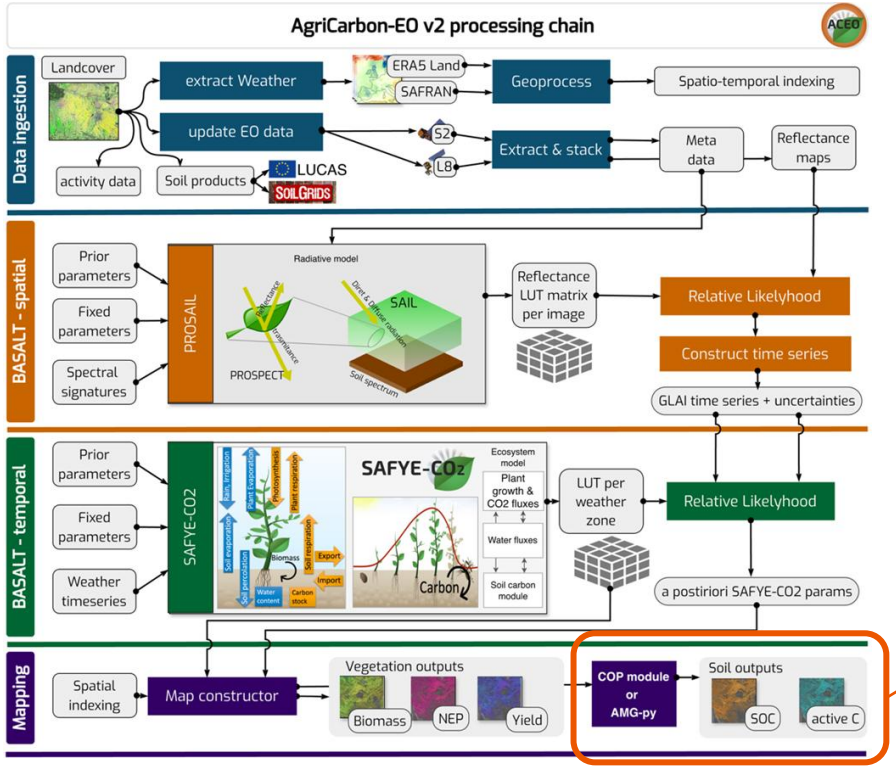
CO_2 Net Flux

Consistent set of agro-environmental variables



Dry above biomass

Agricarbon-EO : processing chain with spatialized plant model SAFYE CO_2 + soil models

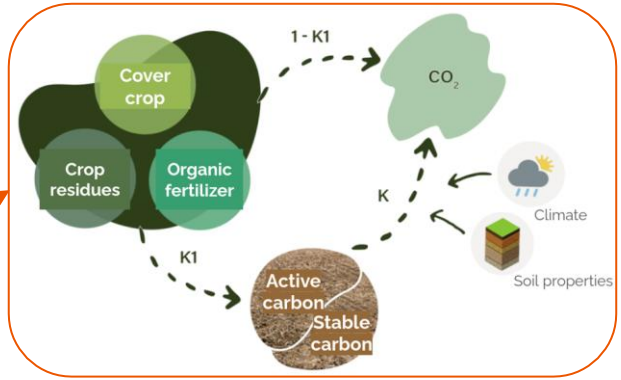


New : include soil model

⇒ Use parsimonious plant and soil models for spatialization. (Now AMG, next step RothC…)

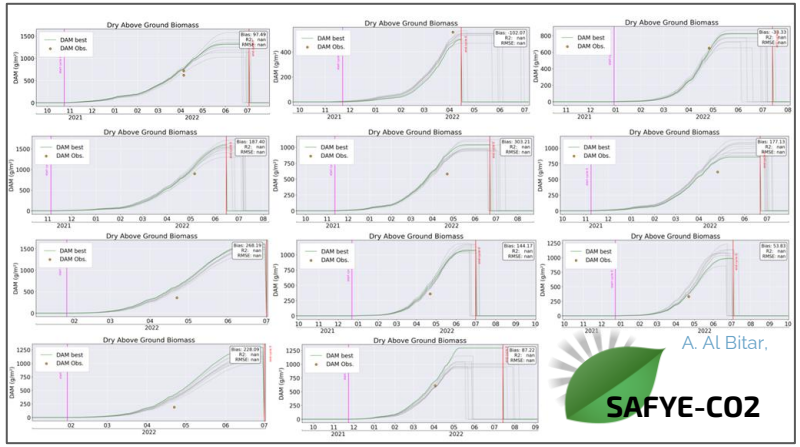
⇒ Consider spatial heterogeneity of vegetation inside the plot.

⇒ Improve the carbon input estimation of the soil model.

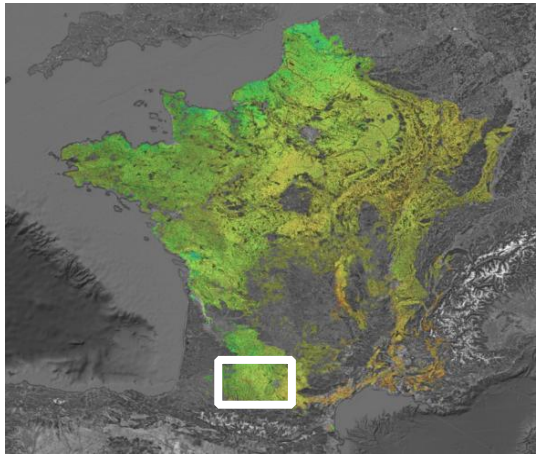


AMG soil model (Clivot et al 2019)

Effect of cover crop compared to bare soil on Soil Organic Carbon (SOC) stock



Biomass validation of cover crops



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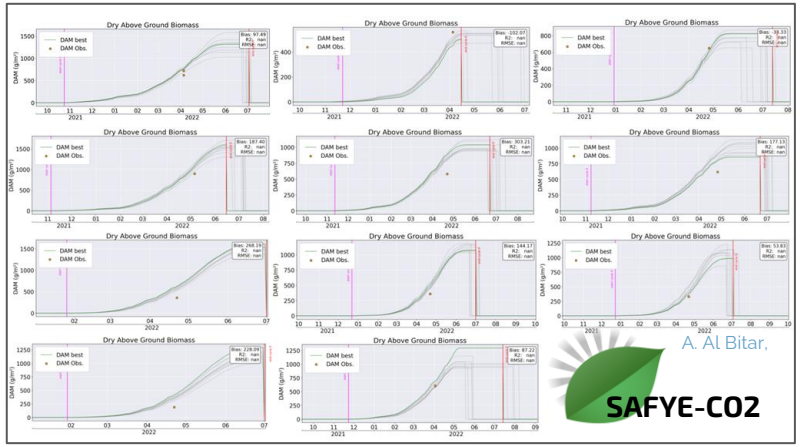


Biomass validation of cover crops

Simulations over a 2 years crops rotation.

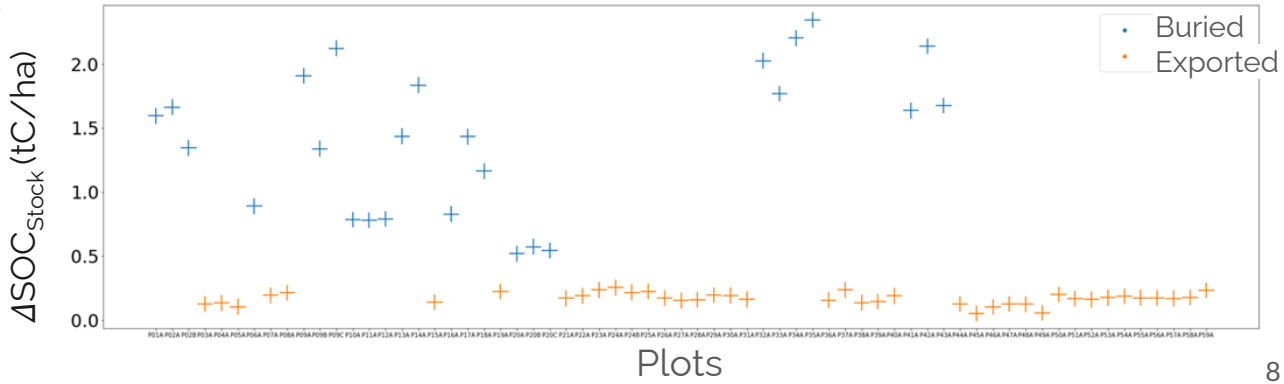
2 scenarii :

1. Real practice = Cover crop (CC) (**buried** **or** **exported**) between the 2 main crops.

1. Baseline = Bare soil (BS) between the 2 main crops.

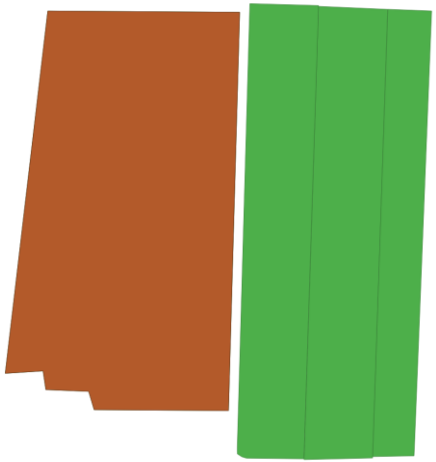
$\Rightarrow \Delta SOC_{Stock} = SOC_{Stock\_final}(CC) - SOC_{Stock\_final}(BS)$

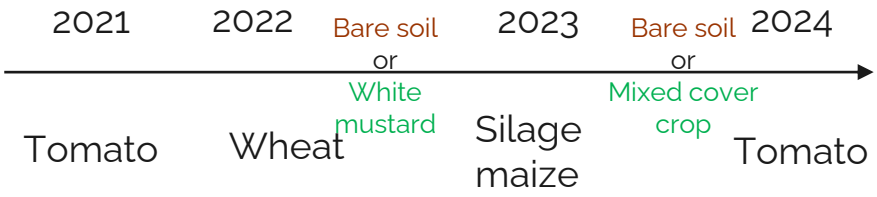
+ AMG



Study site : Piacenza, Italy → Analysis of transposability of the approach

Vegezzi





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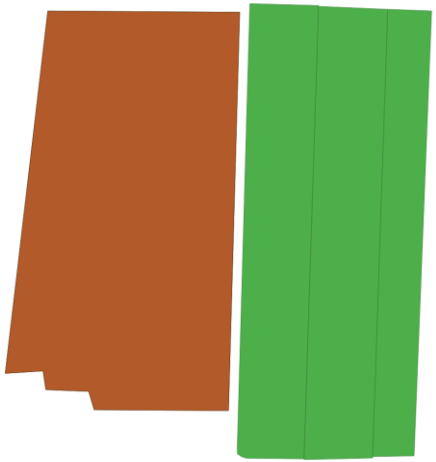
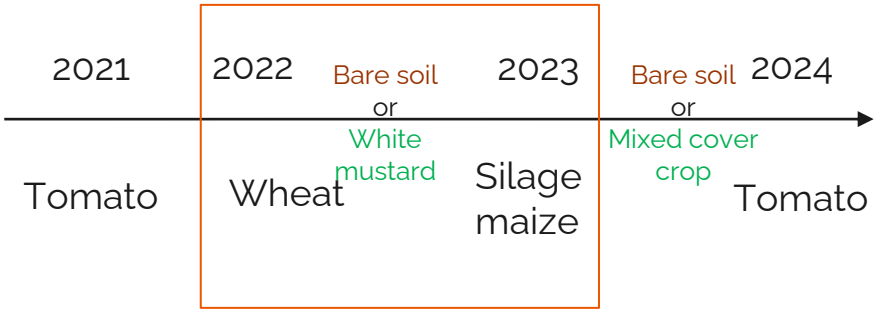
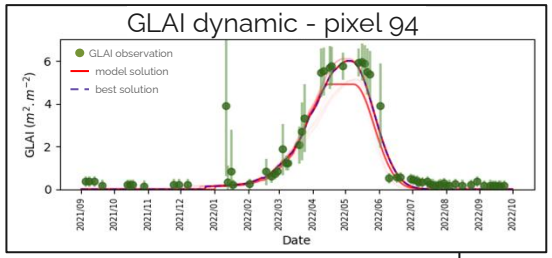
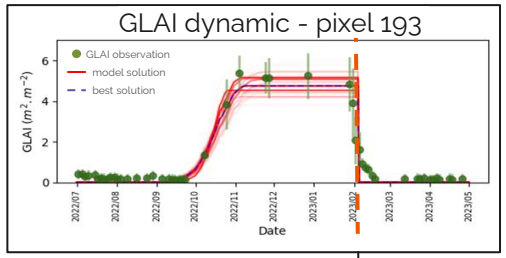


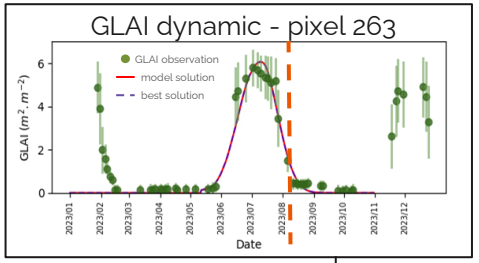


Dry above ground biomass maps at the end of cycle

GLAI Assimilation :

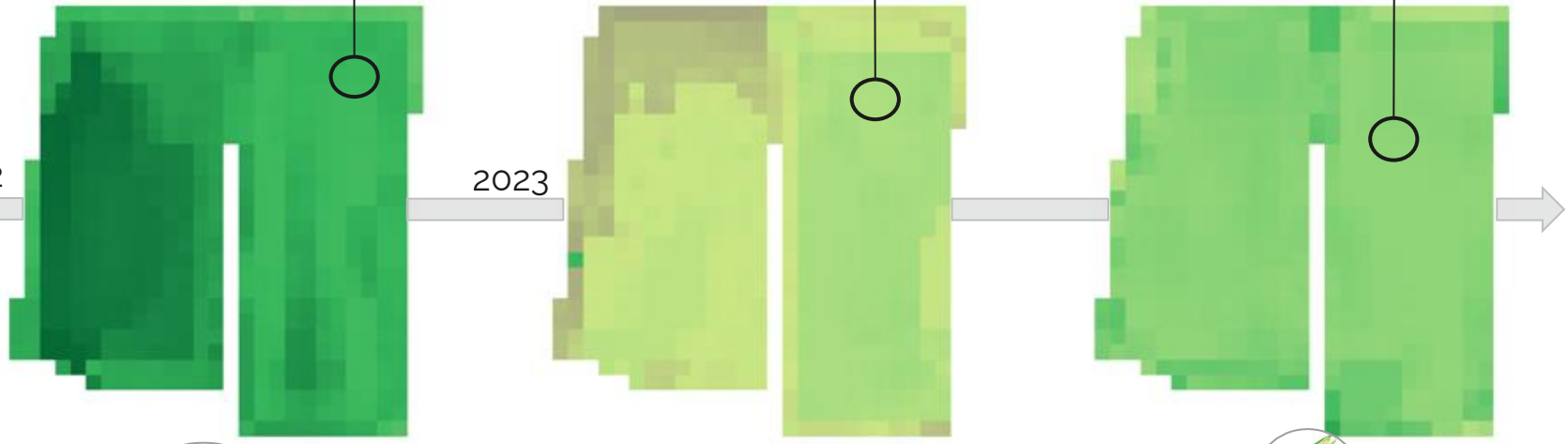






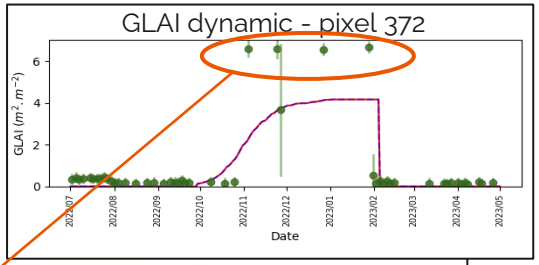
2022

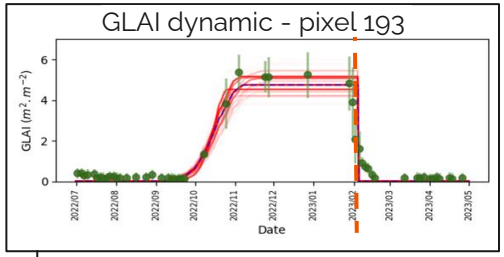
2023



(DAM: “Dry Above Mass”)

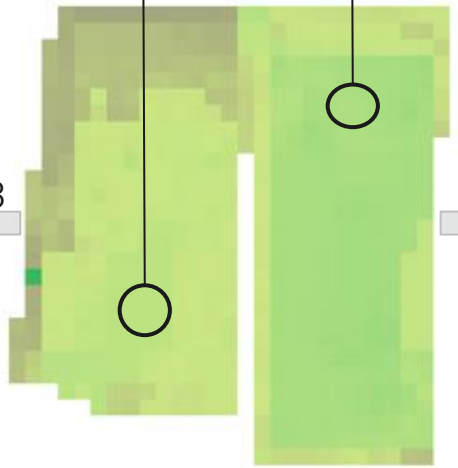
Some limits …





! Falsely detects vegetation due to unfiltered clouds !

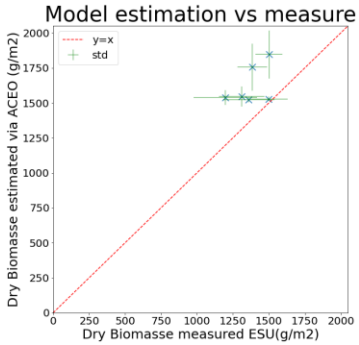
2023



(DAM: “Dry Above Mass”)

Dry above ground biomass maps at the end of cycle

Biomass Validation :



Work in progress..

Work in progress..

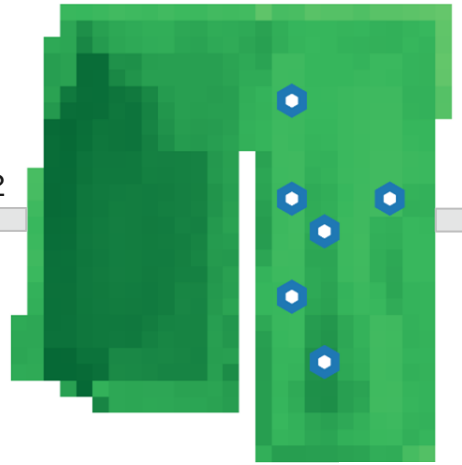
µDAM (t/ha)

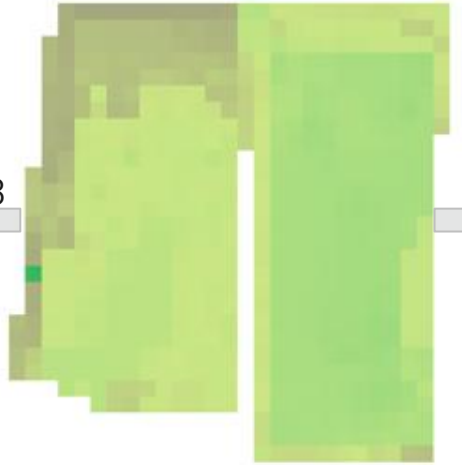
20

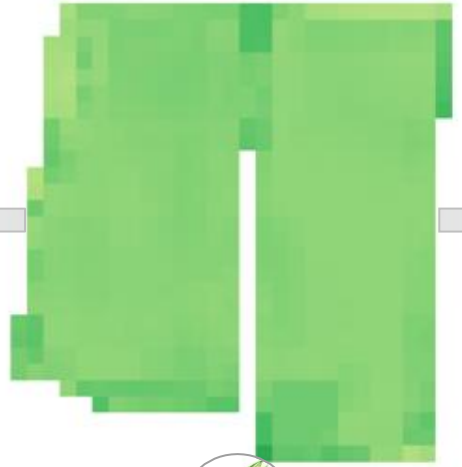
2

2022

2023



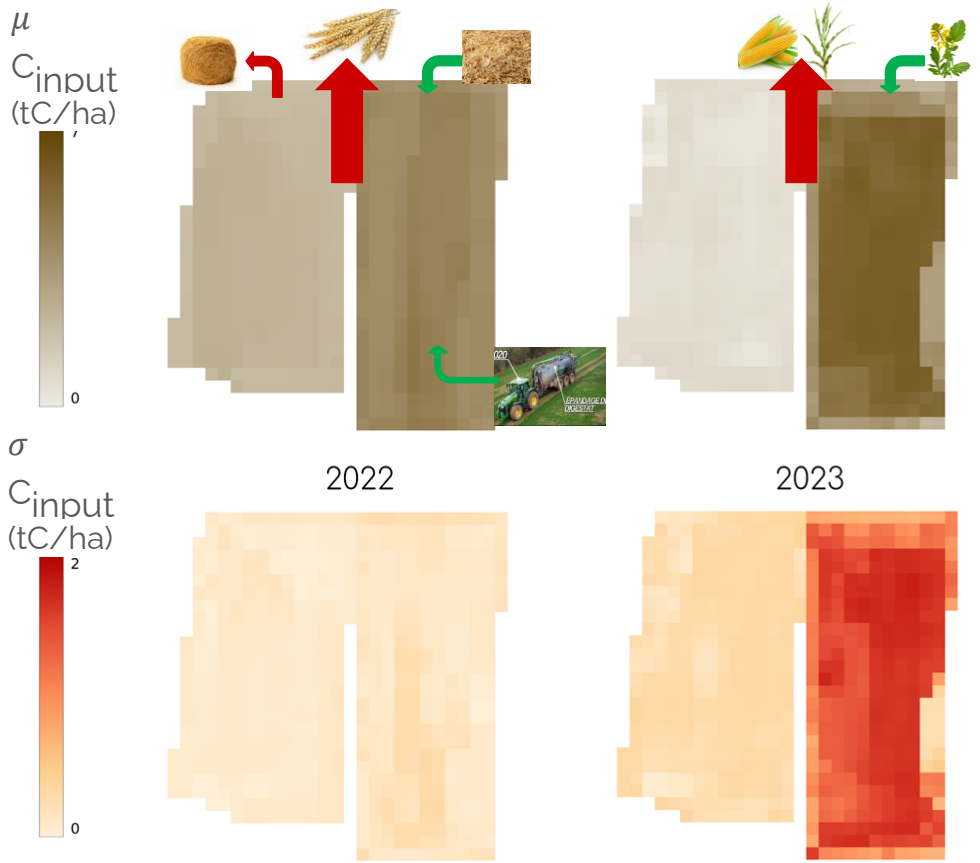




ESU

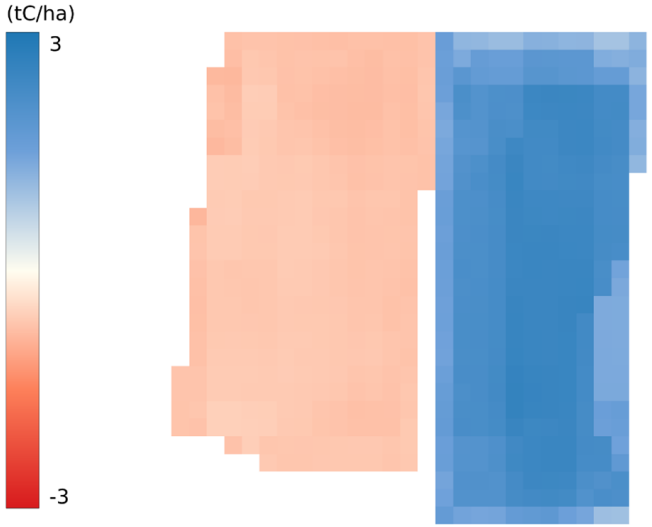
(DAM: “Dry Above Mass”)

Carbon input maps and its uncertainties for each year

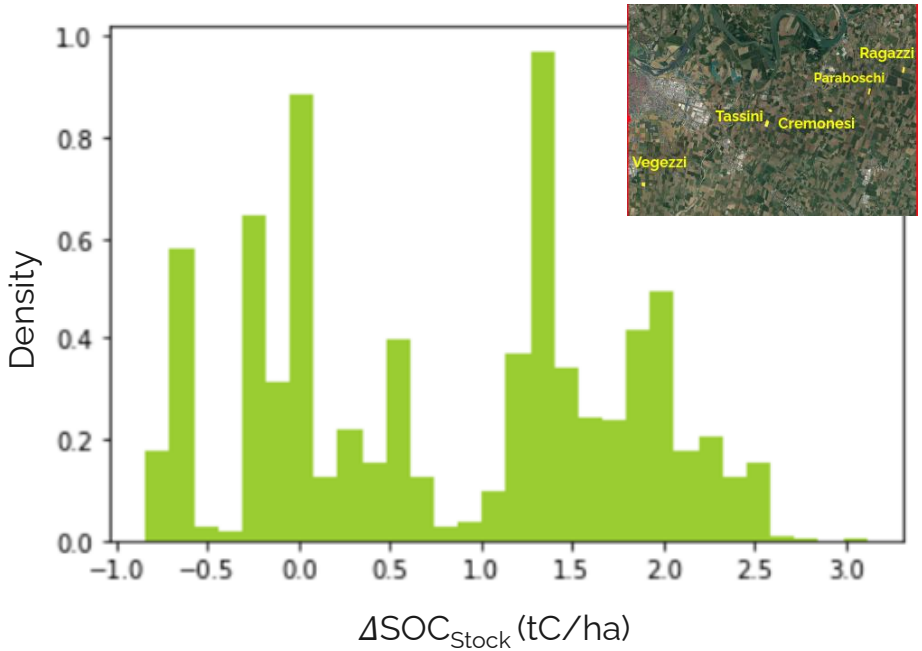


Variation of ΔSOC_{stock} estimated by AMG over 2 years

ΔSOC_{stock} over 2 years on Vegezzi:



ΔSOC_{stock} over 2 years for all 5 plots pixels:



AgriCarbonEO v2

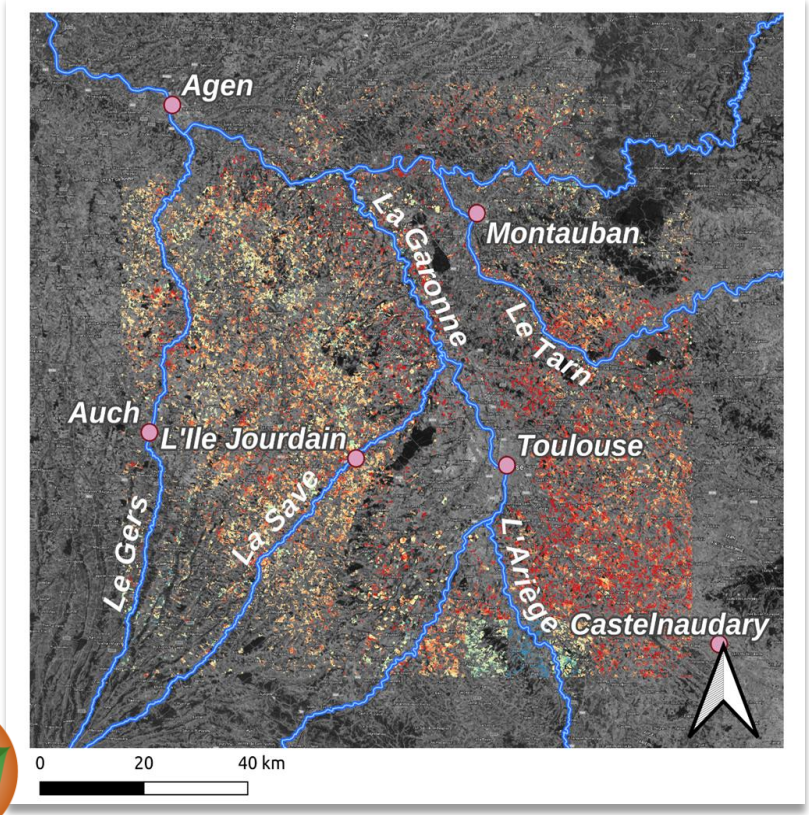
ACEO + AMG

⇒ Allows to evaluate:

1. The effect of contrasting practices on variations in carbon stocks in different soil pools.
2. Over short periods (<5ans).

Variation of ΔSOC_{stock} estimated by ACEO v2 over 5 years

T31TCJ Sentinel 2 Tile



ΔSOC_{stock} (tC/ha)

2,5

0

-2,5

⇒ Use LUCAS data for soil properties in AMG.

⇒Set uniform initial carbon stock at 46 tC/ha for the 30cm top soil.

⇒ Use french RPG for crop rotation.

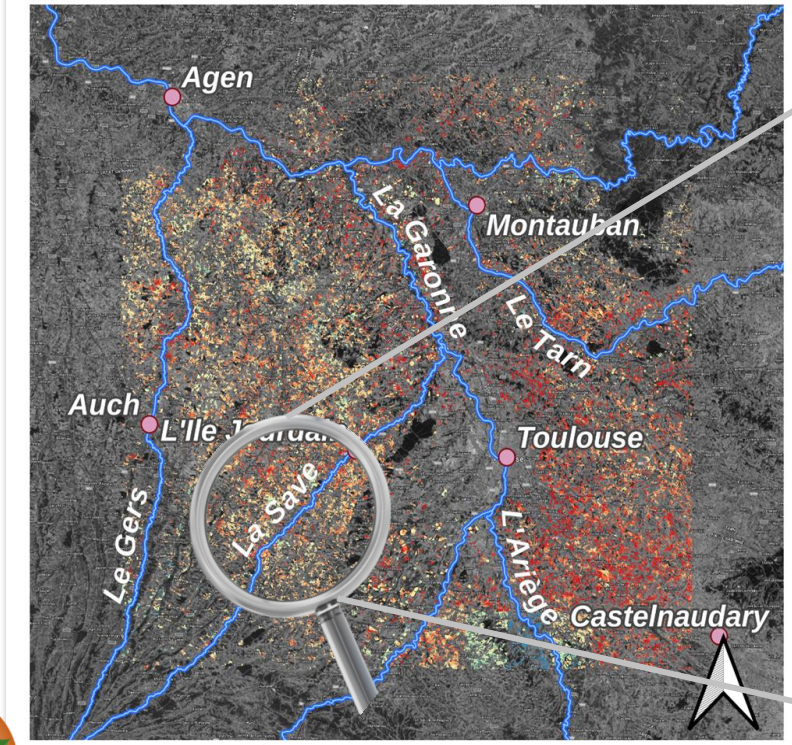
⇒To detect cover crop : at least 75% of the plot with NDVI>0.4 during january-march (usually faba bean and phacelia).

⇒Assume straw incorporation and no organic amendment (realistic for the region).

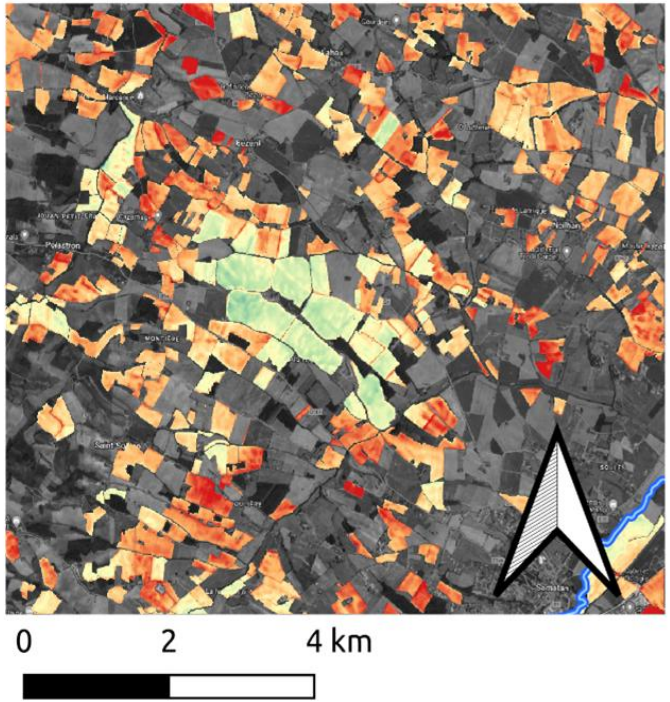
Source : T. Wijmer in preparation

Variation of ΔSOC_{stock} estimated by ACEO v2 over 5 years

T31TCJ Sentinel 2 Tile

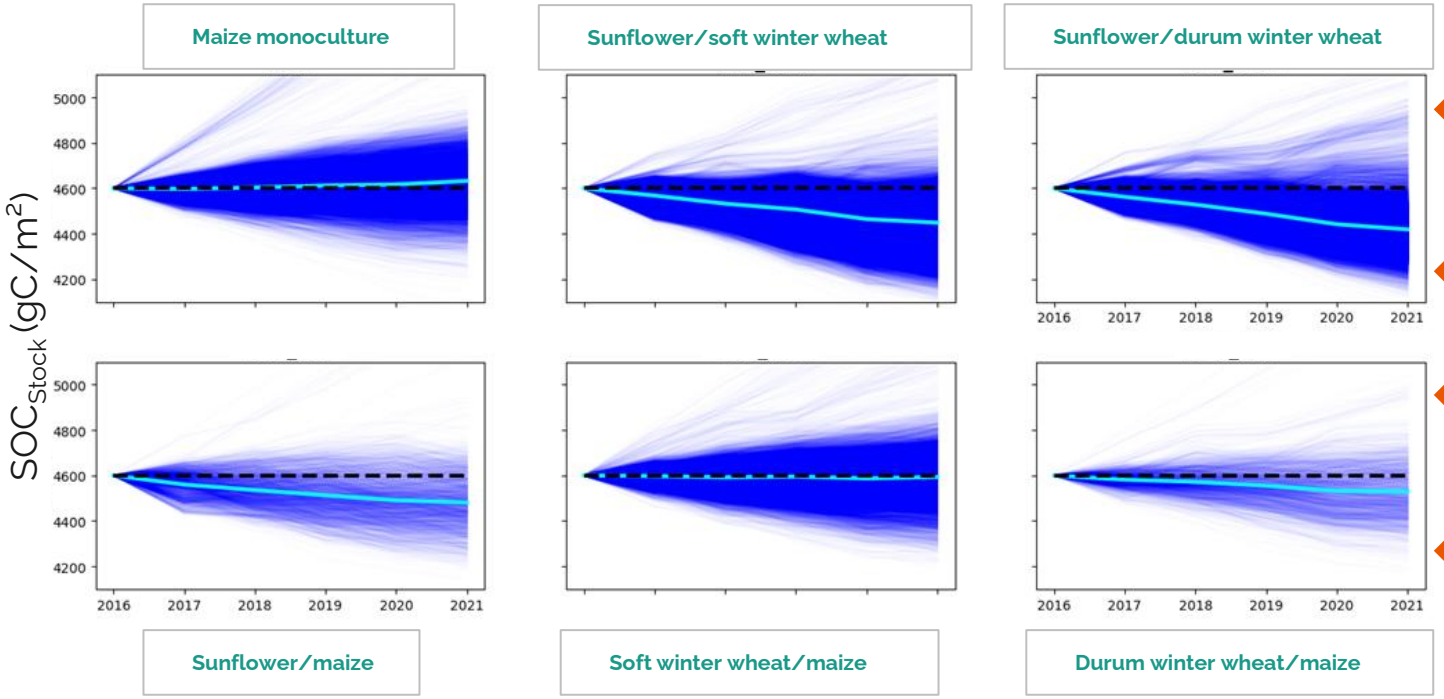


Villeneuve farm



Source : T. Wijmer in preparation

Analyses of ΔSOC_{Stock} per crop rotations (gC/m2) per pixel



Source : T. Wijmer in preparation

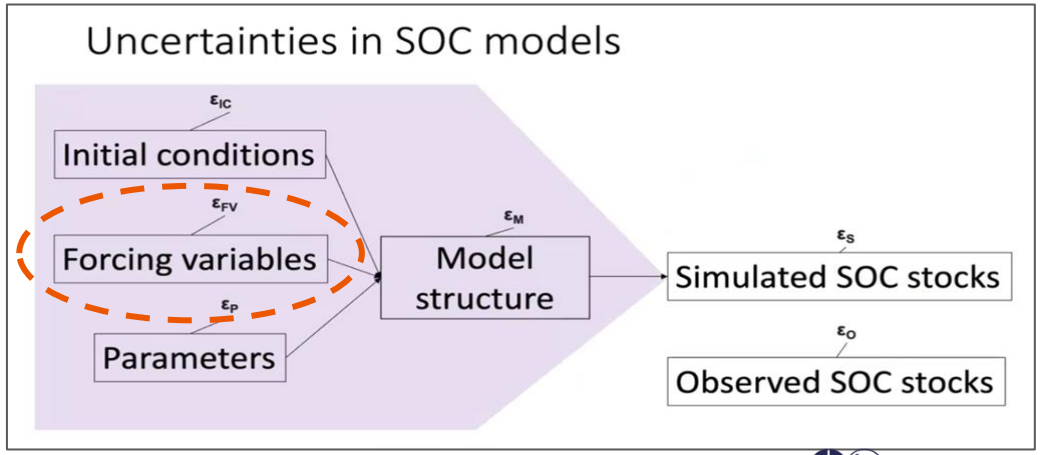
Conclusion

Objective : Quantify the components of the C budget at high resolution and large scale

⇒ Use of an operational processing chain ACEO with new soil module (AMG) taking into account the spatial variability of biomass production/restitution (+ uncertainties) and soil properties.

AgriCarbonEO v2

ACEO + AMG



Source : Elisa Bruni, Marvic Webinar 7

MARVIC
MRV for carbon farming

Conclusion

Objective : Quantify the components of the C budget at high resolution and large scale

⇒ Use of an operational processing chain ACEO with new soil module (AMG) taking into account the spatial variability of biomass production/restitution (+ uncertainties) and soil properties.

⇒ Study of transposability of the chain (validated in France on biomass, yield, flux) in Italy.

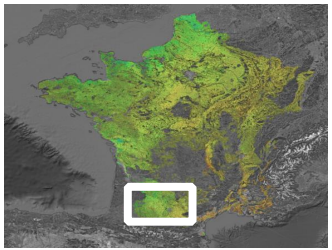
⇒ Assessment of the impact of different practices on variations in soil organic carbon stocks.

Perspectives

1. Evaluate the reduction of uncertainties in the initialization of the soil model using the Rock Eval method

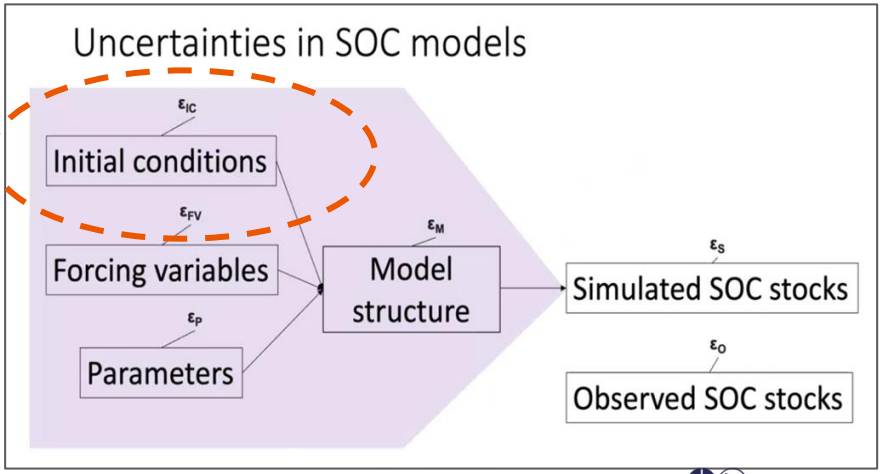
1. Evaluate the overall approach against in situ **Δ** SOC_{Stock}/fluxes measurements and compare the performances of AMG with other soil models

ICOS flux sites



Nataïs plots

ClieNFarms plots



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MARVIC
MRV for carbon farming

Future perspective : when mature, using digital soil map of soil organic carbon from remote sensing as an input.

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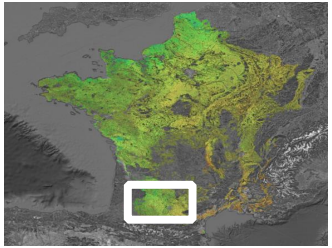

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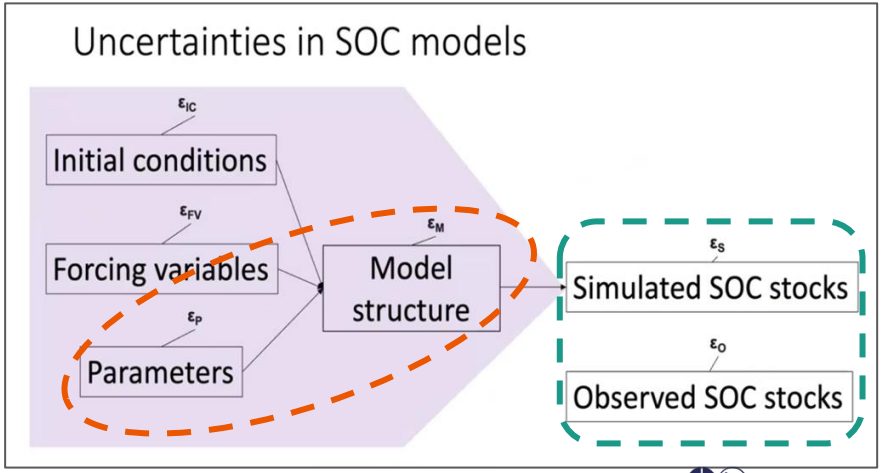

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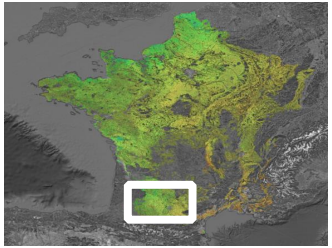
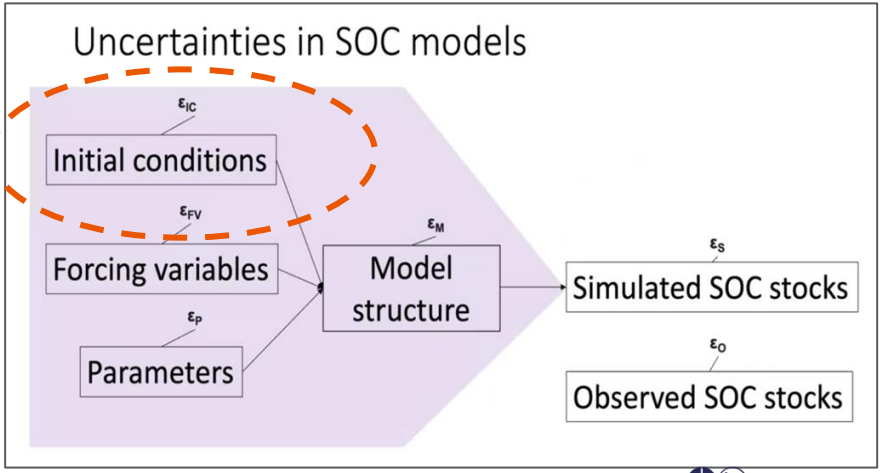


Nataïs plots

ClieNFarms plots



Source : Elisa Bruni, Marvic Webinar 7

MARVIC
MRV for carbon farming

Future perspective : when mature/accurate enough, using digital soil map of soil organic carbon from remote sensing as an input.

Thank you for your attention !

Ainhoa IHASUSTA : ainhoa.ihasusta@inrae.fr

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Annexes

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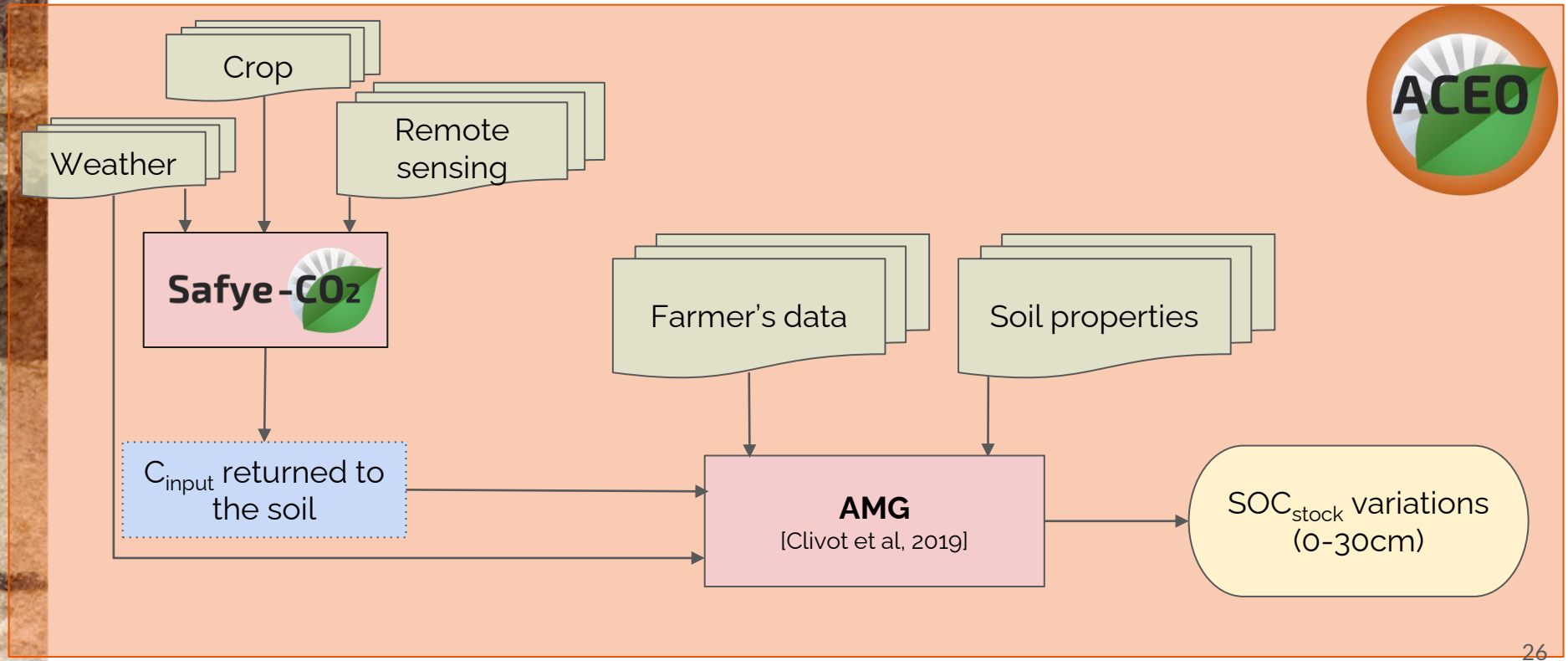
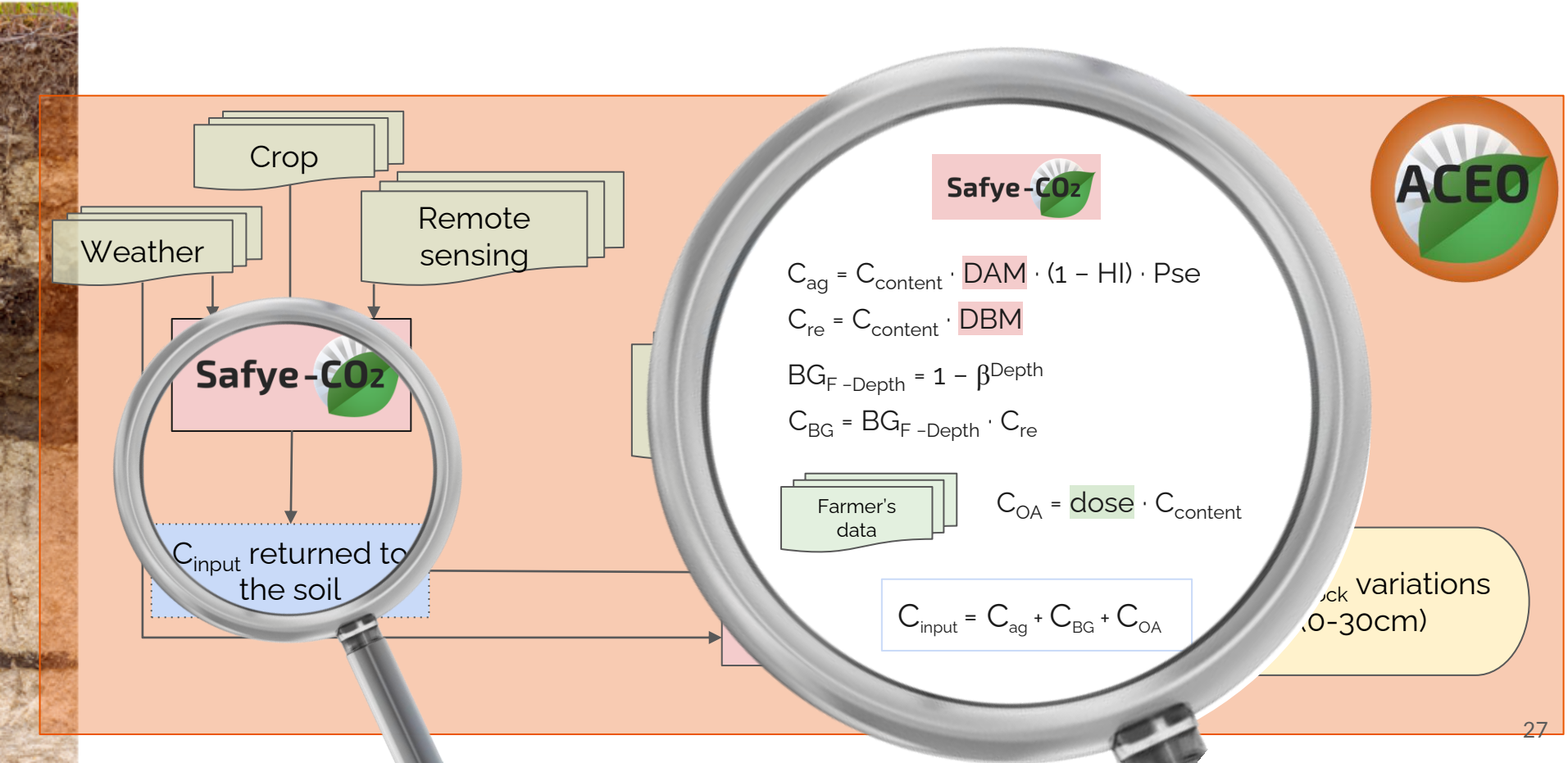
AMG forced SAFYE CO_2 biomass



AMG forced SAFYE CO_2 biomass



Propagation of biomass uncertainties of SAFYE CO_2 into the C_{input} estimation

Safye-CO2

$C_{ag} = C_{content} \cdot DAM \cdot (1 - HI) \cdot Pse = a \cdot DAM$

$C_{re} = C_{content} \cdot DBM$

$BG_{F\ -Depth} = 1 - \beta^{Depth}$

$C_{BG} = BG_{F\ -Depth} \cdot C_{re} = b \cdot DBM$

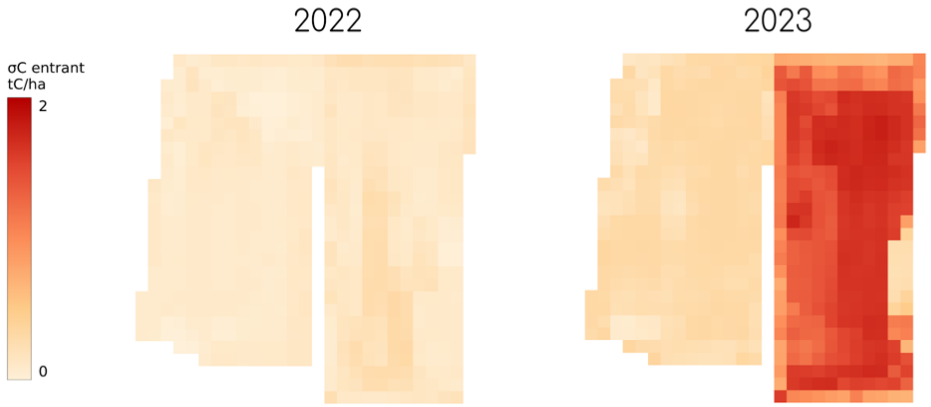
Farmer's data

$C_{OA} = dose \cdot C_{content}$

$C_{input} = C_{ag} + C_{BG} + C_{OA}$

$\sigma(C_{input})^2 = \sigma(C_{ag})^2 + \sigma(C_{bg})^2 + \sigma(C_{OA})^2 + 2ab \cdot cov(DAM, DBM)$

Avec : $\sigma(C_{ag})^2 = a^2\sigma\,(DAM)^2$ et $\sigma(C_{bg})^2 = b^2\sigma\,(DBM)^2$



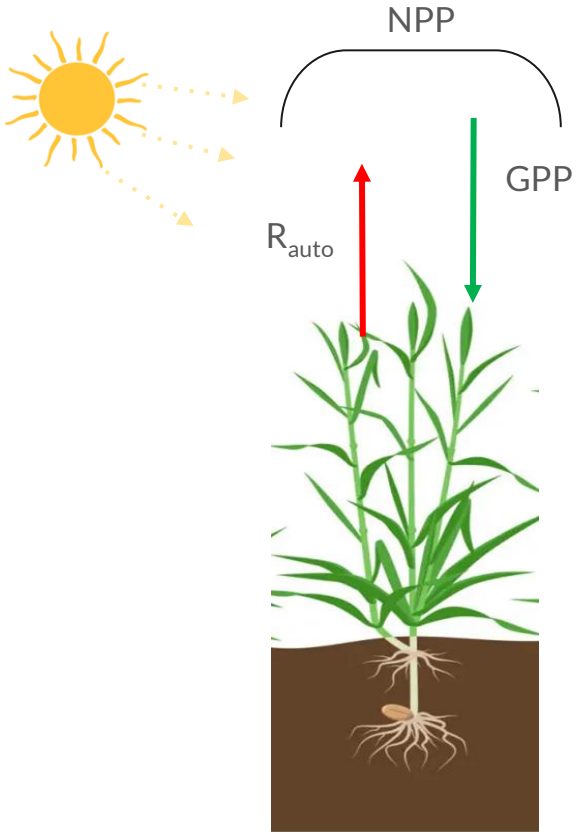
Daily estimation :

$$\mathrm{GPP} = R_{\mathrm{g}} \cdot \epsilon_c \, f_T(T_{\mathrm{a}}) \cdot f_{\mathrm{w}}(\mathrm{WC}) \cdot \mathrm{ELUE} \cdot \mathrm{APAR} \cdot \mathrm{SR}_{10},$$

Source : T. Wijmer et al 2024

Safye-CO_2

Daily estimation :



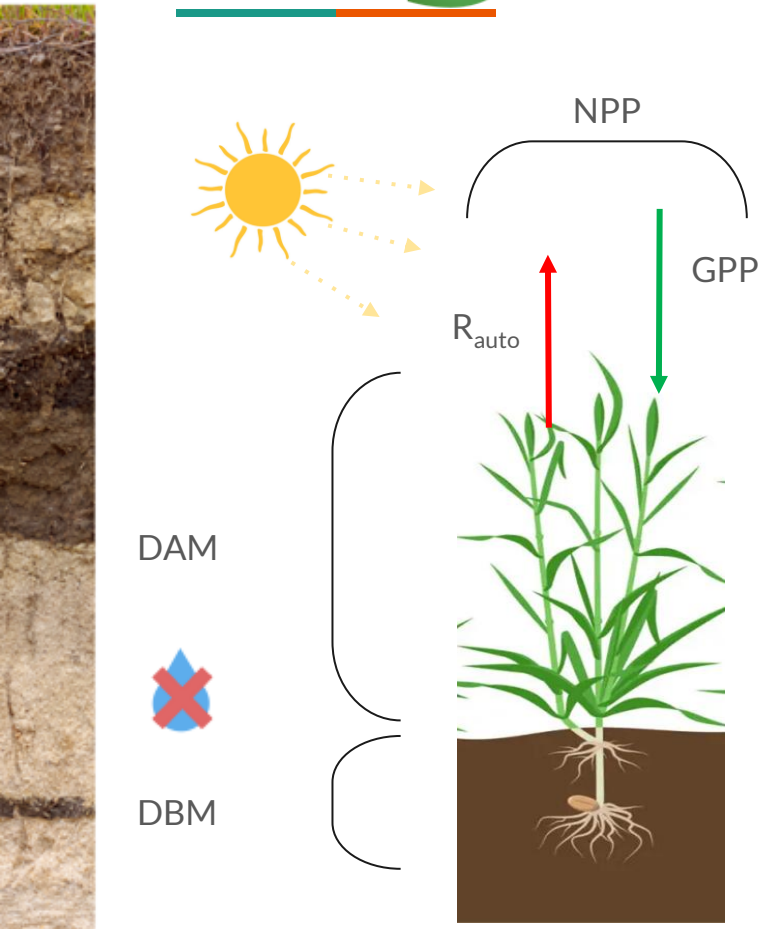
$$\mathrm{GPP} = R_g \cdot \epsilon_c f_T(T_a) \cdot f_w(\mathrm{WC}) \cdot \mathrm{ELUE} \cdot \mathrm{APAR} \cdot \mathrm{SR}_{10},$$

$$\begin{cases} R_{auto} = R_{maint} + R_{grow}, & \text{where} \\ R_{maint} = R_{10} \cdot Q_{10}^{-0.1 \cdot (T-10)} \cdot \mathrm{SR}_{10} \\ R_{grow} = (1 - Yg) \cdot (\mathrm{GPP} - \mathrm{R}_{maint}) \end{cases}$$

Source : T. Wijmer et al 2024

Safye-CO_2

Daily estimation :



$$\mathrm{GPP} = R_g \cdot \epsilon_c f_T(T_a) \cdot f_w(\mathrm{WC}) \cdot \mathrm{ELUE} \cdot \mathrm{APAR} \cdot \mathrm{SR}_{10},$$

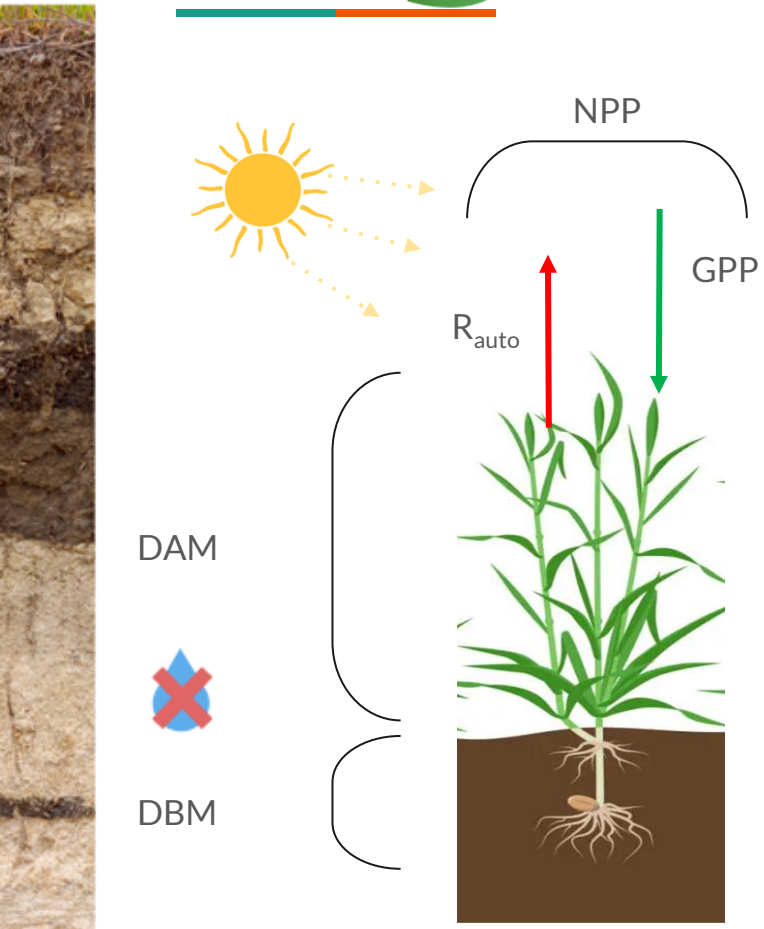
$$\begin{cases} R_{auto} = R_{maint} + R_{grow}, & \text{where} \\ R_{maint} = R_{10} \cdot Q_{10}^{-0.1 \cdot (T-10)} \cdot \mathrm{SR}_{10} \\ R_{grow} = (1 - Yg) \cdot (\mathrm{GPP} - \mathrm{R}_{maint}) \end{cases}$$

$$\begin{cases} \Delta\mathrm{DAM} = \dfrac{\mathrm{NPP}}{C_{veg}} \cdot (1 - \mathrm{PRT\_R}) \\ \Delta\mathrm{DLM} = \Delta\mathrm{DAM} \cdot (\mathrm{PRT\_L}) \\ \Delta\mathrm{DBM} = \dfrac{\mathrm{NPP}}{C_{veg}} \cdot (\mathrm{PRT\_R}), \end{cases}$$

Source : T. Wijmer et al 2024

Safye-CO_2

Daily estimation :



$$\mathrm{GPP} = R_g \cdot \epsilon_c f_T(T_a) \cdot f_w(\mathrm{WC}) \cdot \mathrm{ELUE} \cdot \mathrm{APAR} \cdot \mathrm{SR}_{10},$$

$$\begin{cases} R_{auto} = R_{maint} + R_{grow}, & \text{where} \\ R_{maint} = R_{10} \cdot Q_{10}^{-0.1 \cdot (T-10)} \cdot \mathrm{SR}_{10} \\ R_{grow} = (1 - Yg) \cdot (\mathrm{GPP} - \mathrm{R}_{maint}) \end{cases}$$

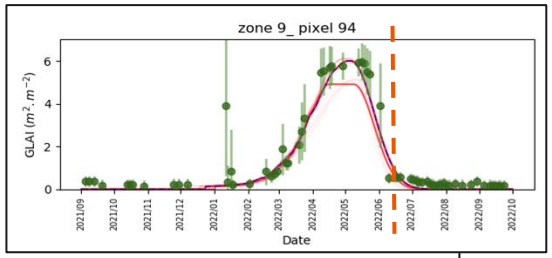
$$\begin{cases} \Delta\mathrm{DAM} = \dfrac{\mathrm{NPP}}{C_{veg}} \cdot (1 - \mathrm{PRT\_R}) & (\Sigma\,\text{=SMT}) \\ \Delta\mathrm{DLM} = \Delta\mathrm{DAM} \cdot (\mathrm{PRT\_L}) & (\Sigma\,\text{=SMT}) \\ \Delta\mathrm{DBM} = \dfrac{\mathrm{NPP}}{C_{veg}} \cdot (\mathrm{PRT\_R}), & (\Sigma\,\text{=SMT}) \end{cases}$$

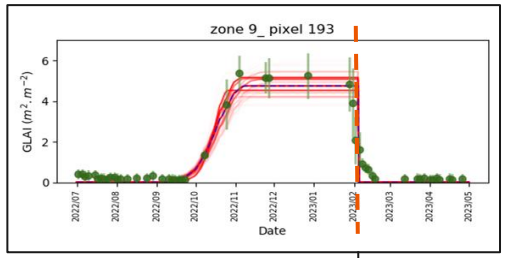
$$\begin{cases} \Delta\mathrm{GLAI}^{+} = \mathrm{DLM} \cdot \mathrm{SLA} \\ \Delta\mathrm{GLAI}^{-} = \mathrm{GLAI} \cdot (\mathrm{SMT} - \mathrm{Sen}_a) \cdot \mathrm{Sen}_b^{-1}, \end{cases}$$

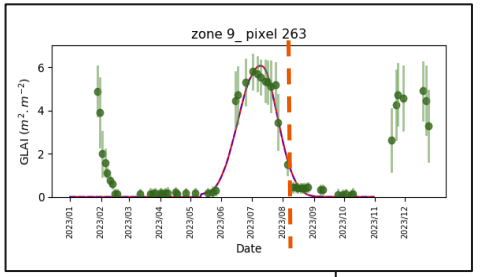
Assimilated variable

Source : T. Wijmer et al 2024

Dry above ground biomass uncertainties maps at the end of cycle







σDAM (t/ha)

5

0

2022

2023

(DAM: "Dry Above Mass")