MRV4SOC PROJECT

EO-based monitoring of cropland management and soil carbon dynamics

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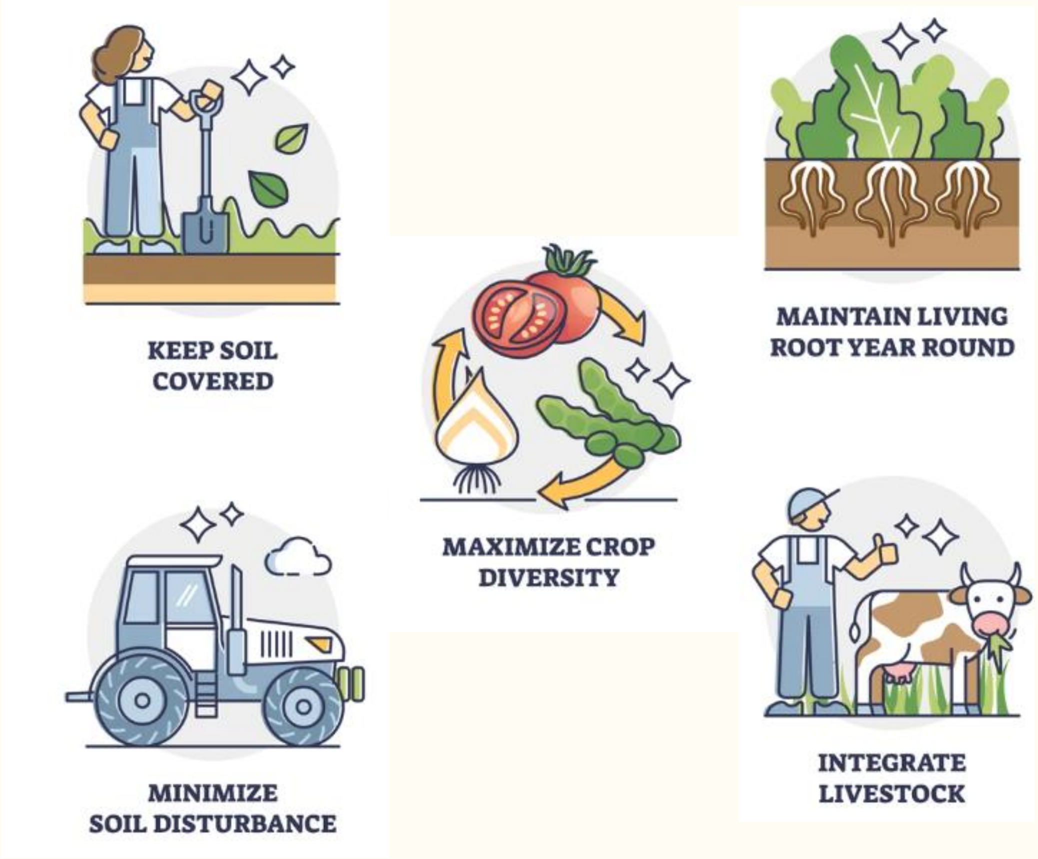
Funded by
the European Union

Improved management practices can increase SOC stocks

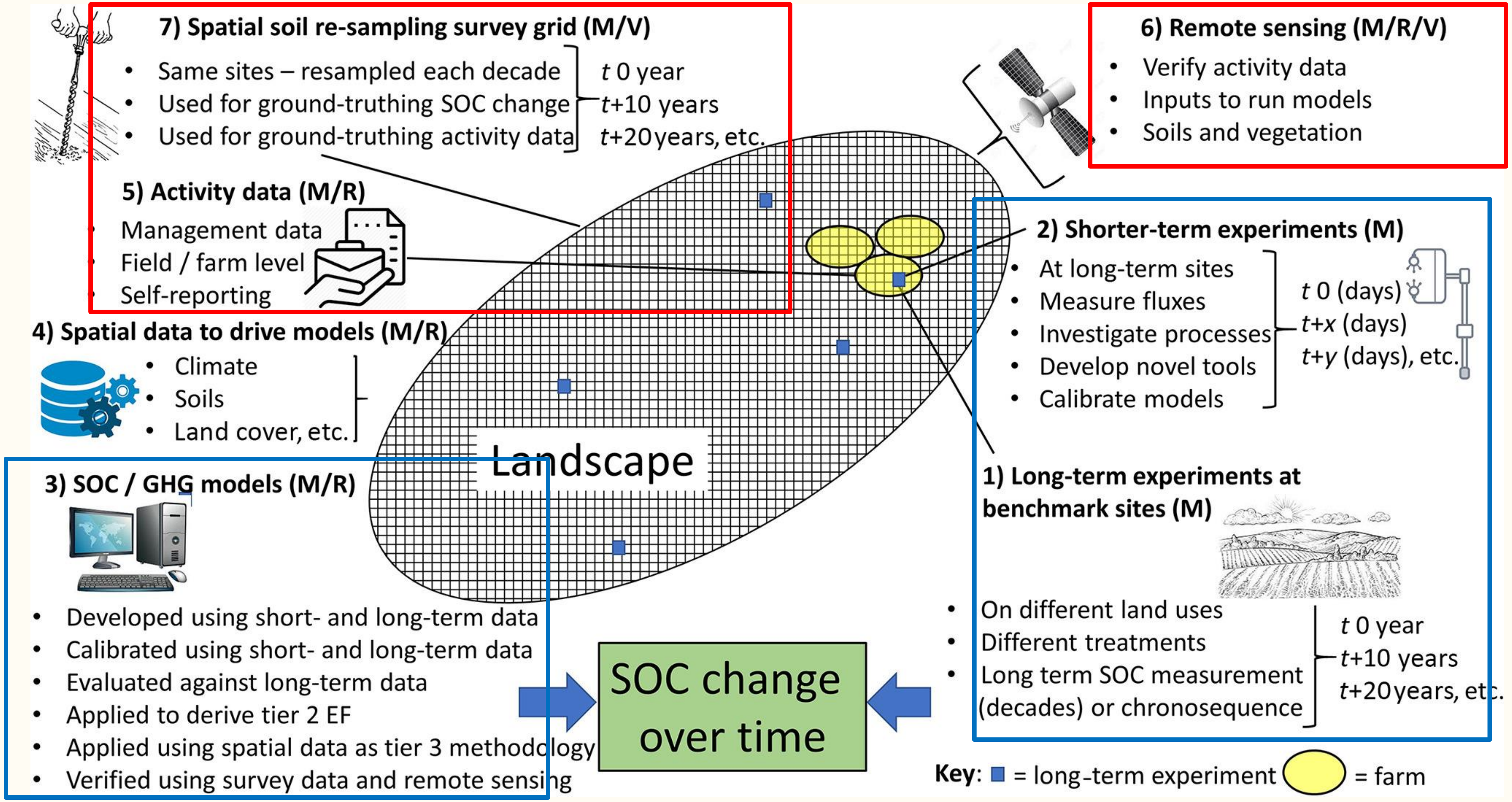
- **land cover changes and unsustainable land management practices leads to SOC loss**



https://www.moore-unidrill.com/

- **Agricultural fields** can **increase SOC stocks** through **improved management practices**, which could play a crucial role in **mitigating atmospheric CO_2 levels**.

How can we quantify the dynamics of SOC stock?
How management practices influence SOC changes?



(Smith et al., 2020)

Focus of this Presentation

1. How to use RS for predicting cropland management practices
2. How to assimilate these RS products into process-based models (MRV4SOC & CRCF)

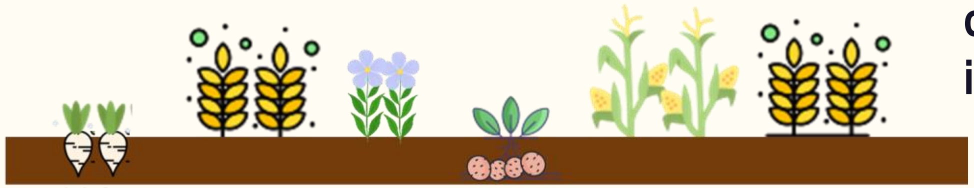
Core Idea

Conservation Agriculture

Species diversification

- Field-scale agricultural census databases
- (Land Parcel Information System , LPIS)

Rotations **One field**



Permanent soil organic cover

How to get the cover crop info?

Differentiate remote sensing signals from soil, main crops and cover crops

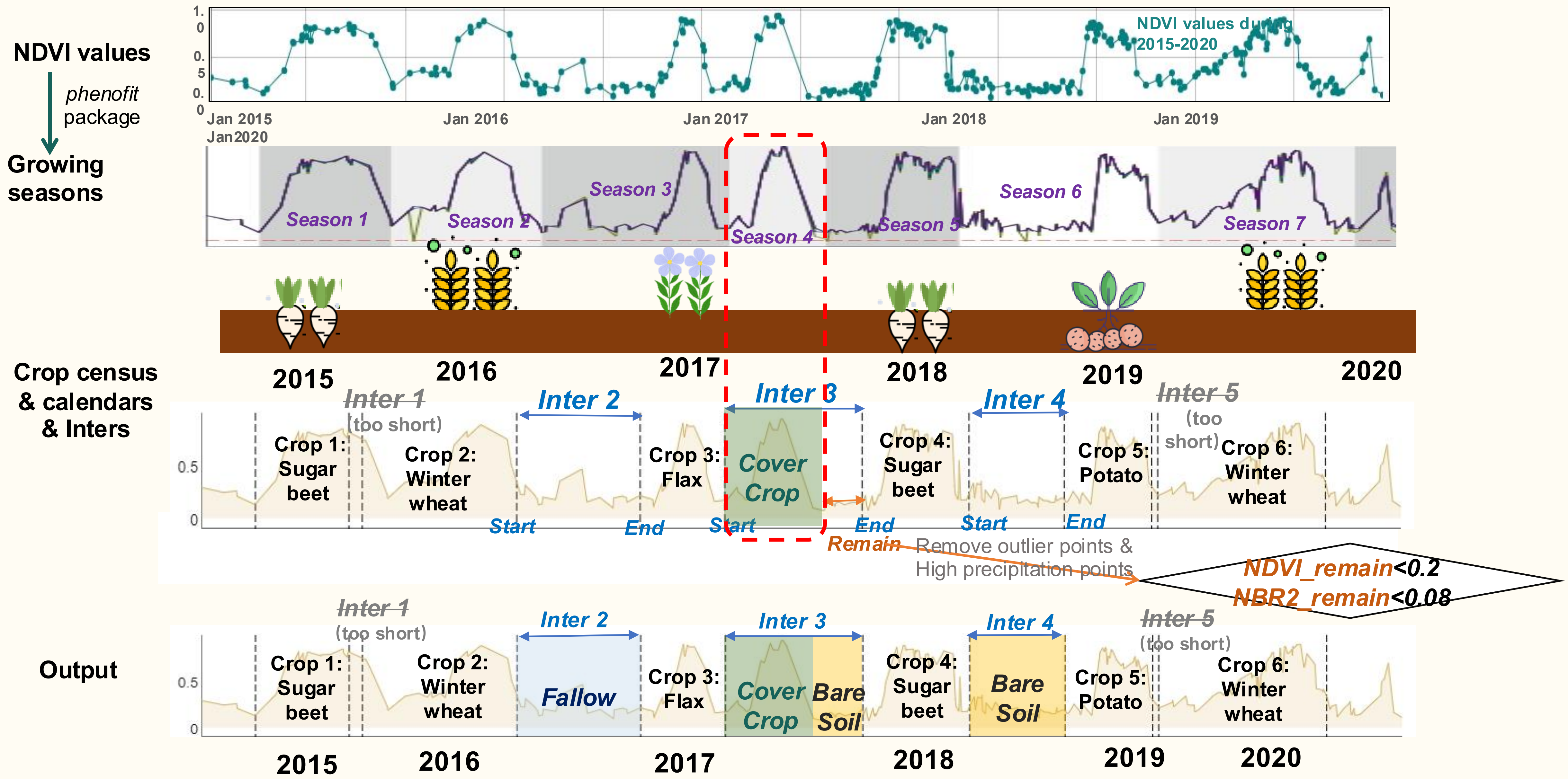
- Separate main crops by phenology
- Distinguish between bare soil and cover crop using RS vegetation indices and soil indices

NDVI=(NIR-RED)/(NIR+RED)--plant

NBR2=(SWIR1-SWIR2)/(SWIR1+SWIR2)--crop residue

Minimum mechanical soil disturbance

Cover crop identification: Whether there is a strong crop emergence during the no main crop periods?



Core Idea

Conservation Agriculture

Minimum mechanical soil disturbance

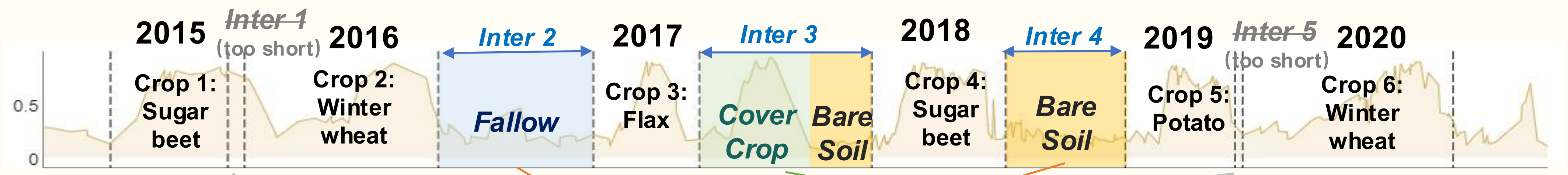
Tillage practices can be detected through the differences in residue cover.

- **Narrowband indices:** Cellulose Absorption Index (CAI)
- **Broadband indices:** Normalized Burn Ratio 2 (NBR2)

Main idea: Build inversion/non-inversion tillage models under three different scenarios

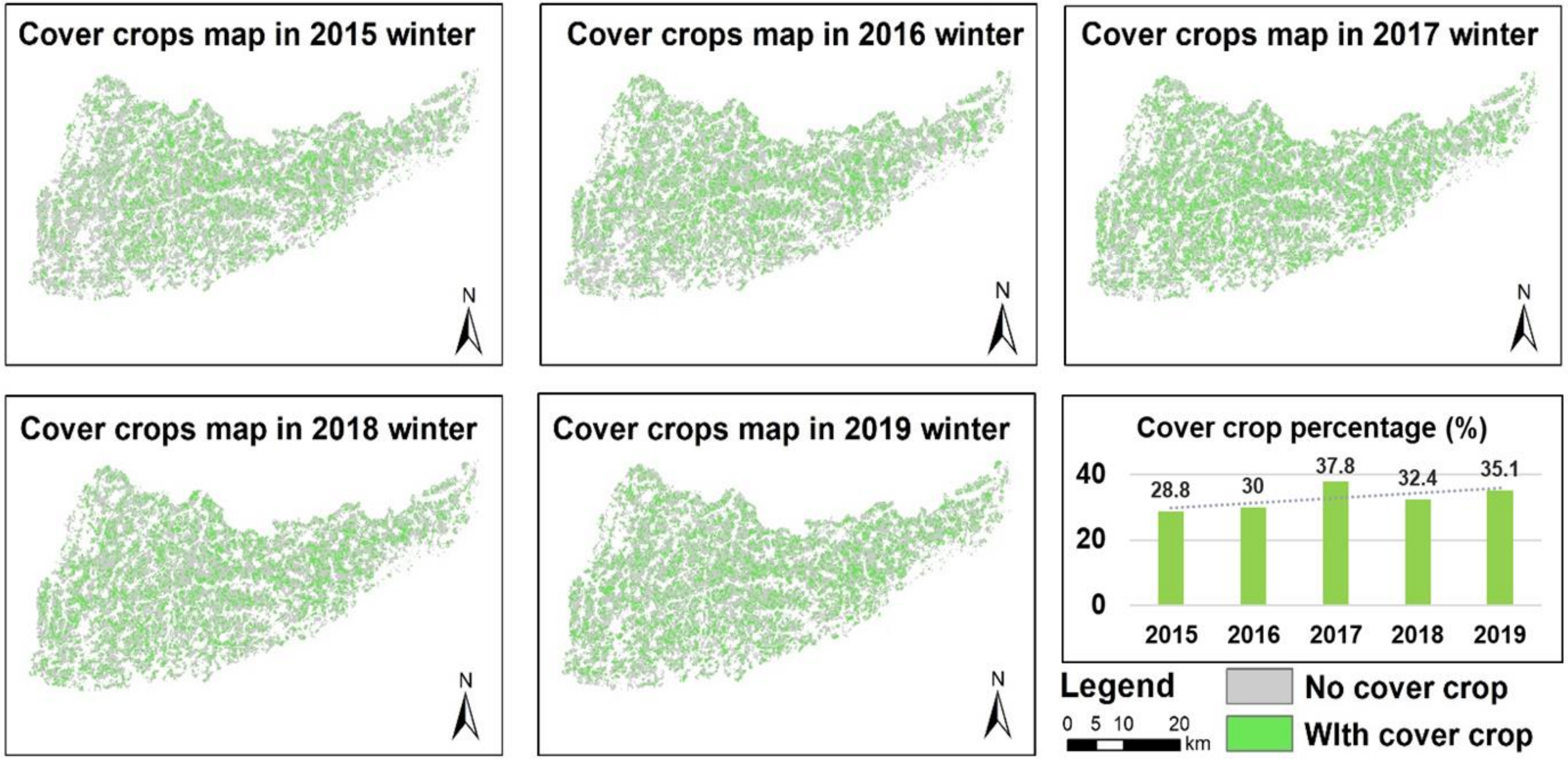
One field:

Inversion tillage



Scenario	Short Interval (<30 d)	No Cover Crops	With Cover Crops
Independent variables	NA (often occurs when next crop is a winter crop)	mean/min values of NBR2, NDVI, VV and VH backscatter	proportion of CC/BS mean/min values of NBR2, NDVI, VV and VH backscatter
Dependent variable		inversion/non-inversion	inversion/non-inversion
Output	NA	Model I	Model II

Ploughing may occur within this interval, but usually farmers complete the ploughing and the land preparation in one day.
Hence it is not possible to obtain sufficient information within such a short period from satellite imagery.



Remote Sensing of Environment 328 (2025) 114858

Contents lists available at ScienceDirect

Remote Sensing of Environment

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

A framework for mapping conservation agricultural fields using optical and radar time series imagery

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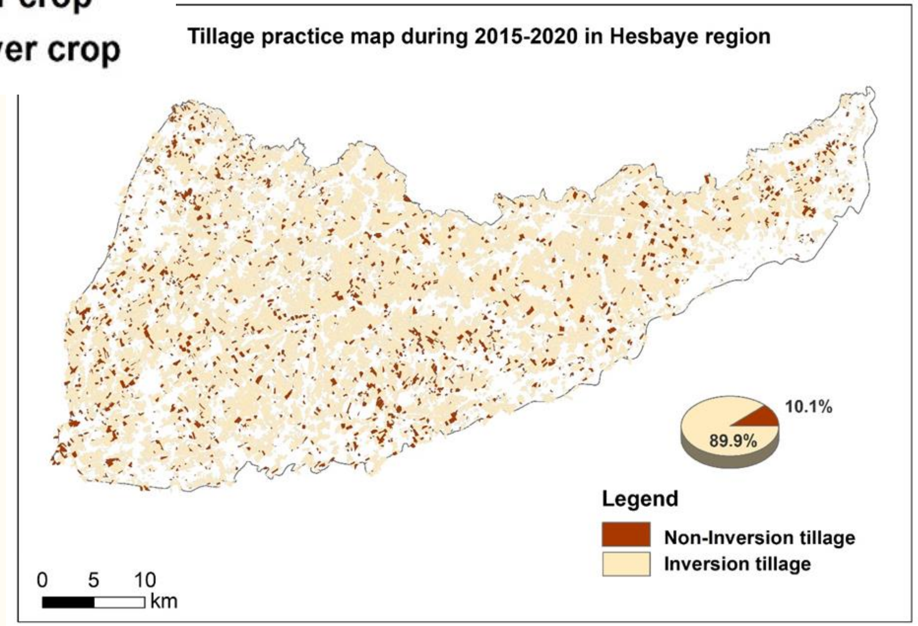


2. How to assimilate these RS products into process-based models (MRV4SOC & CRCF)

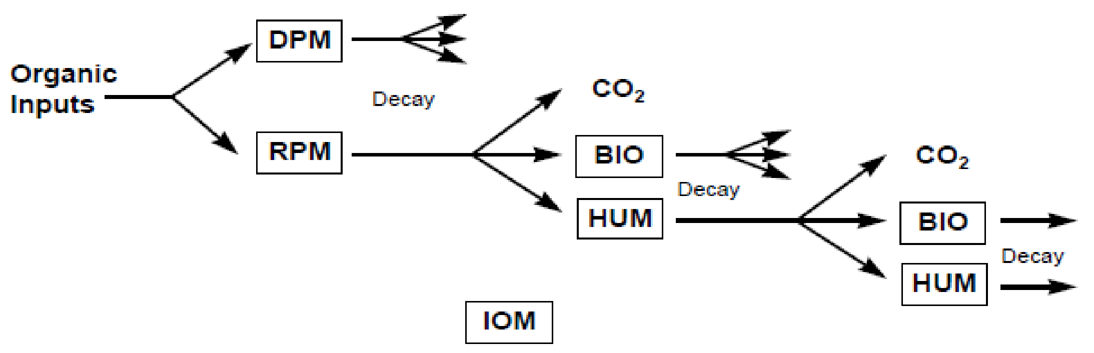
Model selection: RothC Model

$$Y_t = Y_0 \times (1 - e^{-abc \cdot kt})$$

Y_0 is the active pool at the beginning of the month
Y_t is the active pool at the end of the month
k is the **decomposition rate constant** for that pool (usually default value)
t is 1 / 12, since *k* is based on a yearly decomposition rate.

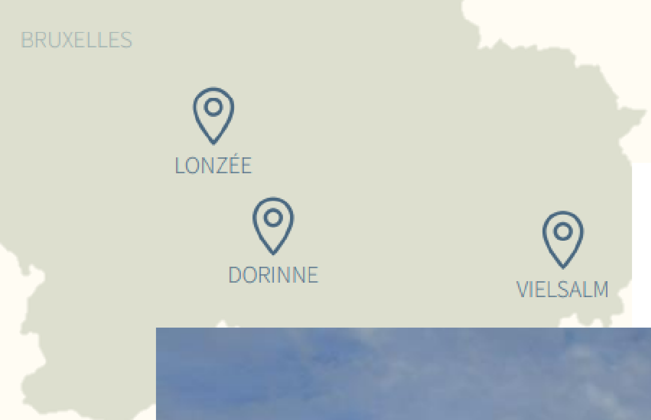
a is the rate modifying factor for **temperature**
b is the rate modifying factor for **moisture**
c is the **soil cover** rate modifying factor

Figure 1 - Structure of the Rothamsted Carbon Model

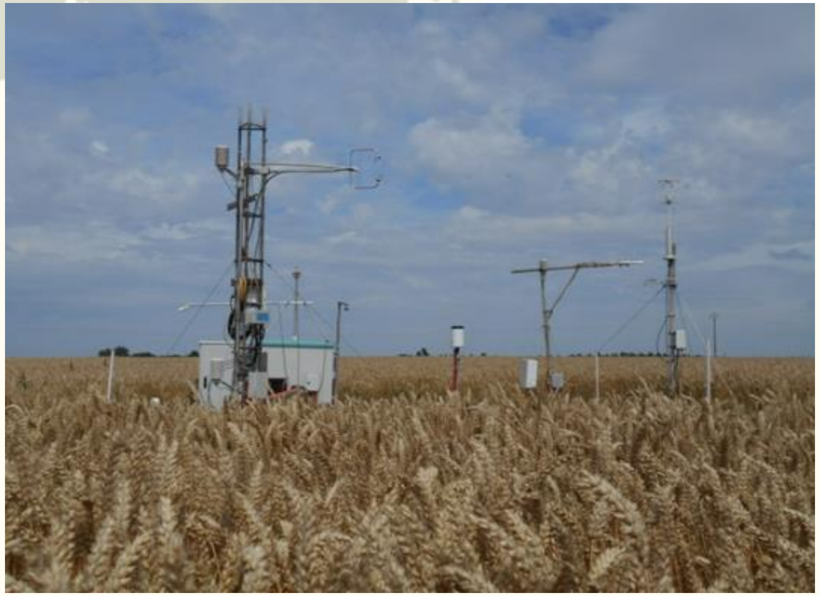


RPM : Resistant Plant Material
DPM : Decomposable Plant Material
BIO : Microbial Biomass
HUM : Humified OM
IOM : Inert Organic Matter

	Variable	Units
Climate data	Monthly mean air temperature	ºC
	Monthly precipitation	mm
	Monthly open pan evaporation	mm
Soil data	Initial carbon pool	$t{\cdot}ha^{-1}$
	Clay content of the soil	%
	Depth of soil layer sampled	cm
Soil cover	Soil cover (0 or 1)	none
Management	Monthly C input plant residues	$t\ C\ ha^{-1}$
	Monthly C input farmyard manure	$t\ C\ ha^{-1}$



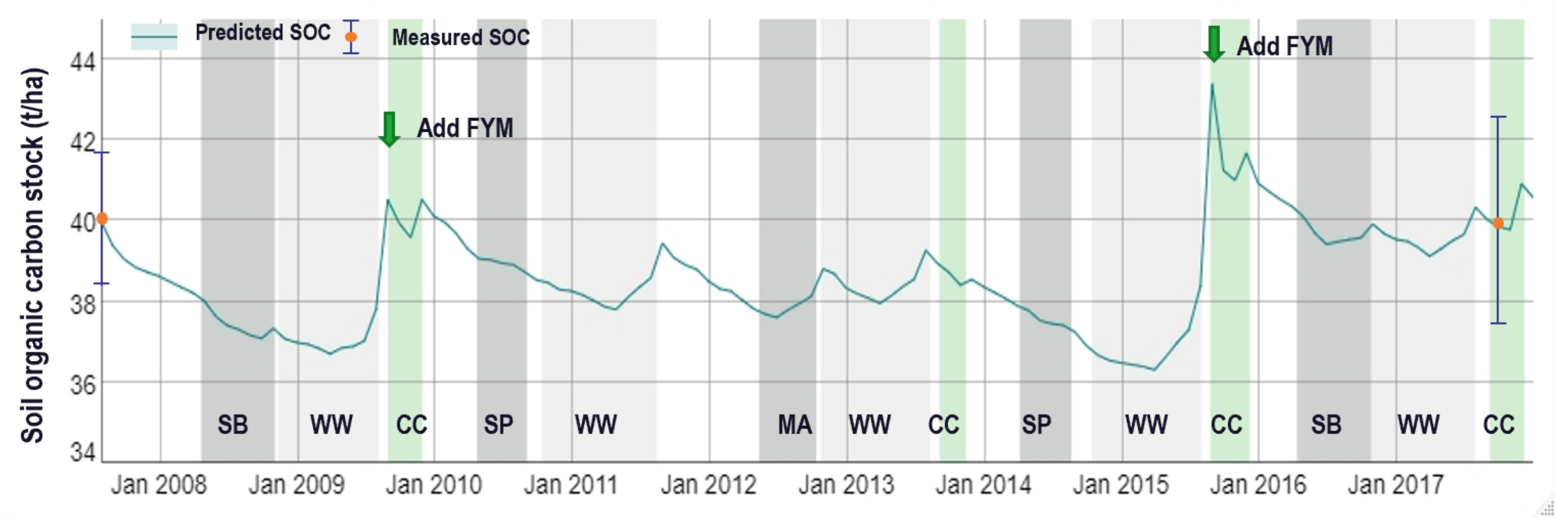
ICOS INTEGRATED CARBON OBSERVATION SYSTEM



Model 0	Climate	Clay	Soil cover	C_input_main_crop	C_input_cover_crop	FYM	Baseline C
Model 1	Climate	Clay	Soil cover	C_input_main_crop	C_input_cover_crop	FYM	Baseline C
Model 2	Climate	Clay	Soil cover	C_input_main_crop	C_input_cover_crop	FYM	Baseline C
Model 3	Climate	Clay	Soil cover	C_input_main_crop	C_input_cover_crop	FYM	Baseline C
Model 4	Climate	Clay	Soil cover	C_input_main_crop	C_input_cover_crop	FYM	Baseline C
Model 5	Climate	Clay	Soil cover	C_input_main_crop	C_input_cover_crop	FYM	Baseline C
Model 6	Climate	Clay	Soil cover	C_input_main_crop	C_input_cover_crop	FYM	Baseline C
Model 7	Climate	Clay	Soil cover	C_input_main_crop	C_input_cover_crop	FYM	Baseline C
Model 8	Climate	Clay	Soil cover	C_input_main_crop	C_input_cover_crop	FYM	Baseline C

In-situ RS

Model 0 — All in-situ boundary conditions



LONZÉE TERRESTRIAL OBSERVATORY, 2004

- One of the longest and most complete data series on cropland in Europe
- Four years rotation crop (sugar beet, winter wheat, potato, winter wheat)
- Flux and meteorological data since 2004
- Coordinates: 50° 33'05.7"N 4° 44'46.1"E

Prepare boundary conditions with remote sensing

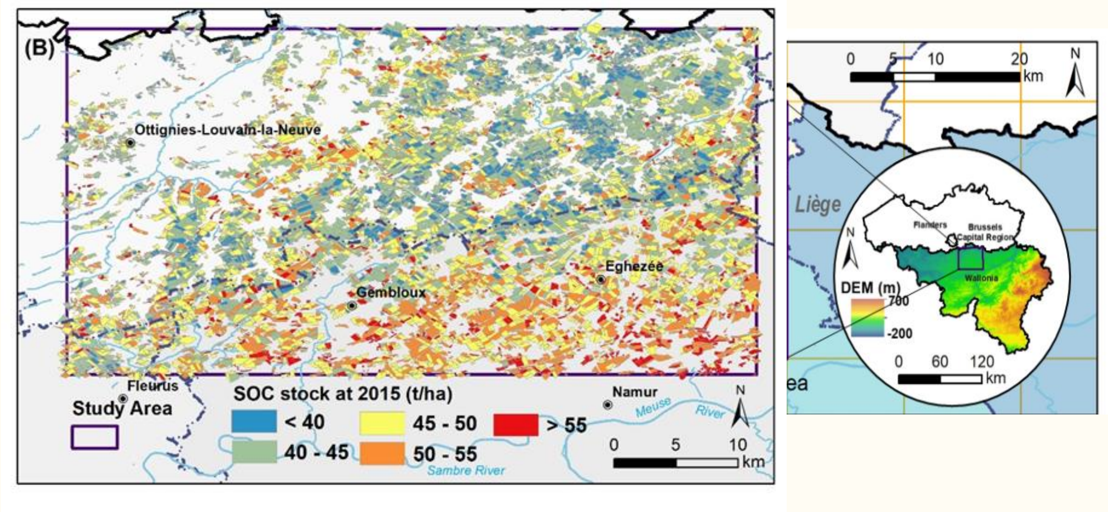
	Variable	Units	Remote Sensing Source	Spatial Resolution
Climate data	Monthly mean air temperature	ºC	Terra Climate	~4 km
	Monthly precipitation	mm	Terra Climate	
	Monthly open pan evaporation	mm	Calculated from monthly mean air temperature	
Soil data	Initial carbon pool	$t{\cdot}ha^{-1}$	Zhou et al., 2022	30 m
	Clay content of the soil	%	Geoportal of Wallonia	~100 m
	Depth of soil layer sampled	cm	Set as 30	
Soil cover	Soil cover (0 or 1)	none	Time series NDVI dataset	30 m
Management	Monthly C input plant residues	$t\ C\ ha^{-1}$	C input from Main crops <-> Bolinder Equation + Yield info C input from Cover crops <-> Cover crop maps + Estimated AGB of CC	Per field
	Monthly C input farmyard manure	$t\ C\ ha^{-1}$	Calculated based on livestock numbers	Per province

RS-only model vs. in-situ model ⟶ error ≈ 1.76 t/ha

Simulations

cover eight 0.125° ORCHIDEE grid cells
~ 98,391 ha

10,102 cropland fields,
with a total area of 50,656 ha.



Business As Usual

Using all actual boundary conditions

Climate

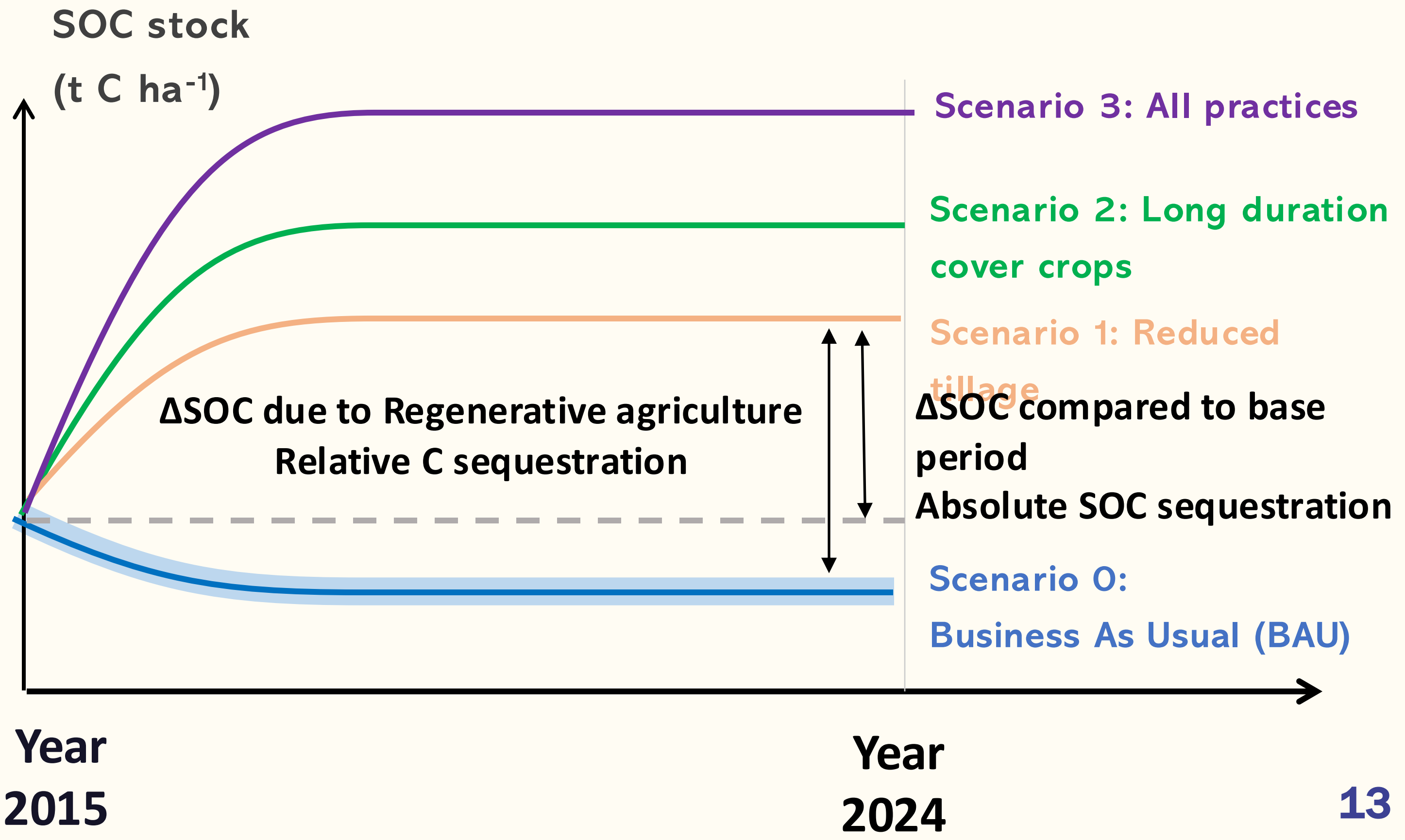
Terra Climate	Average
2015 – 2023	2023 – 2024

Manure

Regional Stat	Average
2015 – 2022	2022 – 2024

Main crops and CC & Tillage

Census & Predicted CC & Tillage	Repeat year 2015-2018
2015 – 2018	2018 – 2024



Scenario 1: Reduced tillage

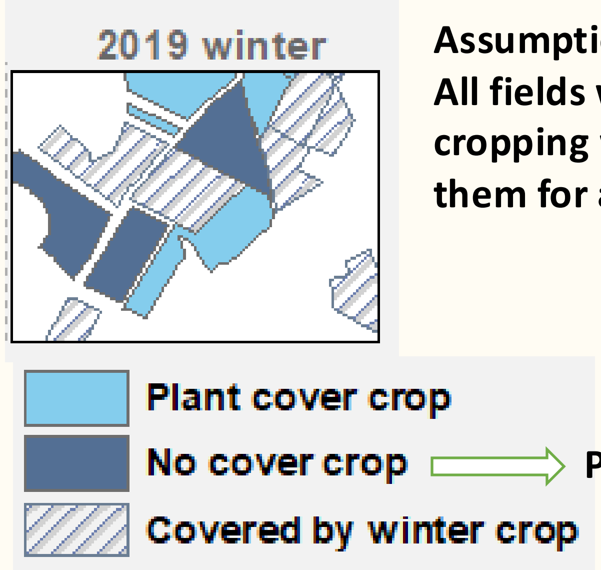
Assumption:
All fields adopt reduced tillage

Reduced tillage: 9.6%
Traditional tillage: 90.4%

Reduced tillage

Effect on Modelling:
Slow down decomposition rate of each pool. (Jordon & Smith, 2022; proposed a modifier value of 0.93)

Scenario 2：Long Cover Crop

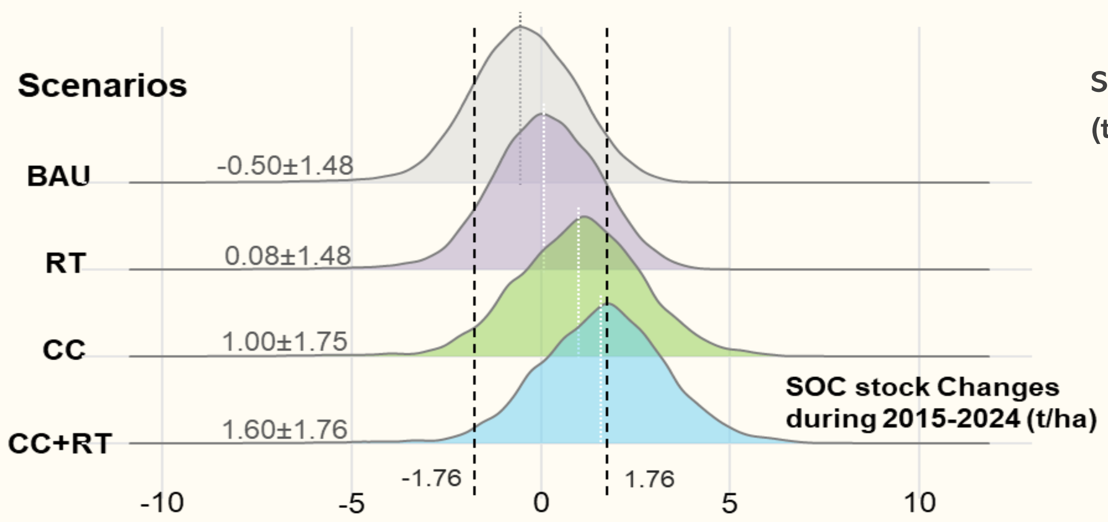


Plant cover crop

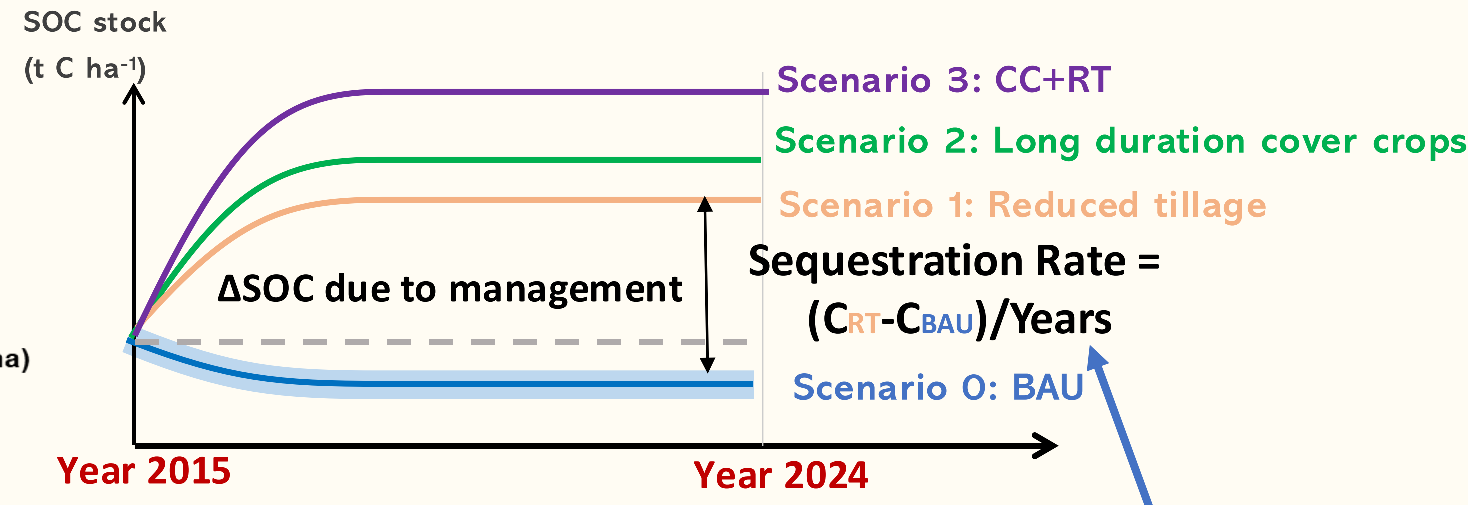
Plant Long duration cover crop

Assumption:
All fields with the potential for cover cropping will plant cover crops and keep them for a long duration.

Effect on Modelling:
Increase carbon input from crop residues.
Extend the period during which the field is covered rather than bare.



	Decrease	No change	Increase
BAU	17.6%	77.2%	5.2%
Reduced Tillage	9.3%	78.9%	11.8%
Long Cover Crop	5.0%	62.3%	32.7%
CC+RT	2.6%	50.1%	47.3%



	SOC 2015 $(t \cdot ha^{-1})$	SOC 2024 $(t \cdot ha^{-1})$	Δ C $(t \cdot ha^{-1})$ ($C_{2024}-C_{2015}$)	Sequestration Rate of management $(t \cdot ha^{-1} \cdot yr^{-1})$	Δ CO_2 Mt
BAU	46.42	46.023	-0.39		
RT		46.68	0.26	0.07	0.11
CC		47.56	1.14	0.15	0.25
CC+RT		48.22	1.80	0.22	0.35

3.8‰

Carbon source → Carbon sink

Conclusion & Policy Relevance

- EO-based datasets enable consistent monitoring of management practices (cover crop adoption, tillage practices).
- Predicted practices provide robust inputs for large-scale SOC modelling.
- Management scenarios (RT, CC, RT+CC) built on EO-based maps improve the reliability of SOC dynamics and mitigation potential assessments.
- This reproducible and scalable workflow can directly support the CRCF certification by delivering transparent management data and SOC stock simulations.

Thank you!

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