UCSC Field Crops Group

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Soil carbon credits accounting in agricultural soils: approaches and technologies in

ClieNFarms Climate Neutral Farms

FARMS 4 CLIMATE

projects

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Monitoring, **R**eporting and **V**erification of **C removal**

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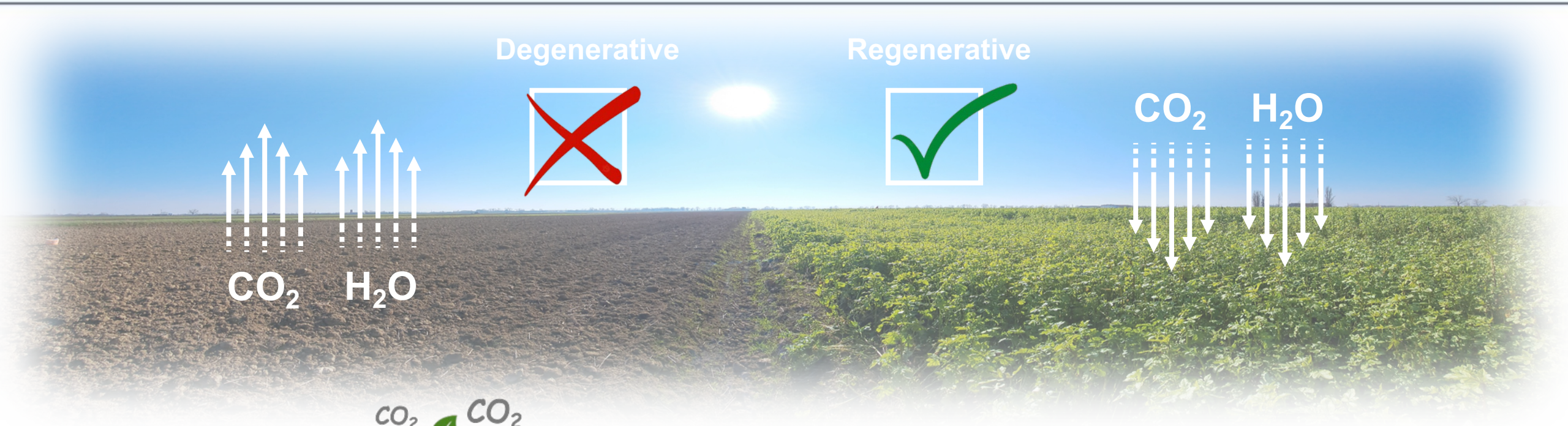
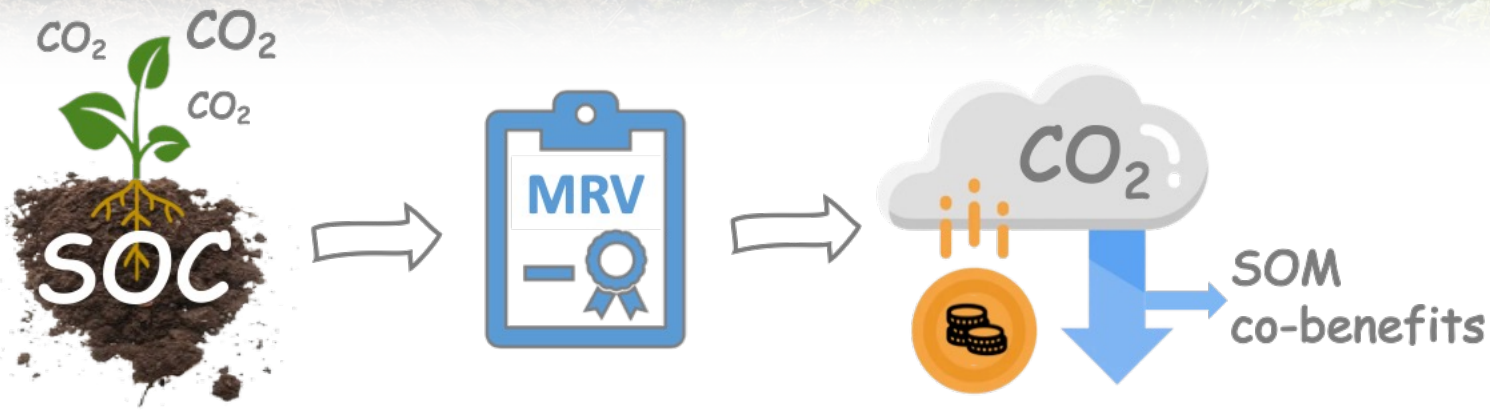




Scaling soil C credit generation at scale

Agricultural SOC MRV protocols

A combination of physical soil sampling, remote monitoring, and soil modelling will be required to map SOC stock consistently and at scale.

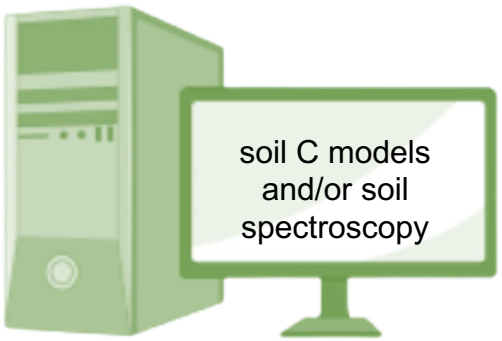
Measurement → **Modelling/ quantification**

Sub-surface sampling

Soil modelling

Sub-surface sampling + soil modelling

Surface sampling + soil modelling



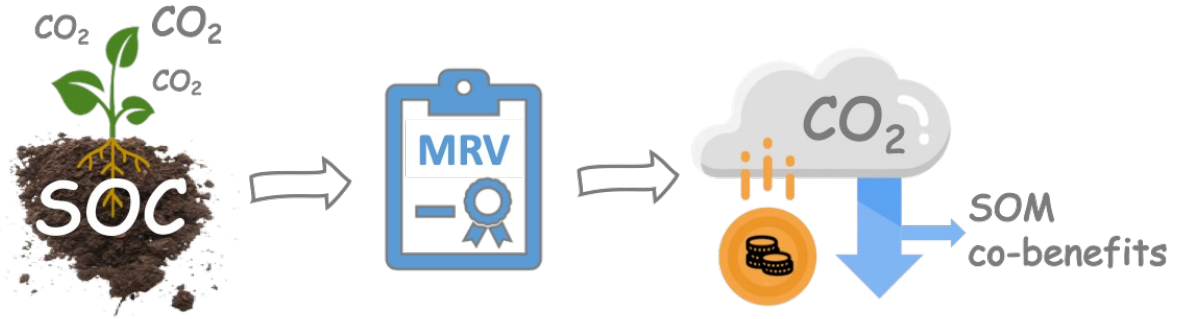
Satellite data

SOC MRV challenges

RESULT-BASED SOC MRV PROTOCOLS

To reduce uncertainty on yearly SOC changes detection

To integrate spatially estimates of plant C input in soil C modelling



SAMPLING & MEASURING SOC

To capture spatial and temporal variability

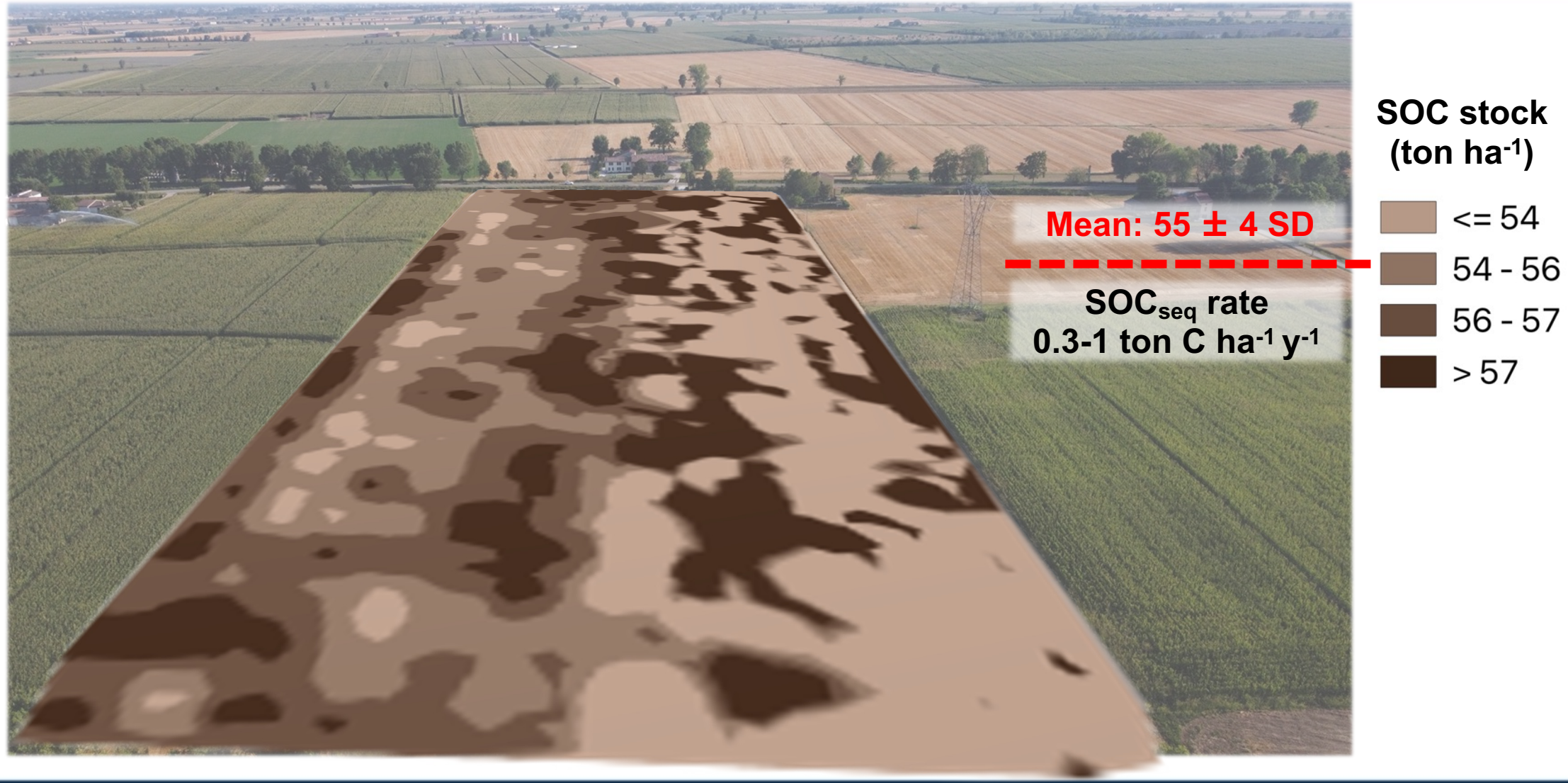
To reduce the costs of sampling & analysis and enable higher throughput

CARBON FARMING SOLUTIONS

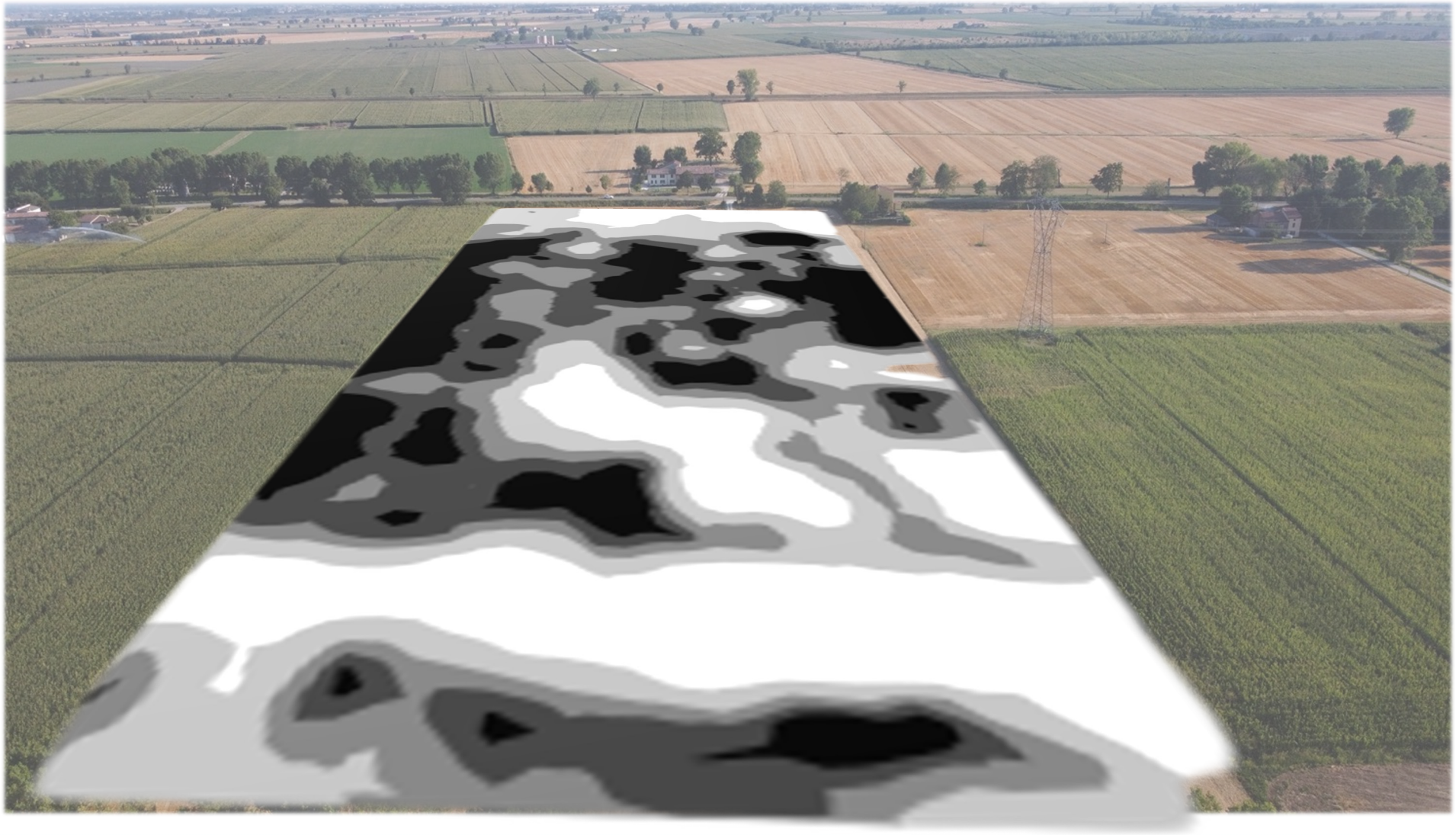
To reduce technical and economic constraints to theorical SOCseq

To assess practices at field scale that build SOC in stable forms

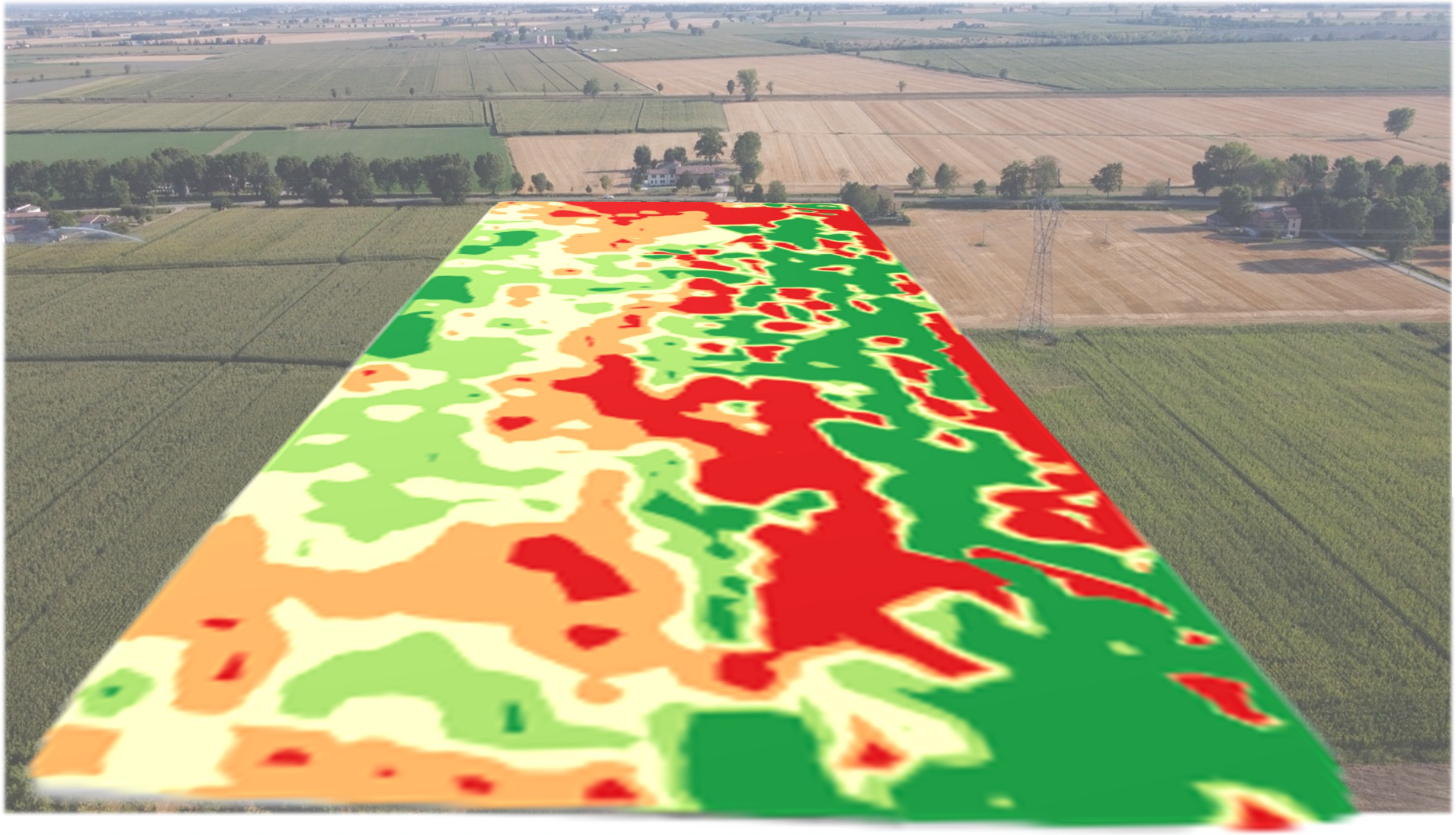
Challenges of sampling & measuring SOC



Challenges of sampling & measuring SOC

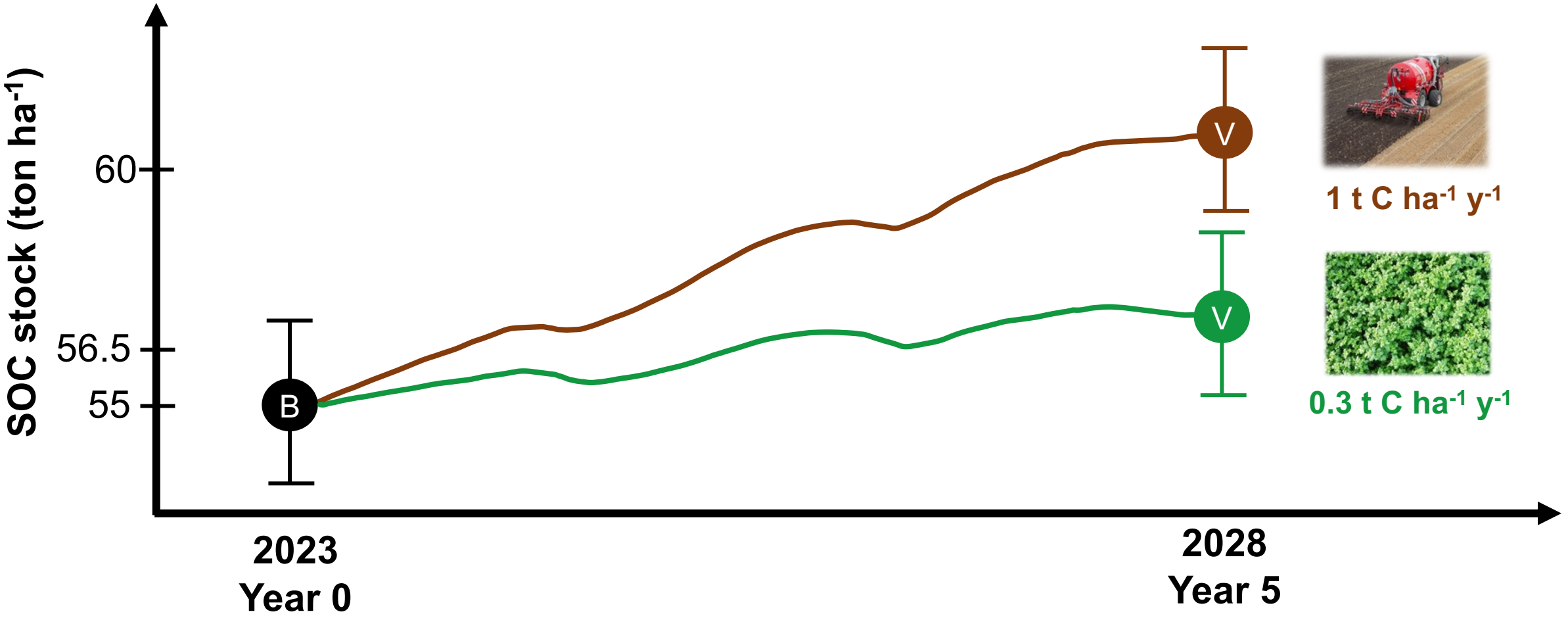


Challenges of sampling & measuring SOC

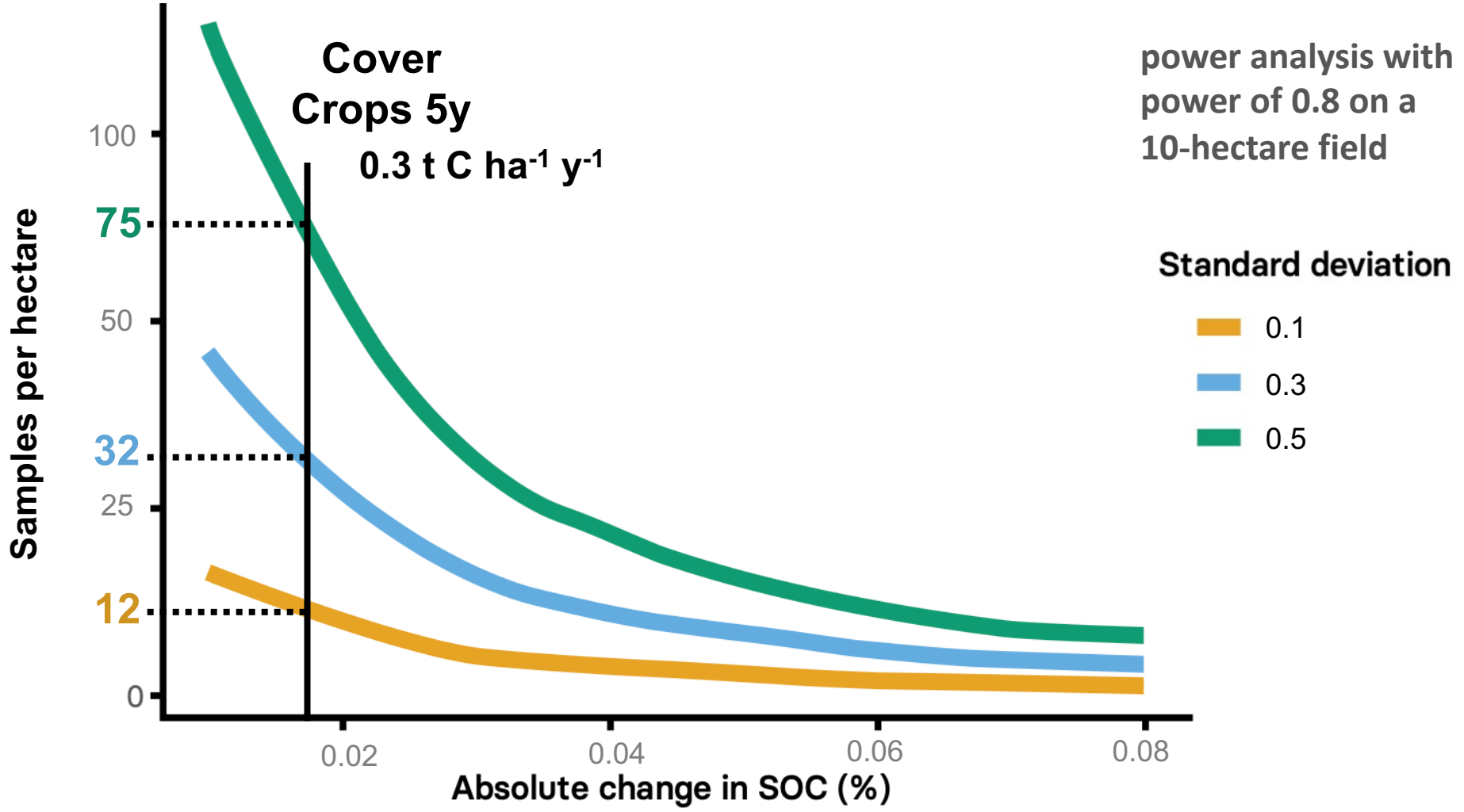


Challenges of sampling & measuring SOC

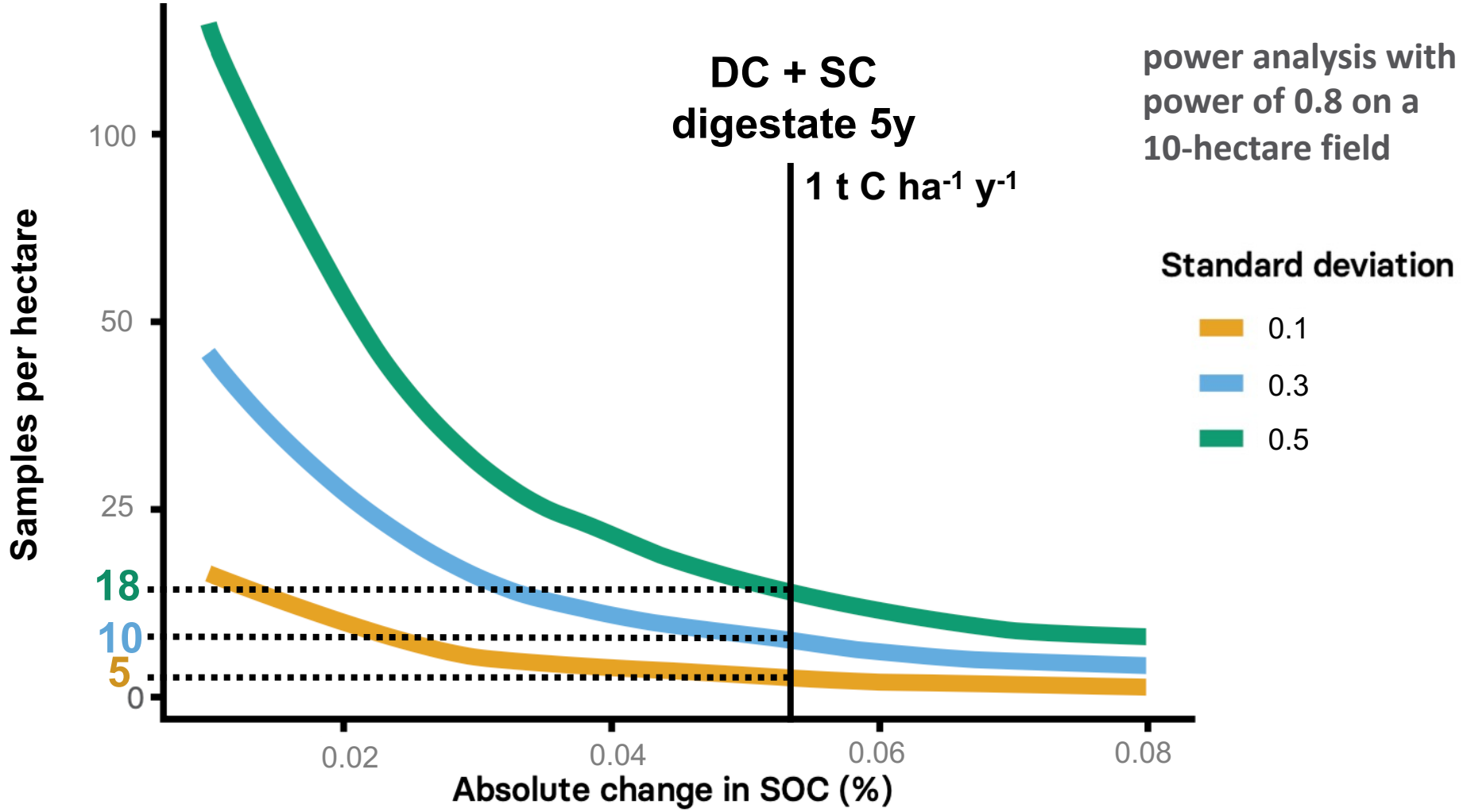
SOC stock = $[SOC]_{conc}$ x BD x CF x Depth



Samples required to detect change in SOC



Samples required to detect change in SOC



UCSC projects on SOC MRV

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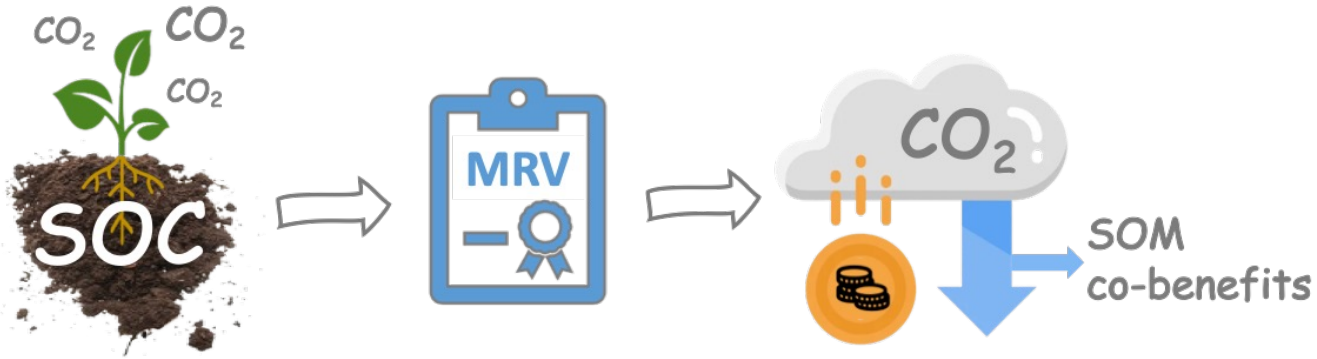
Scaling soil C credit generation at scale



THE PROJECTS

ClieNFarms
Climate Neutral Farms

FARMS 4 CLIMATE

MARVIC

THE TEST SITES

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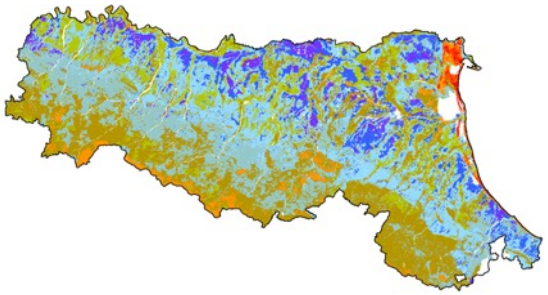
6 farms
13 fields
84 ha

8 farms
15 fields
50 ha



> **300 ha** mapped
> **500 samples** analyzed

UCSC *on-the-go* soil proximal multi-sensor

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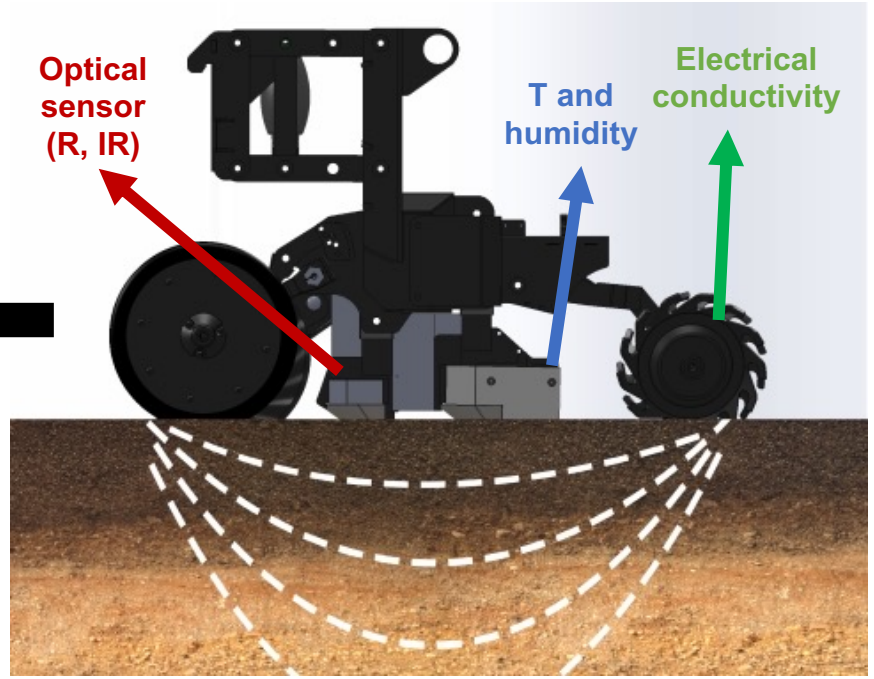
iScan PRO



Veris technologies

20 years ARVAtec

SIRbit

FIELDFUSION currently returns maps of:

- Soil texture (% clay, silt, sand)
- Cation Exchange Capacity (CEC)
- Soil Organic Matter (SOM)
- Soil water content and temperature

We are training/validating local prediction model for:

- Soil organic carbon (SOC)
- Bulk density (for SOC stock calculations)

In 2023 we will validate prediction model to map:

- AWC (available water capacity)
- Total nitrogen
- Soil microbial biomass

UCSC *on-the-go* soil proximal multi-sensor

Soil proximal mapping workflow

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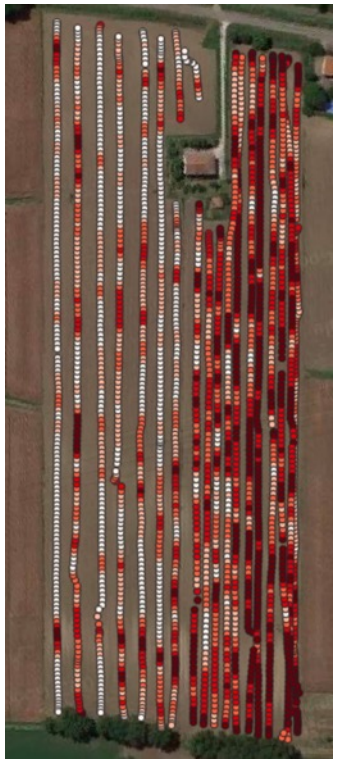
1

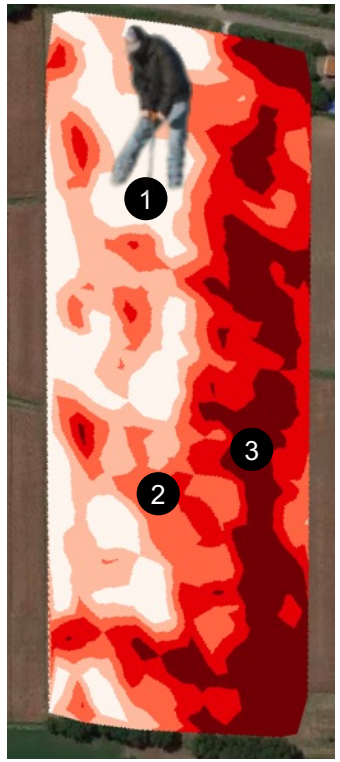
FIELD MAPPING

3.5 ha
6703 points
> 1.8 k points/ha



2 3

SOIL SAMPLING + LAB ANALYSIS



4

HIGH RESOLUTION SOIL MAP

On-the-go SOC stock mapping

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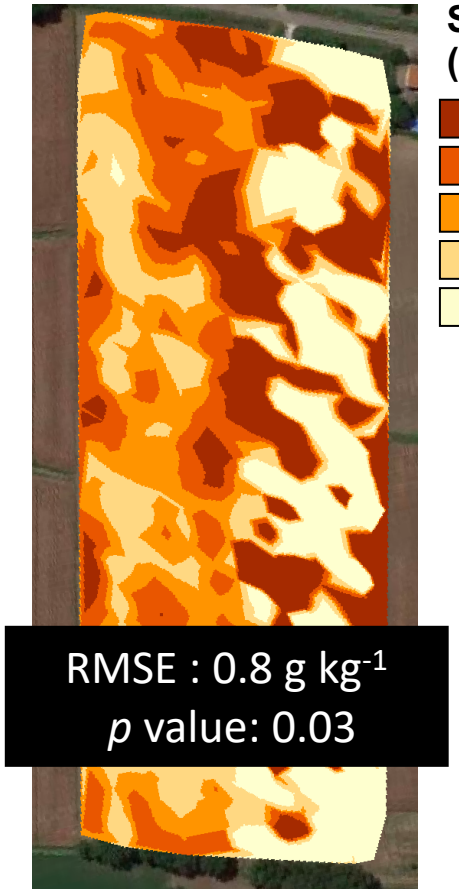
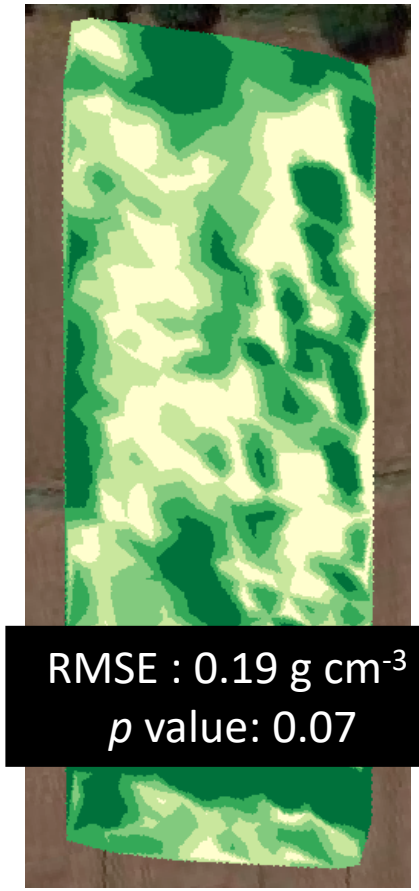
SOC stock = $[SOC]_{conc}$ x BD x CF x Depth



SOC (g kg^{-1})

- < 13.3
- 13.3-13.8
- 13.8-14.0
- 14.0-14.3
- > 14.3

RMSE : 0.8 g kg^{-1}
p value: 0.03



Bulk density (g cm^{-3})

- < 1.30
- 1.30-1.38
- 1.38-1.42
- 1.42-1.46
- > 1.46

RMSE : 0.19 g cm^{-3}
p value: 0.07

SOC stock (ton C ha^{-1})

- < 53
- 53-55
- 55-56
- 56-58
- > 58

RMSE : 1.15 ton ha^{-1}
p value: 0.02

UCSC *on-the-go* soil proximal multi-sensor

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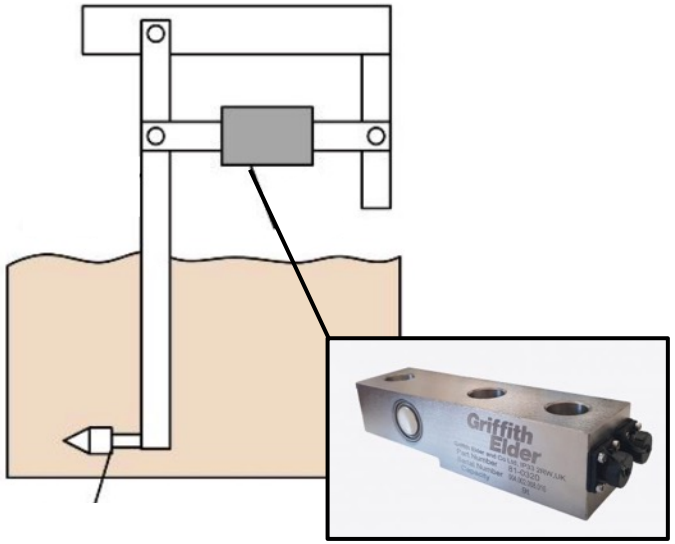
SOC stock = $[SOC]_{conc}$ x BD x CF x Depth

AI-based Prediction model

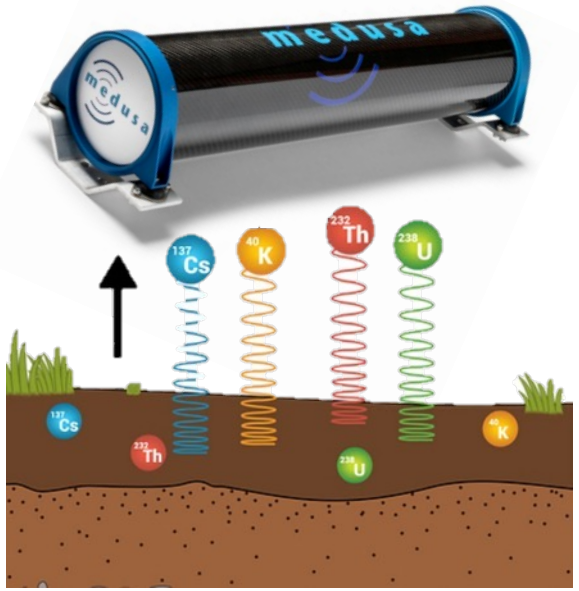
Training
Validation
Prediction

	2022	2023
ha mapped	220	>120
samples	449	>300

New sensor for BD mapping



Gamma-ray sensor



High-throughput soil sampling & analysis

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Top-soil autosampler

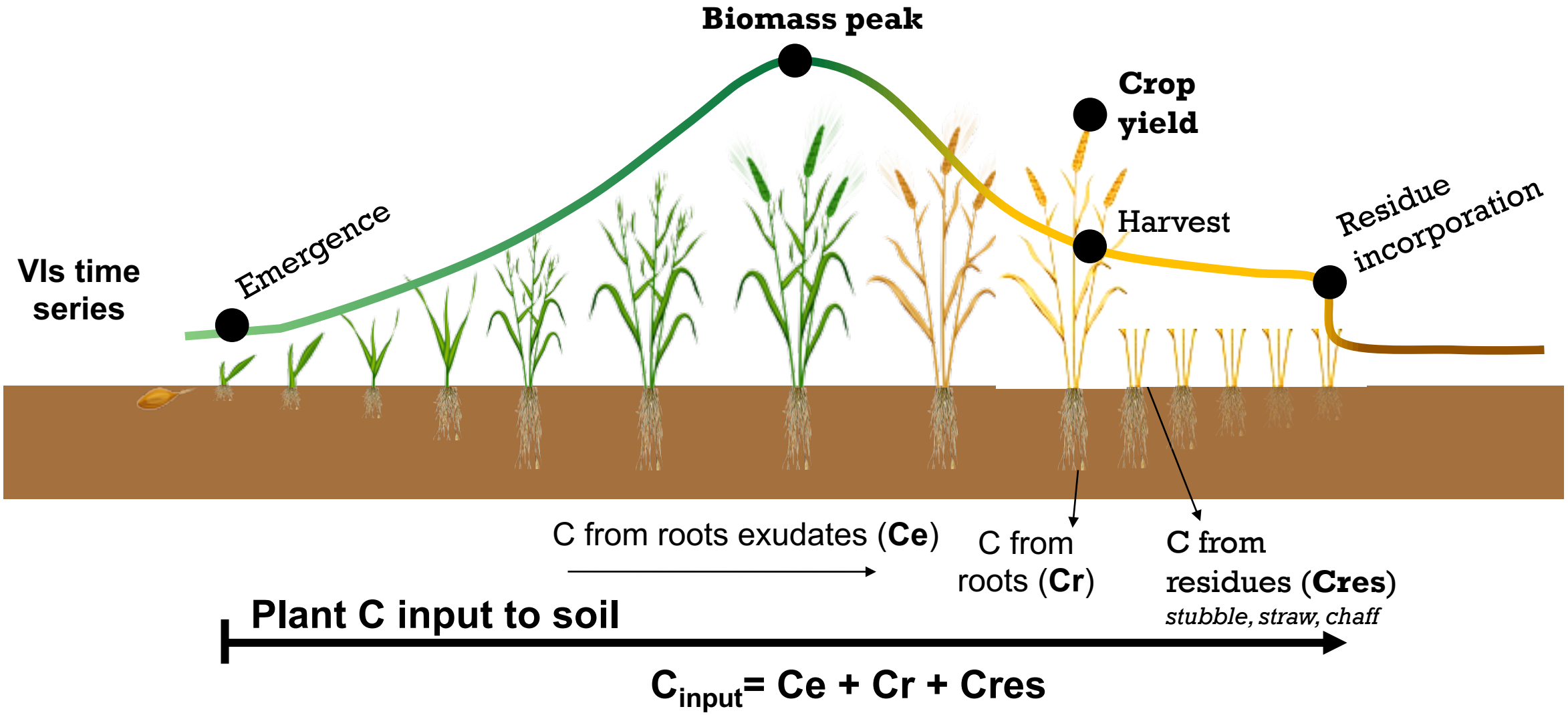
Samples logistics

Improving soil analysis and sampling

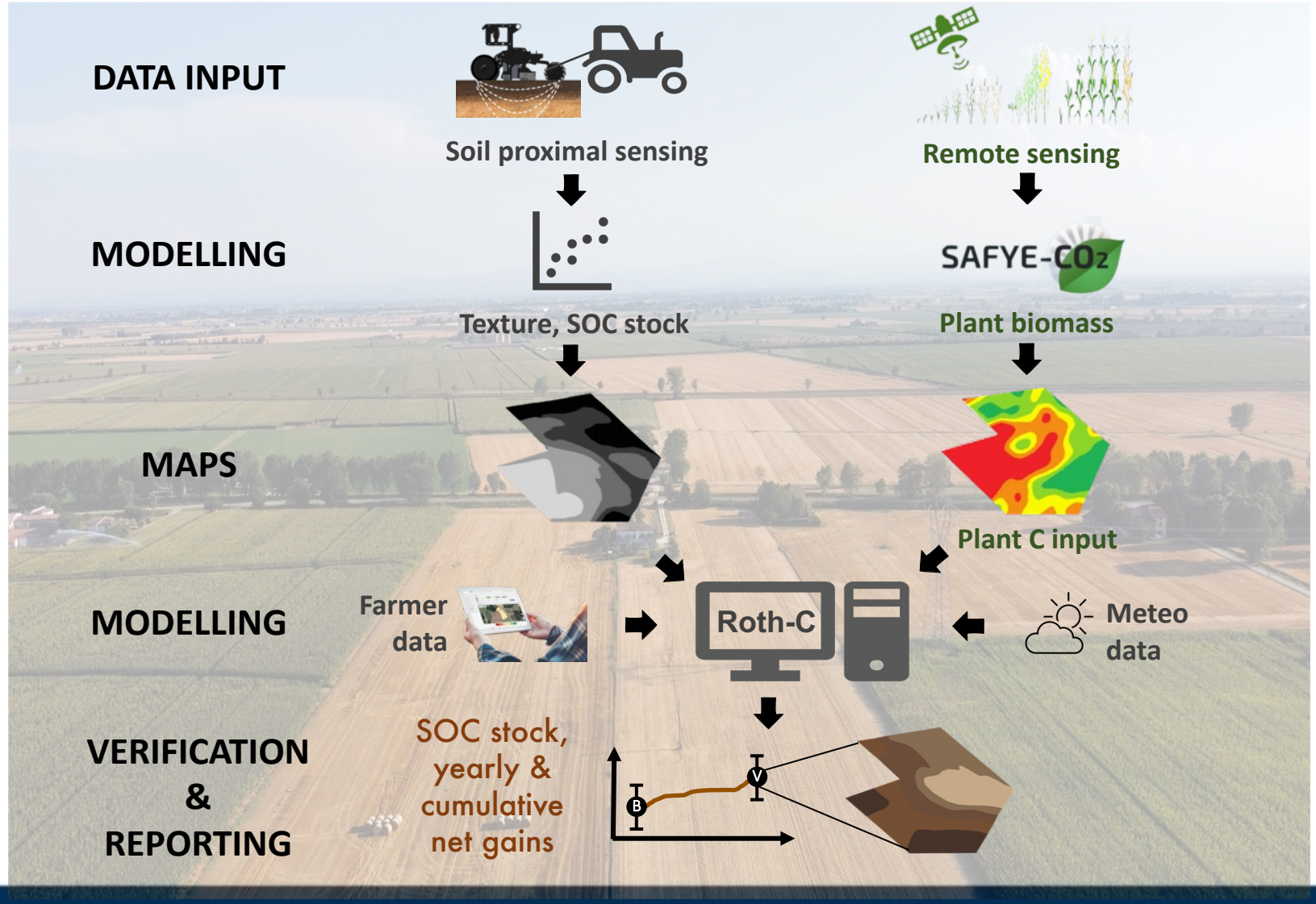
cost-accuracy ratio

DRIFT FT-IR (UV-MIR) spectrometer

Improving SOC MRV trough remote sensing products



The Remote-C UCSC SOC MRV approach



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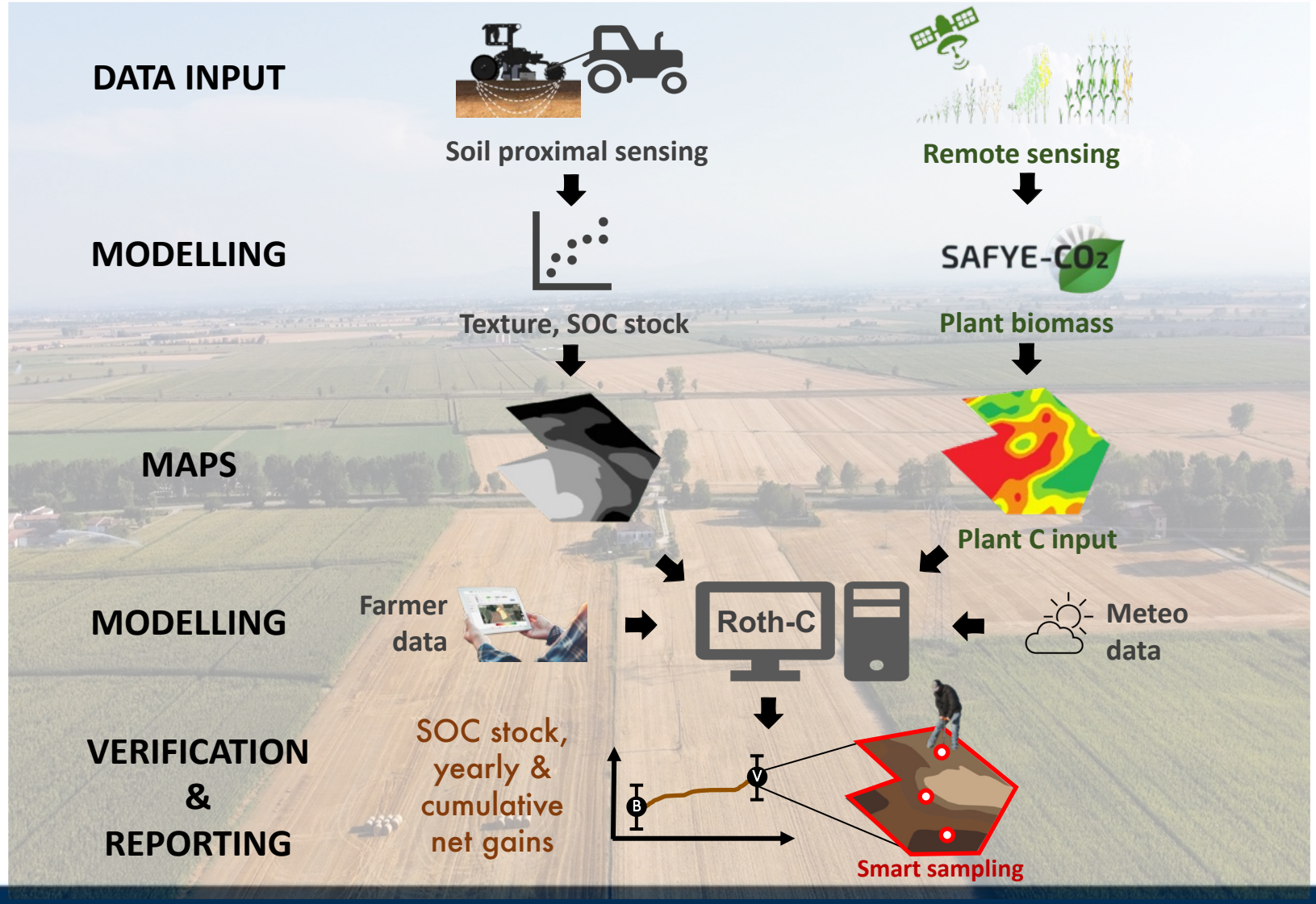

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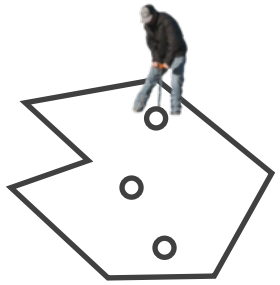
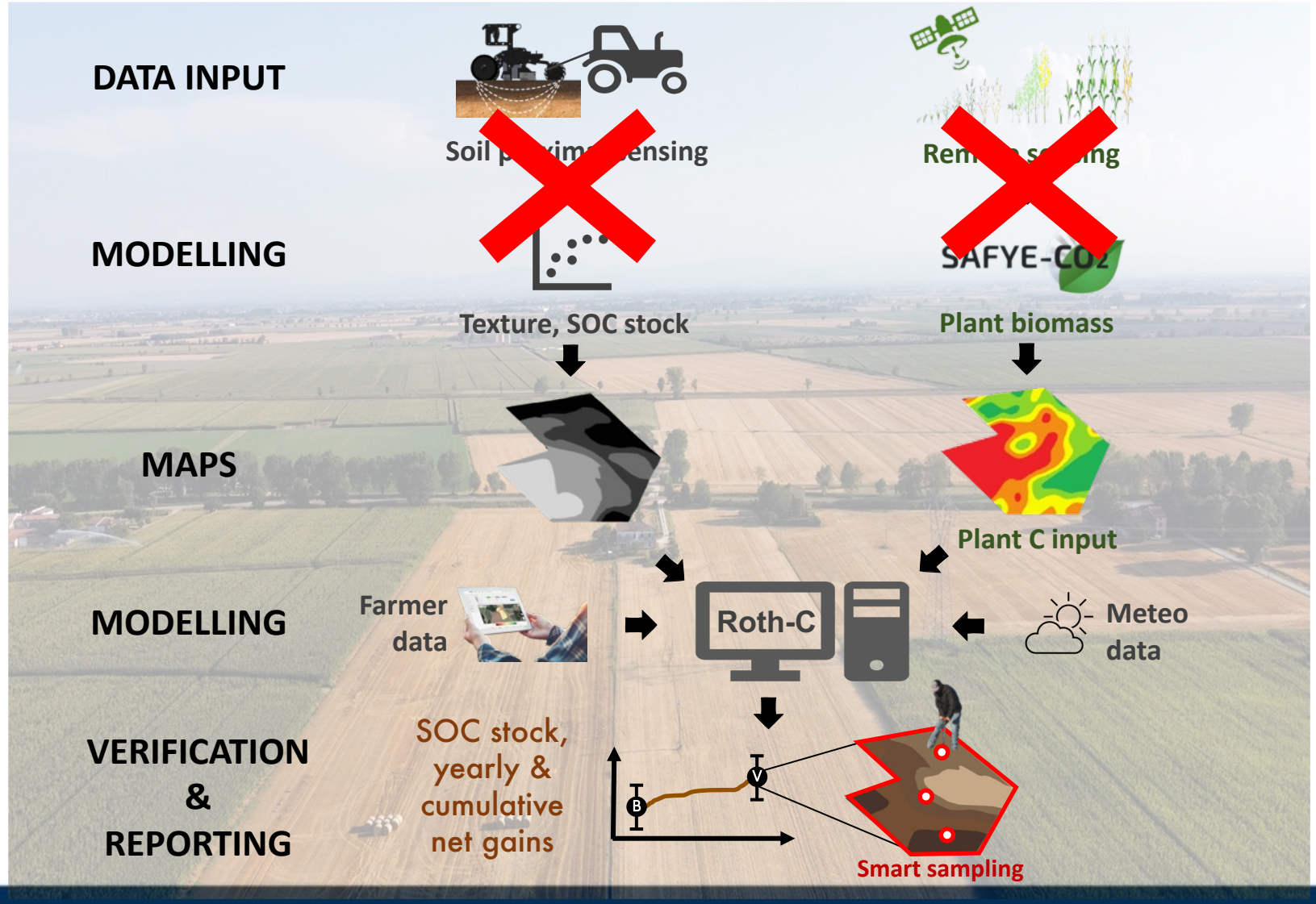


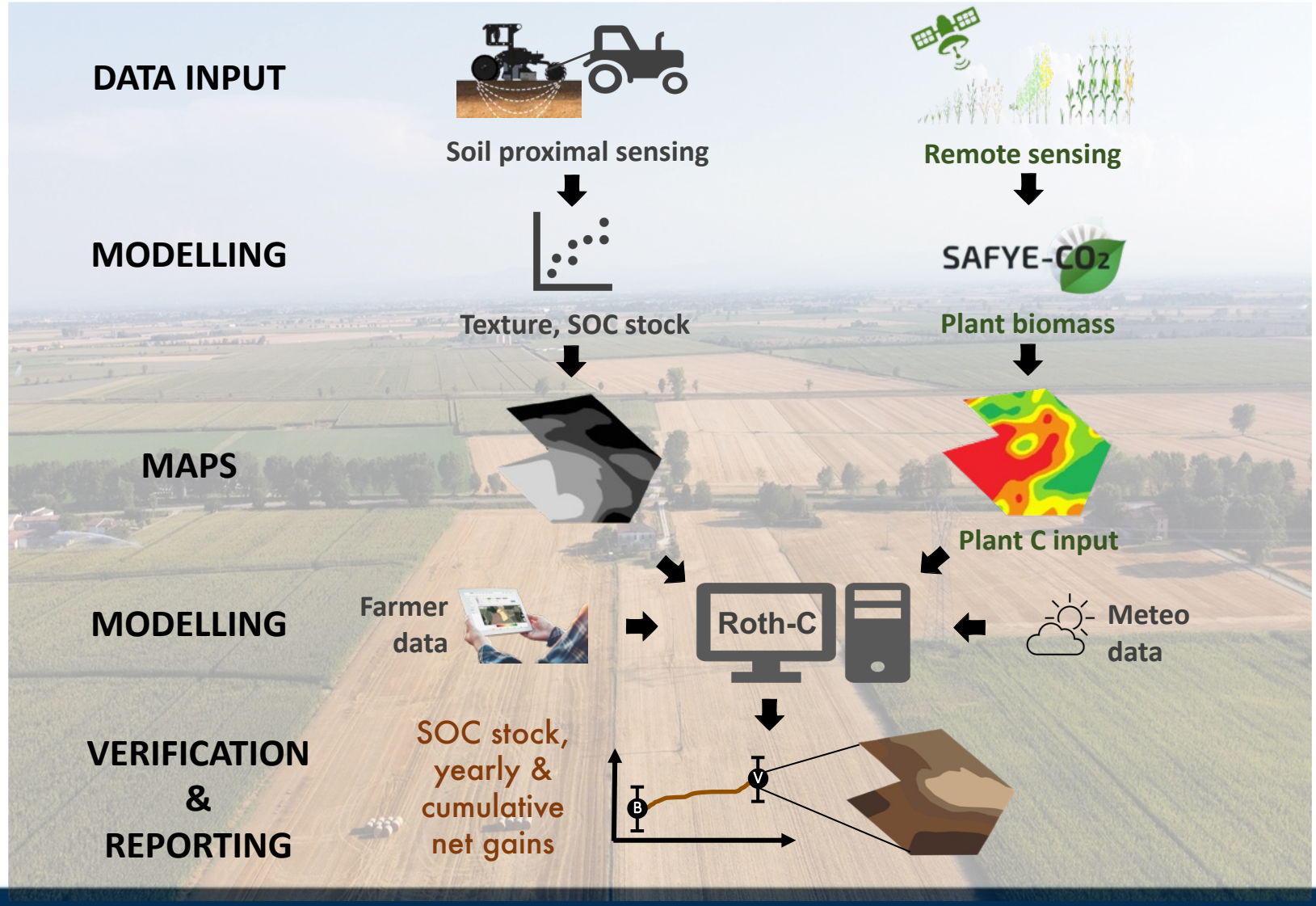
Discrete smart sampling

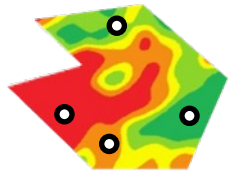
RS-based soil mapping



Harvest map or farmer declaration

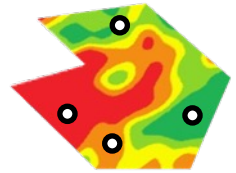
The Remote-C UCSC SOC MRV approach



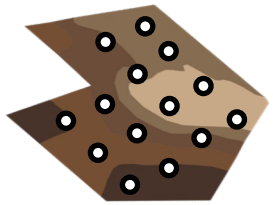


Leaf Area Index

VALIDATION STRATEGY



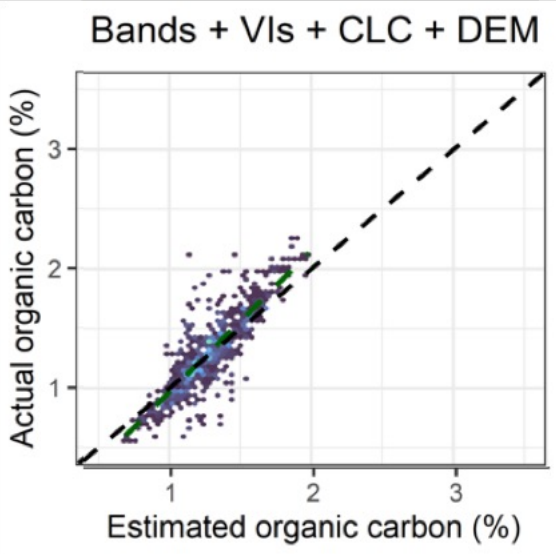
Yield HI R:S ratio



Mapping SOC_{stock} over time via remote sensing

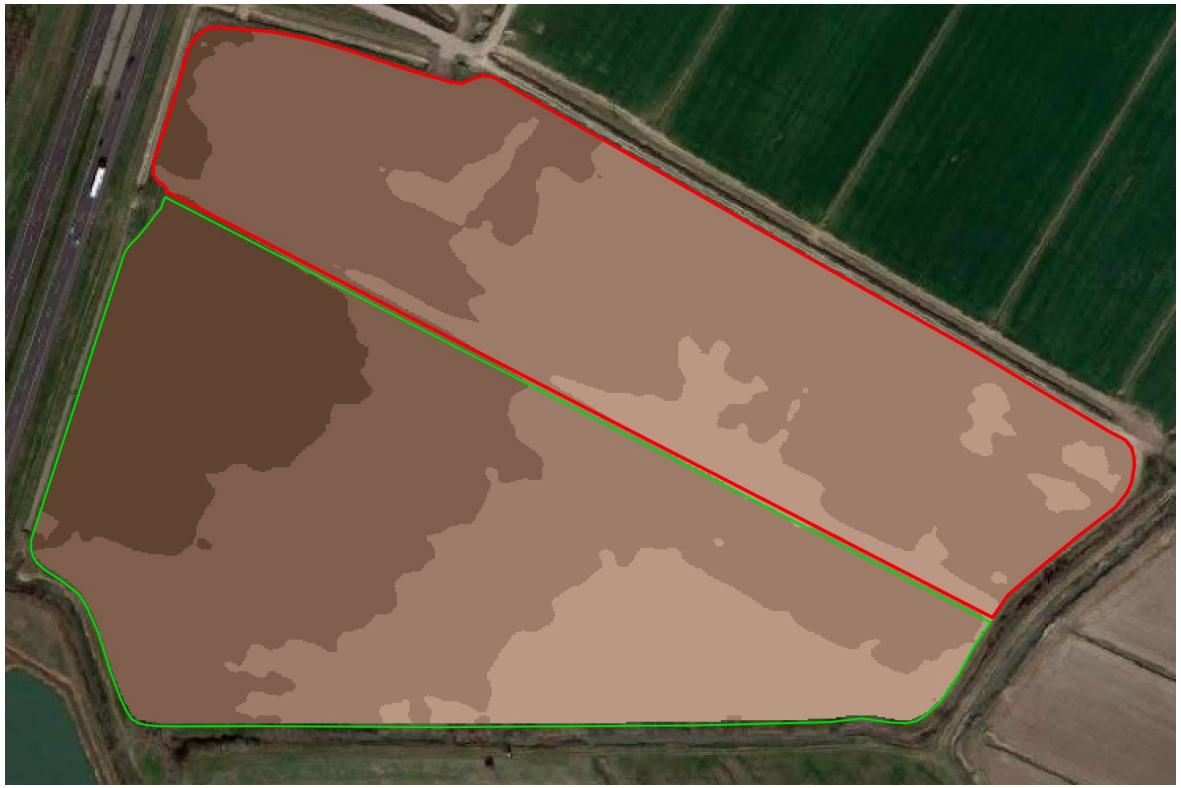
Regione Emilia-Romagna

Satellite	Data availability
Landsat 8	April 2013 - Present
Landsat 7	1999 - Present
Sentinel-2	2015 – Present



First outputs of Remote-C on double + strip cropping

Data Input:



SOC stock (ton ha^{-1})

2019 77.4 ± 11.3

84.1 ± 17.2

SOC stock (ton C ha^{-1})

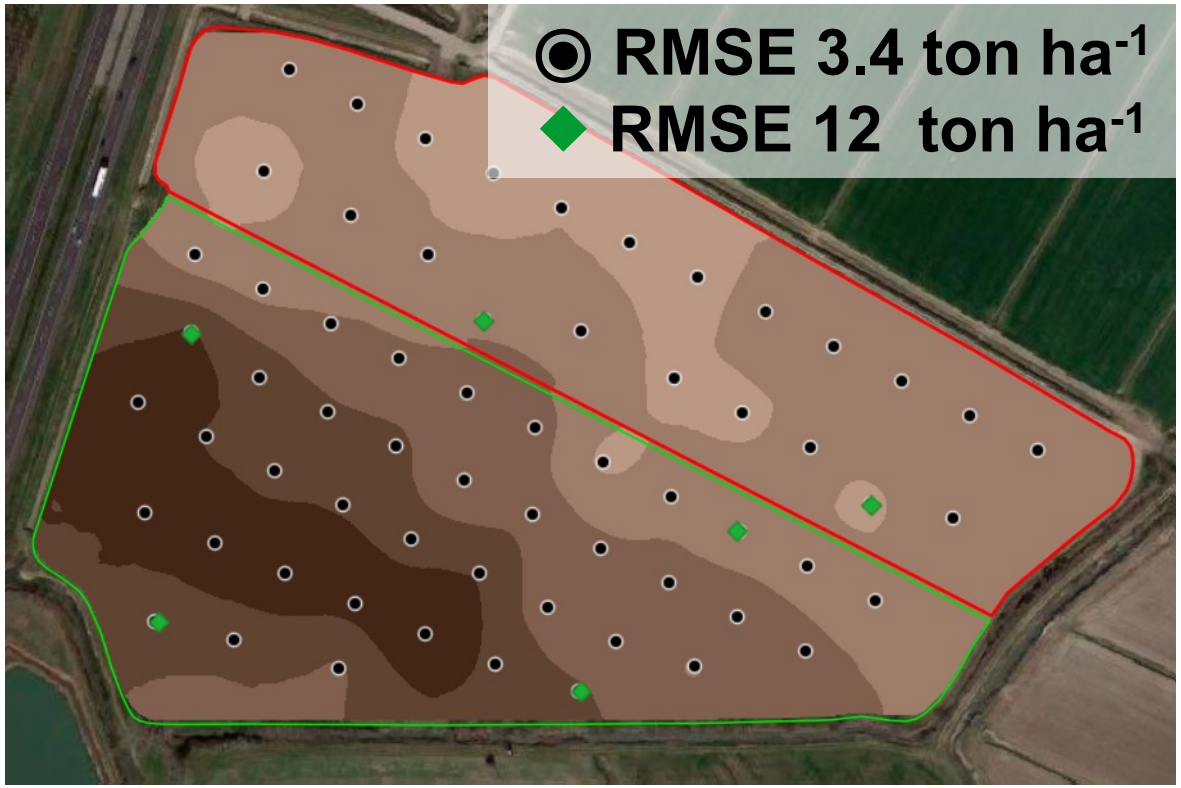
- < 65
- 65-83
- 83-101
- 101-119
- > 119

CIB CONSORZIO ITALIANO BIOGAS

2019	Triticale
2020	Maize
	Wheat
2021	Maize
	Wheat
2022	Maize

First outputs of Remote-C on double + strip cropping

Data Input:



SOC stock (ton ha^{-1})

2019	77.4 ± 11.3	84.1 ± 17.2
2022	72.6 ± 6.8	98.7 ± 17.9

SOC stock (ton C ha^{-1})

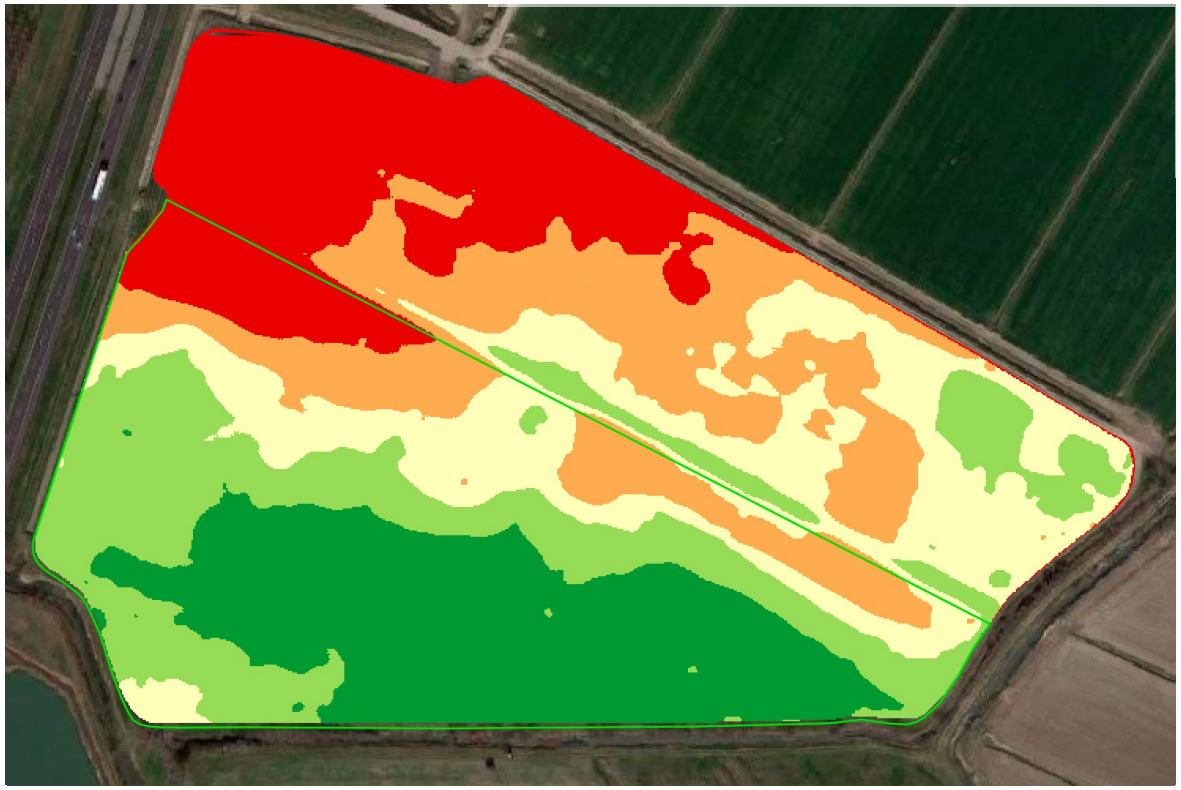
- < 65
- 65-83
- 83-101
- 101-119
- > 119

CIB CONSORZIO ITALIANO BIOGAS

2019	Triticale	
2020	Maize	Wheat
2021	Maize	Wheat
2022	Maize	

First outputs of Remote-C on double + strip cropping

Data Input:



SOC stock (ton ha^{-1})

2019	77.4 ± 11.3	84.1 ± 17.2
2022	72.6 ± 6.8	98.7 ± 17.9

SOC sequestered (ton ha^{-1} y^{-1})

-0.4 ± 1.36

1.49 ± 1.06

CSR (ton ha^{-1}y^{-1})

- < -1.36
- -1.36 – 0
- 0 – 0.86
- 0.86 – 2.23
- > 2.23

CIB CONSORZIO ITALIANO BIOGAS

2019	Triticale
2020	Maize
	Wheat
2021	Maize
	Wheat
2022	Maize

First outputs of Remote-C on wheat-maize-tomato

Data Input: + SAFYE-CO2

SOC stock (ton C ha^{-1})

- < 56
- 56-61
- 61-65
- >65

First outputs of Remote-C on wheat-maize-tomato

Data Input: + SAFYE-CO_2

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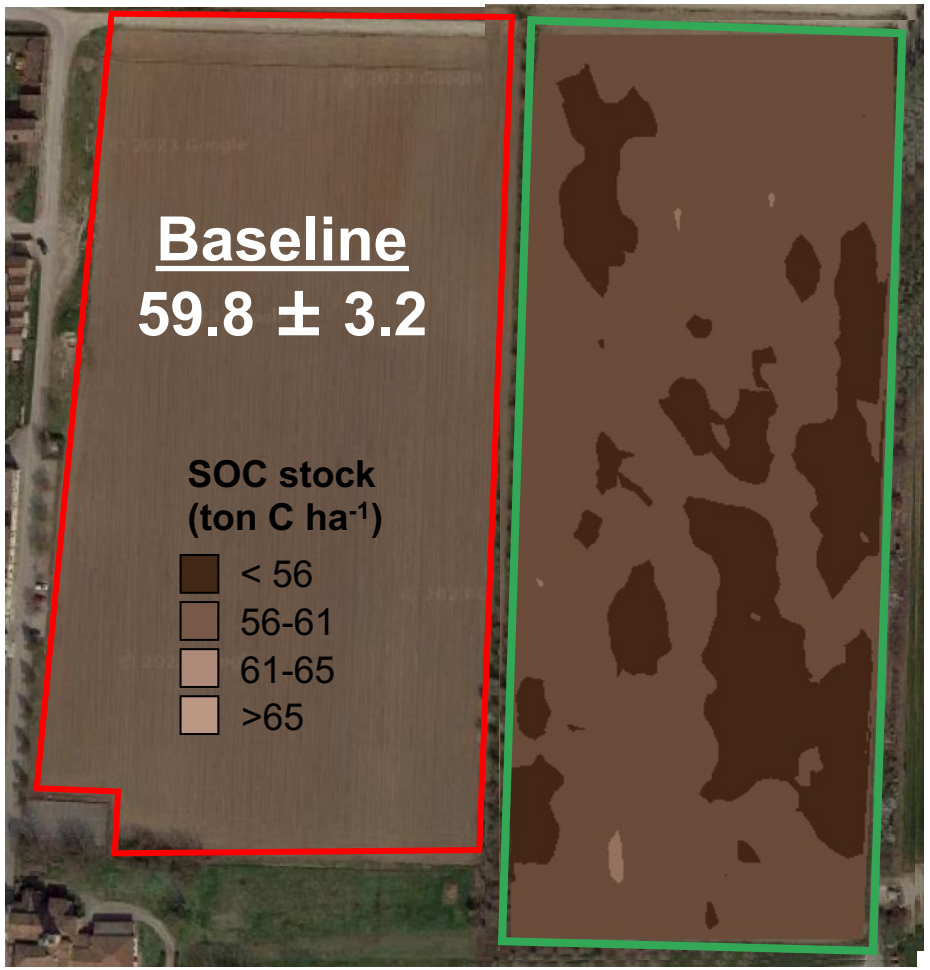
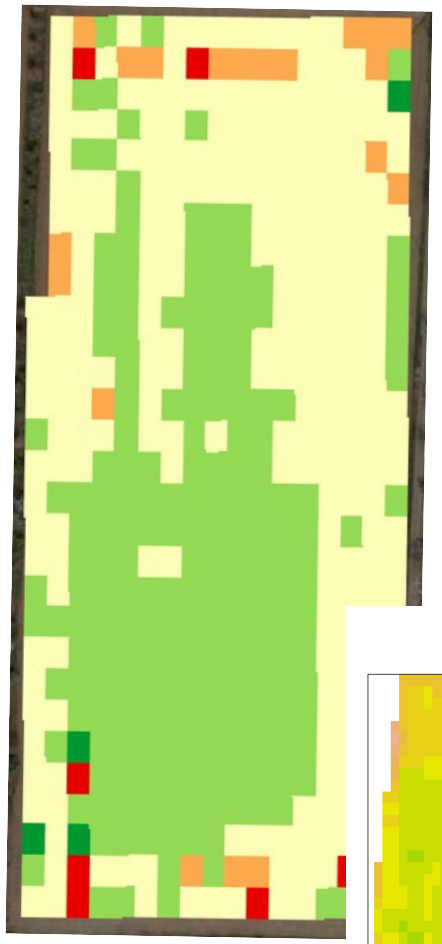
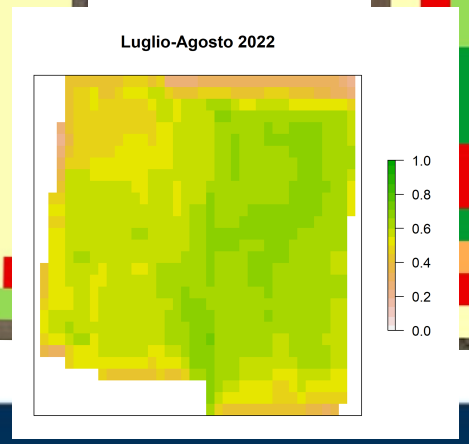


Grain Yield



ton DM ha^{-1}
- <= 3.7
- 3.7 - 5.0
- 5.0 - 6.4
- 6.4 - 7.8
- > 7.8



Straw incorporated

ton DM ha^{-1}
- <= 10.6
- 10.6 - 11.3
- 11.3 - 11.9
- 11.9 - 12.5
- > 12.5

First outputs of Remote-C on wheat-maize-tomato

Data Input: + SAFYE-CO2

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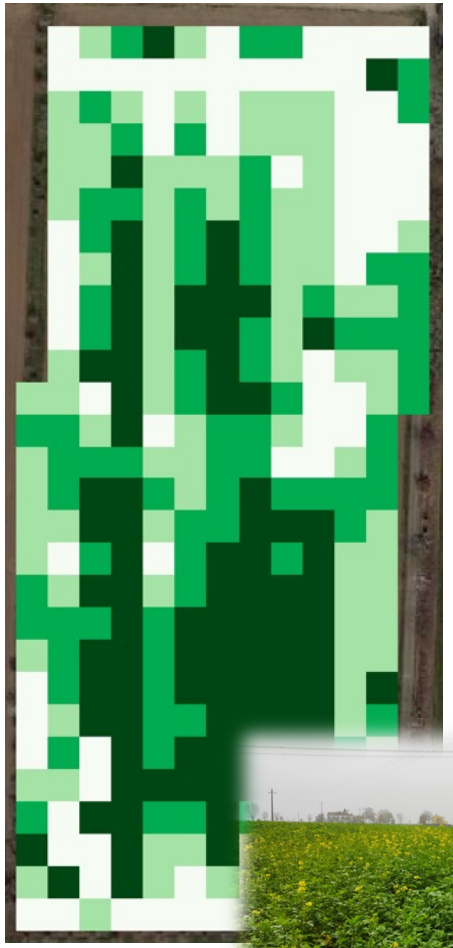
SOC stock (ton C ha^{-1})

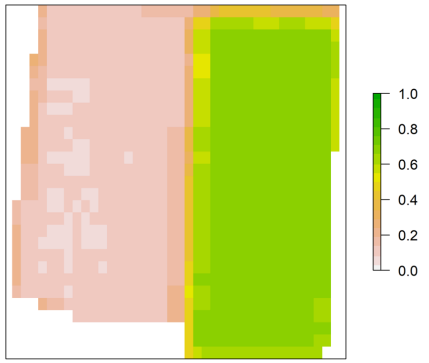
- < 56
- 56-61
- 61-65
- >65

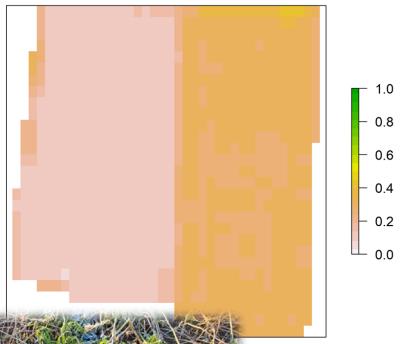
Cover incorporated



ton DM ha^{-1}

- <= 5.1
- 5.1 - 5.6
- 5.6 - 6.0
- > 6.0





First outputs of Remote-C on wheat-maize-tomato

Data Input: + SAFYE-CO2

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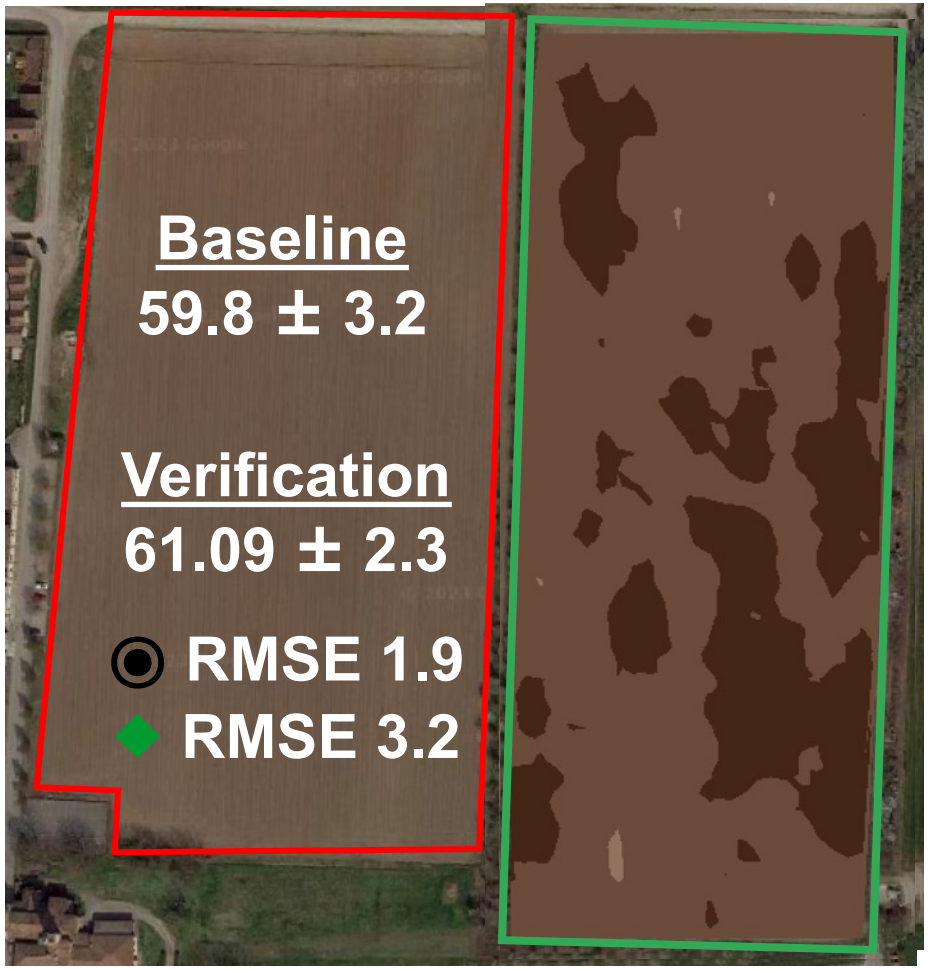

SOC stock (ton C ha^{-1})

- < 56
- 56-61
- 61-65
- >65

Stand Dev (ton C ha^{-1})

- < 1.4
- 1.4-1.45
- 1.45-1.5
- >1.5

First outputs of Remote-C on wheat-maize-tomato

Data Input: + SAFYE-CO_2

CO_2 removed (ton ha^{-1})

- < 1.9
- 1.9 - 4.7
- 4.7 - 6.9
- > 6.9

CO_2 removed: 4.36 ton

SOC sequestered: 1.18 ton

SOM increased of 0.05 %

UCSC Field Crops Group

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The UCSC SOC MRV path

1. Modelling toolbox + first validations
2. Conference CF & SOC MRV
3. Committed new farmers (agreement)
4. New RS-products, lab, smart sampling components available
5. Carbon allowance first 50 ha
6. Platform v1.0 with API released

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UNIVERSITÀ CATTOLICA del Sacro Cuore

UCSC SOC MRV team

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Giorgio Impollonia
Andrea Marcone
Irena Ymeti
Edoardo Volpato
Eric Perez

UCSC Field Crops Group

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