A Monitoring, Reporting and Verification framework combining remote sensing, ICOS data and crop modelling for estimating the components of the carbon budgets for croplands at plot scale over large areas

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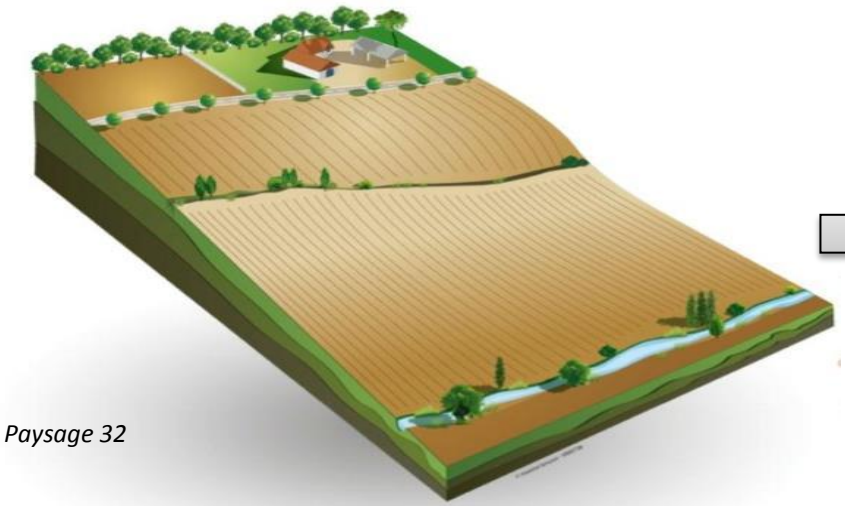
Context/Societal challenges

Questioning of the **durability of the conventional agriculture** (climate change & other environmental impacts)
➔ Greendeal, Low Carbon Label in Agriculture to foster the agroecological transition



Agro-ecological practices

No till

Cover crops

Agroforestery

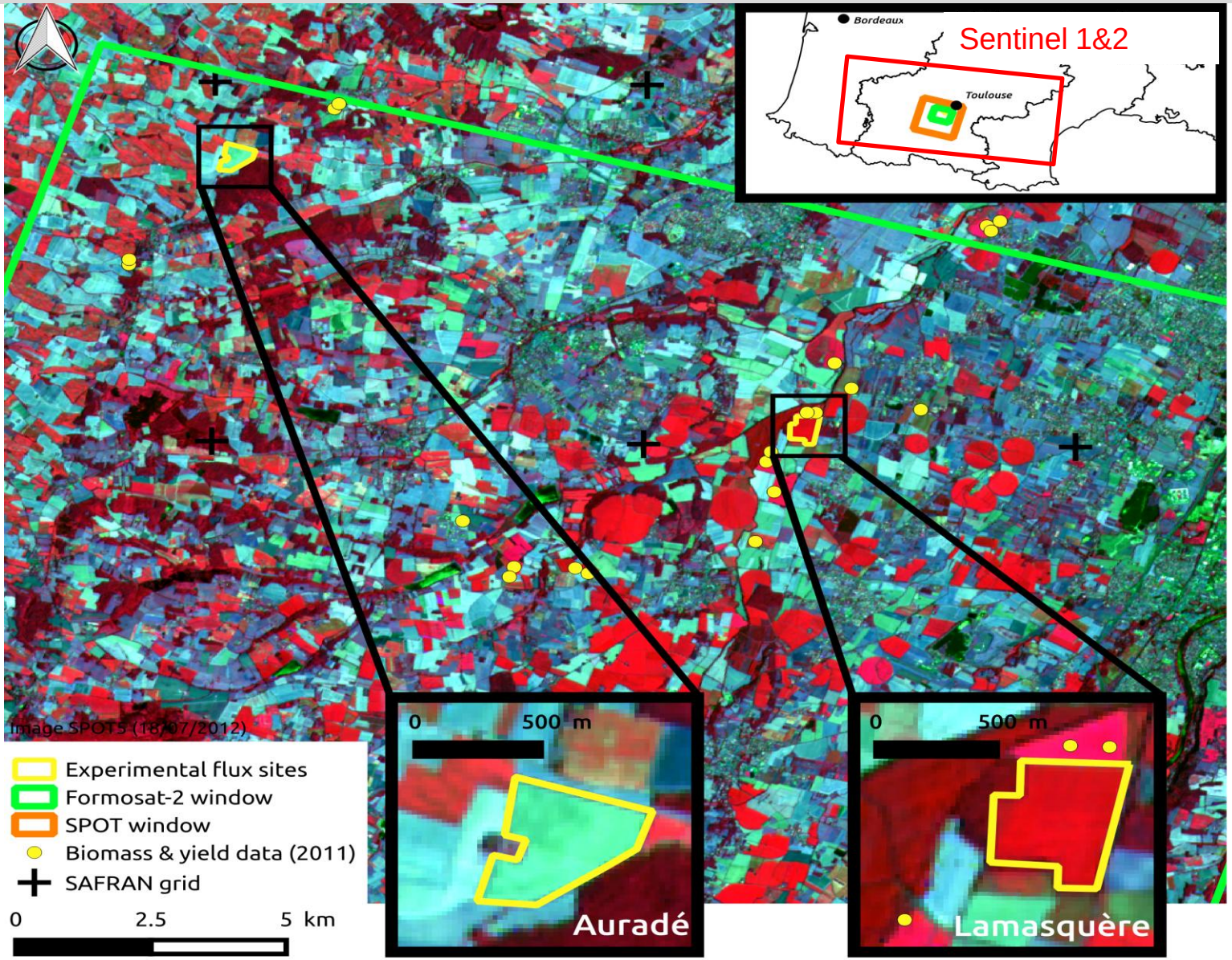
C storage
➔ 4p1000

Illustrations: Arbre et Paysage 32

Lack of **large scale diagnostic modelling tools allowing at plot level** to:

- ✓ Quantify the impact of some management on the components of the C budgets
- ✓ Analyse cropland ecosystem services → Biomass, Yield, ETR, CO_2 fluxes & C storage

The Spatial Regional Observatory (SRO)



- Started in **2002**
- Part of **JECAM** & **ICOS** (FR-Aur & FR-Lam sites) network
- Continuous CO_2 & H_2O **flux** aquisition since **2005**
- Regular intensive **measurement campaigns (Biomass, LAI, yield, soil moisture, land use)**

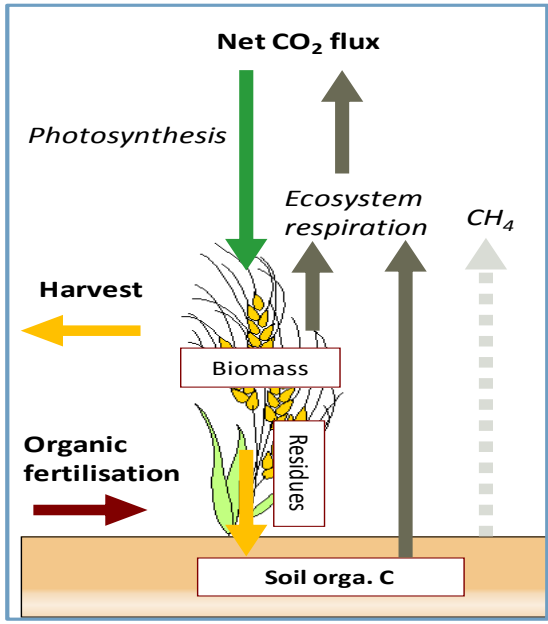
Carbon budgets components: principle

➢ Are calculated for each cropping year (at 10m/plot level), but can be summed over several years (crop rotation),

➢ 3 TIERS:

– TIER 1 (CO_2 fluxes) and TIER 2 (C budget) are based on empirical approaches and can be applied to most crops species except rice,

– TIER 3 is based on the SAFYE-CO2 crop model assimilating LAI derived from Sentinel 2 data ➔ allows other indicators to be calculated (biomass, yield, CO_2 fluxes, evap/transp…) but only for 4 crops species (wheat, sunflower, maize and rapeseed) + cover crops at this stage.



➢ A similar conceptual approach:

TIERs 2 & 3

$$\text{C budget} = \underbrace{\text{Net } CO_2 \text{ flux}}_{\text{TIER 1}} - \underbrace{\text{C harvested} + \text{Organic amendments}}_{\text{Farmer's data (FMIS)}}$$

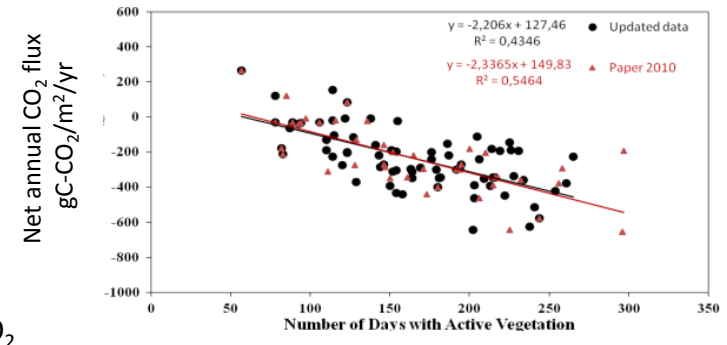
Tier 1 approach: principle

- Objective: estimate empirically the net annual CO_2 flux at parcel/pixel level
  - The net annual CO_2 flux is related to number of days of vegetation (Ceschia et al., 2010)
  - Method valid only on arable land for 13 family crops (not rice)

CO_2 release

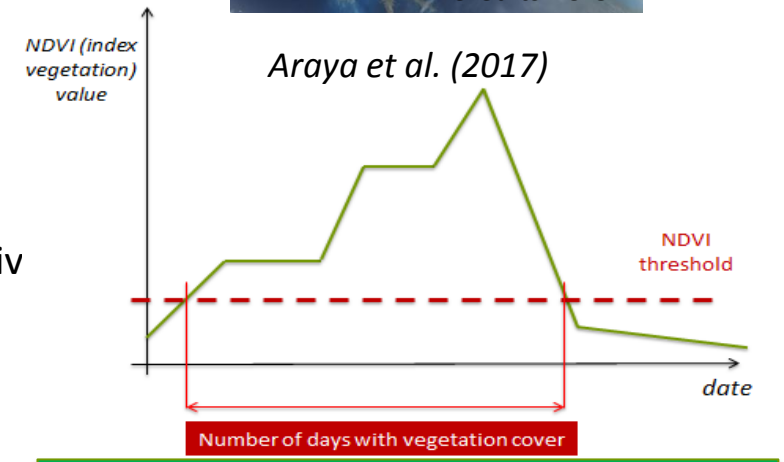
CO_2 fixation

Based on Ceschia et al. (2010) updated in 2020



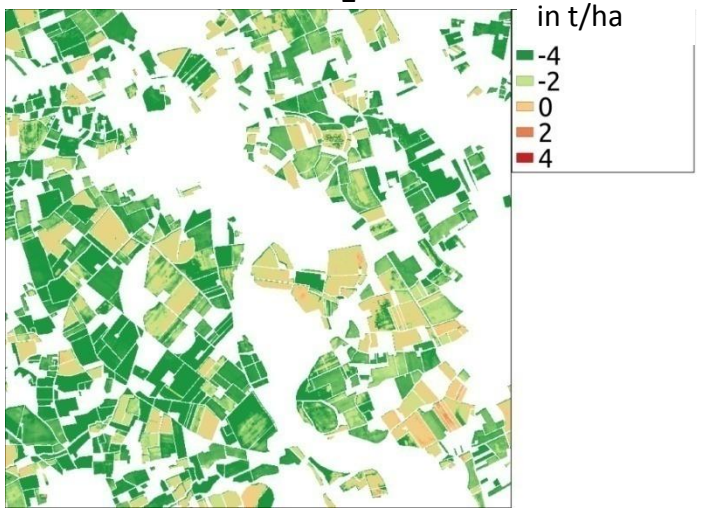
Simple relation between number of days with activ vegetation and CO_2 flux : validated on additional/recent data

Araya et al. (2017)



Apply threshold on NDVI profile to get number of days with active vegetation

10m resolution map of net annual CO_2 fluxes



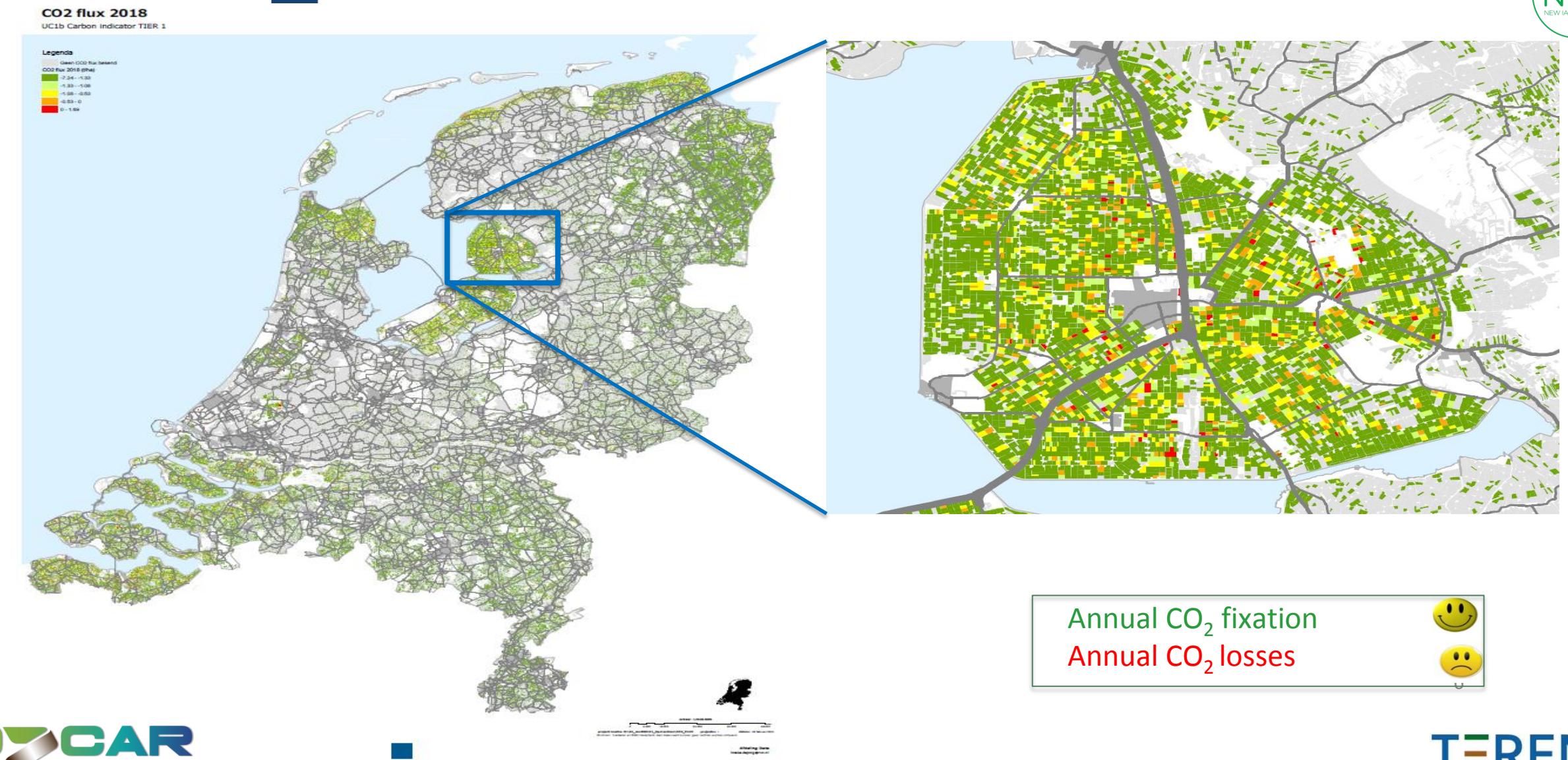
https://gitlab.com/nivaeu/uc1b_indicators_tool

Tier 1 approach : results

Ministerie van Economische Zaken en Klimaat

Net annual CO_2 fluxes of croplands in Netherlands (2018)

NIVA
NEW IACS VISION IN ACTION



Annual CO_2 fixation

Annual CO_2 losses

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Tier 2 approach : principle

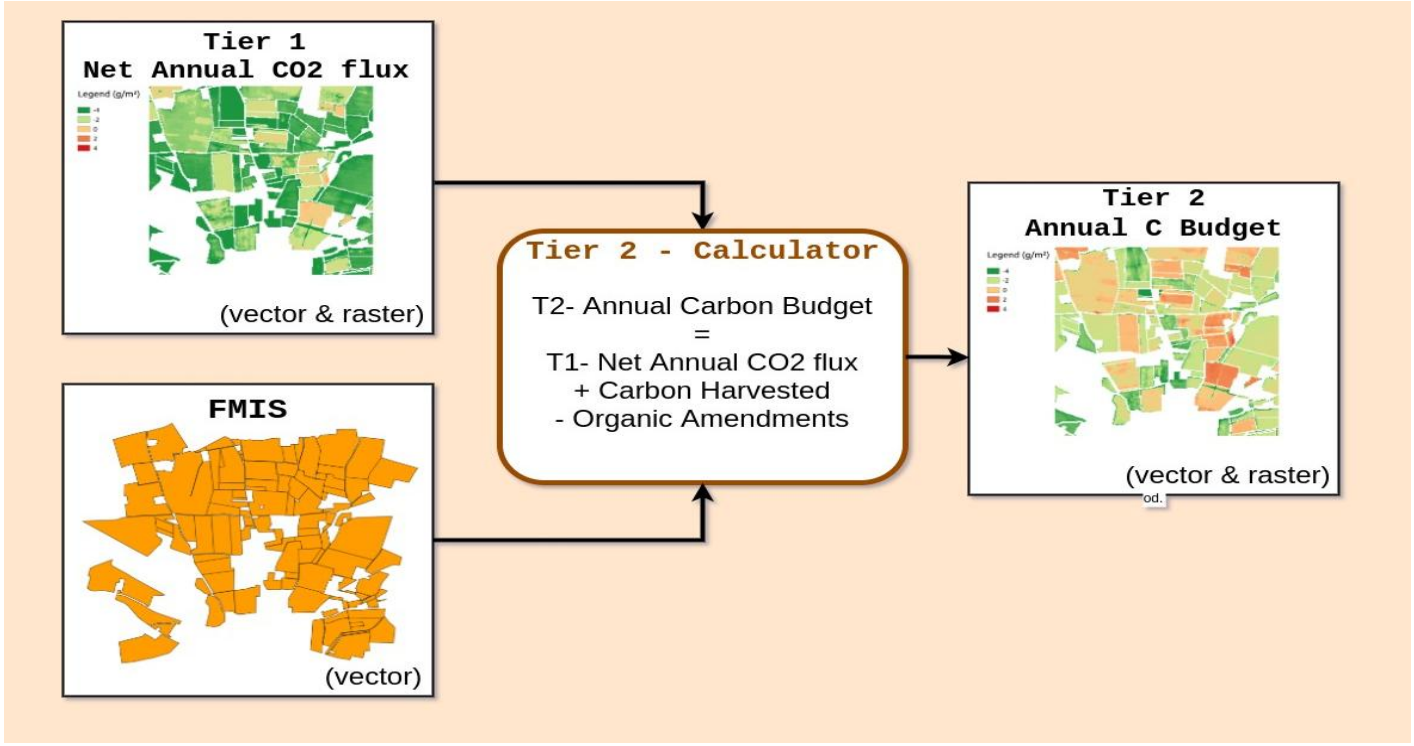
➢ Empirical approaches: plot level/annual

TIER 2

C budget = Net CO_2 flux + C harvested – Org. fertil.

TIER 1

Farmer's data (FMIS)

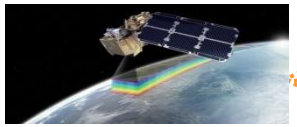


- What do we need to know from the farmers ?

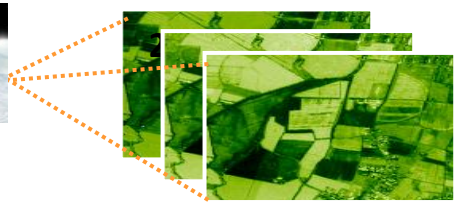
- C harvested:
  - yield (grain t/ha)
  - eventually the amount of straw/cover crop exported (t/ha),

- Are organic amendments applied ? If yes:
  - type of amendment,
  - amount (t/ha).

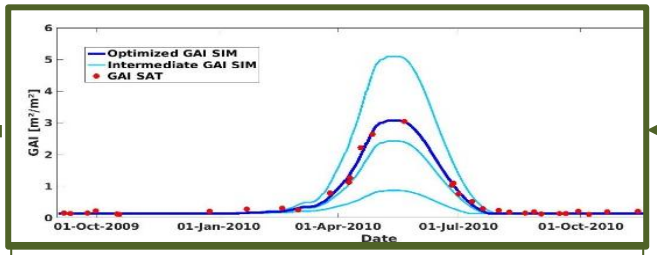
TIER 3 approach: modelling with SAFYE-CO_2



Spot, Landsat, Sentinel 2



Radiative transfer model, SVM…

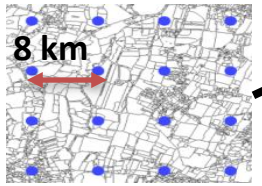


Calibration of phenological parameters & light-use efficiency parameter

Crop maps (LPIS)

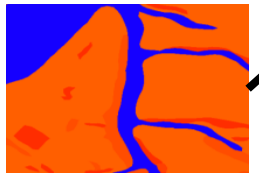
Crop param

Climatic data (e.g. SAFRAN, ERA-INTERIM)



Rg,T°C,Rain

Soil maps (e.g. SoilGrids)



ASWC

SAFYE-CO_2

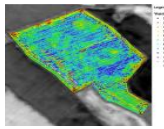
TURC+FAO56

(Pique et al. 2020 a, b, c, d)

Leaf Area Index

Biomass, Yield, irrigation

Validation with farmer's data (yield/irrigation), field campaigns…



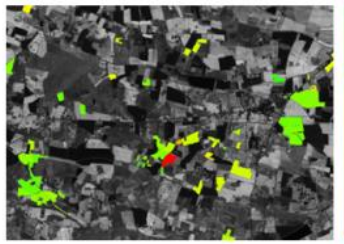
CO_2 & water fluxes

International flux stations networks

ICOS INTEGRATED CARBON OBSERVATION SYSTEM

FLUXNET A Global Network

C & water budgets



Farmer's data (FMIS)

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TIER 3 approach: performances/originality

Limits of the approach

- Diagnostic approach : but some scenarii can be tested
- Optical RS data will be combined with radar data (Sentinel 1) in cloudy areas & for strong crop development (optical RS saturates for high LAI values); ongoing research
- Coupling with a soil organic C module (e.g. AMG) on the way
- Only parametrised for a few crops species (straw cereals, sunflower, maize and soon rapeseed) + cover crops
- In areas with animal farming : impossible to quantify organic fertilization from RS and very difficult to locate fields where straw is exported ➔ main causes of uncertainties on the C budget

** Integrated Administration & Control System*

Carbon indicators

Level of readyness

- MMS test
- Tested in France
- Under development

LPIS

Sentinel 2

Meteo. data

Soil map

Stand alone operational TIER 1 calculator

AgriCarbon-EO

Image processor

NDVI

Prosail (Jacquemoud et al. 2009)

LAI

SAFY-CO2 (Pique et al. 2020 a&b)

TIER1 calculator

FMIS (harvest, orga. amendments)

API

CO_2 fixation/emission

TIER 1 plot map (net CO_2 flux)

FMIS Interface

TIER2 Calculator

TIER3 Calculator AMG (Clivot et al. 2019)

TIER 2 plot map (C budget)

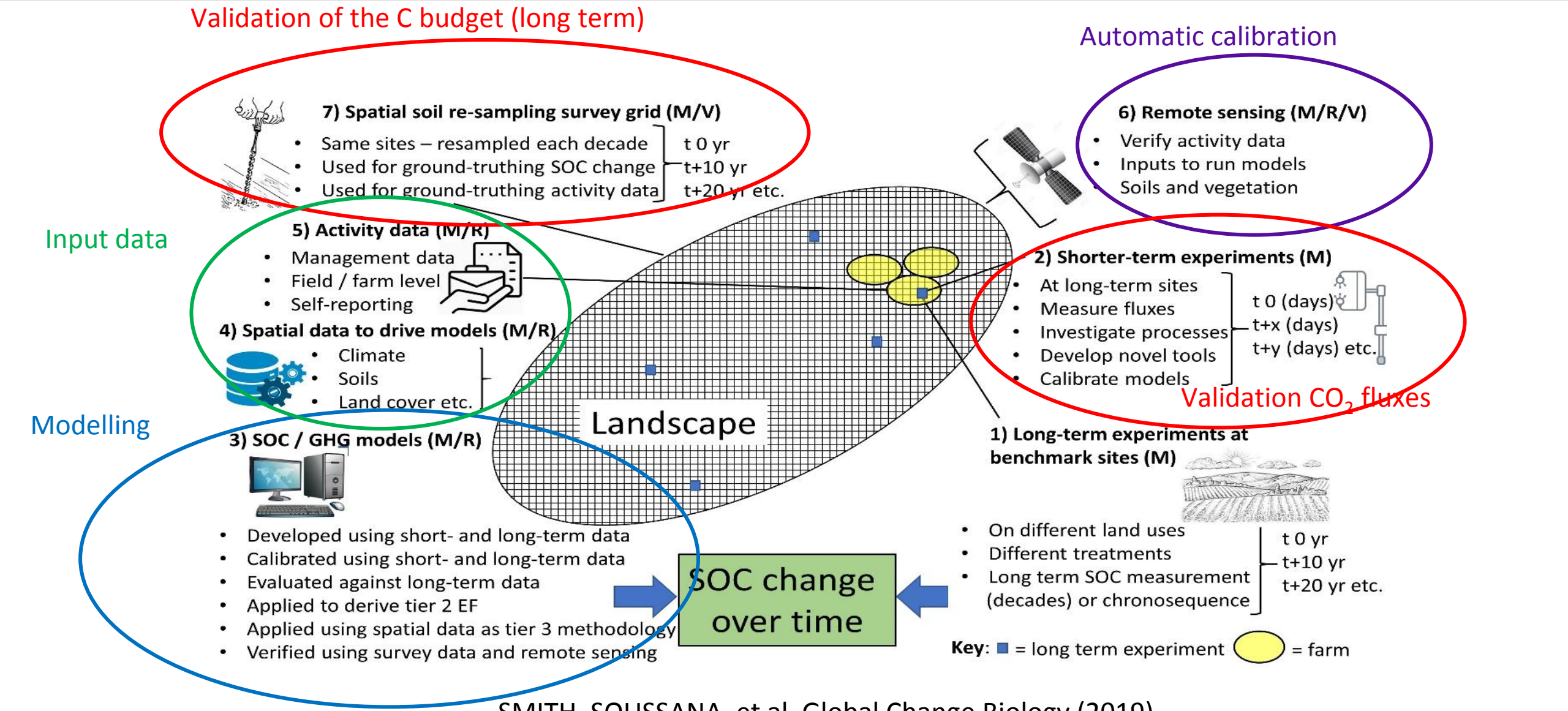
Pixel scale C budget ($gC.m^{-2}$)

+ associated uncertainties

TIER 3 pixel map (C budget)

- Principle of AgriCarbon-EO(bayesian, LUT) ➔ supercomputer

Compliant with the CIRCASA initiative



SMITH, SOUSSANA, et al, Global Change Biology (2019)

Conclusions

- This MRV framework was developed in the perspective of generalizing it by using Sentinel data/products (for model input) and the JECAM & ICOS networks (for validation); with some limits… and some challenges (huge amount of RS data…➔ DIAS*),

- It can be used for:
  - Calculation of carbon indicators for the CAP (H2020 NIVA)/Greendeal
  - Emerging Carbon market in agriculture/French Low Carbon Label
-
- b

* *Data Integrated & Analysis System*

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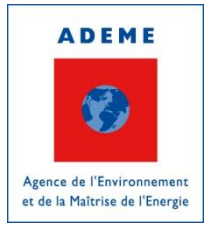
Conclusions

- This approach was developed in the perspective of generalizing it by using Sentinel data/products (for model input) and the JECAM & ICOS networks (for validation); with some limits… and some challenges (huge amount of RS data…➔ DIAS*),
- Well suited for assessing the effects of straw management and cover crops on cropland C budgets➔ can be applied to pixel/plot scale
- The transposability of this modelling approach has been verified (Morocco, Mexico, India…) for the SAFY-WB** version, next is to test SAFY-CO_2 over other areas (e.g. NIVA… & ICOS crop sites),
- The model is parametrised for wheat, sunflower, maize crops and cover crops in order to simulate crop rotations (soon rapeseed),
- Research tool that benefited from recent improvements to be applied in operational mode for mapping cropland C budgets.

* *Data Integrated & Analysis System*
** *SAFYE = SAFY-WB (Claverie et al., 2012)*

Thanks for your attention !!!

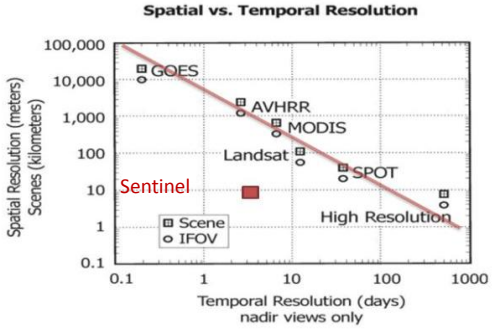


And thanks to our financers

Why is it possible now ?

Sentinel 1
(10 m, 6j, Radar)

A
Revolution !!!
(free all over
the globe)



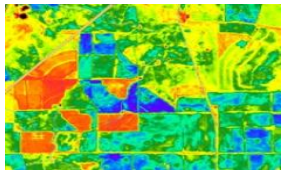
Sentinel 2
(**10 m, 5j, Optical**)

Clear or cloudy sky conditions
Rugosity & surface water content

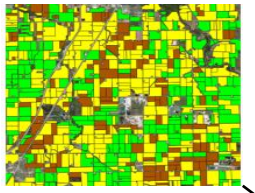
Monitored
parameters

Clear sky conditions
Reflectances (13 bands)

Soil water content



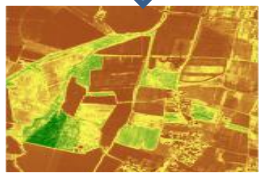
Biomass



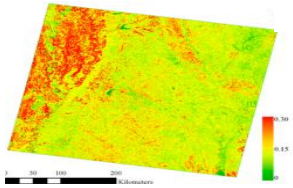
Soil work

Dynamic mapping

Land cover



LAI/ phenology



Albedo

How to use those RS derived products to answer scientific and societal challenges related to agriculture ?