Soil carbon sequestration through crops rotation in a Mediterranean Cambisols: measurement and modelling

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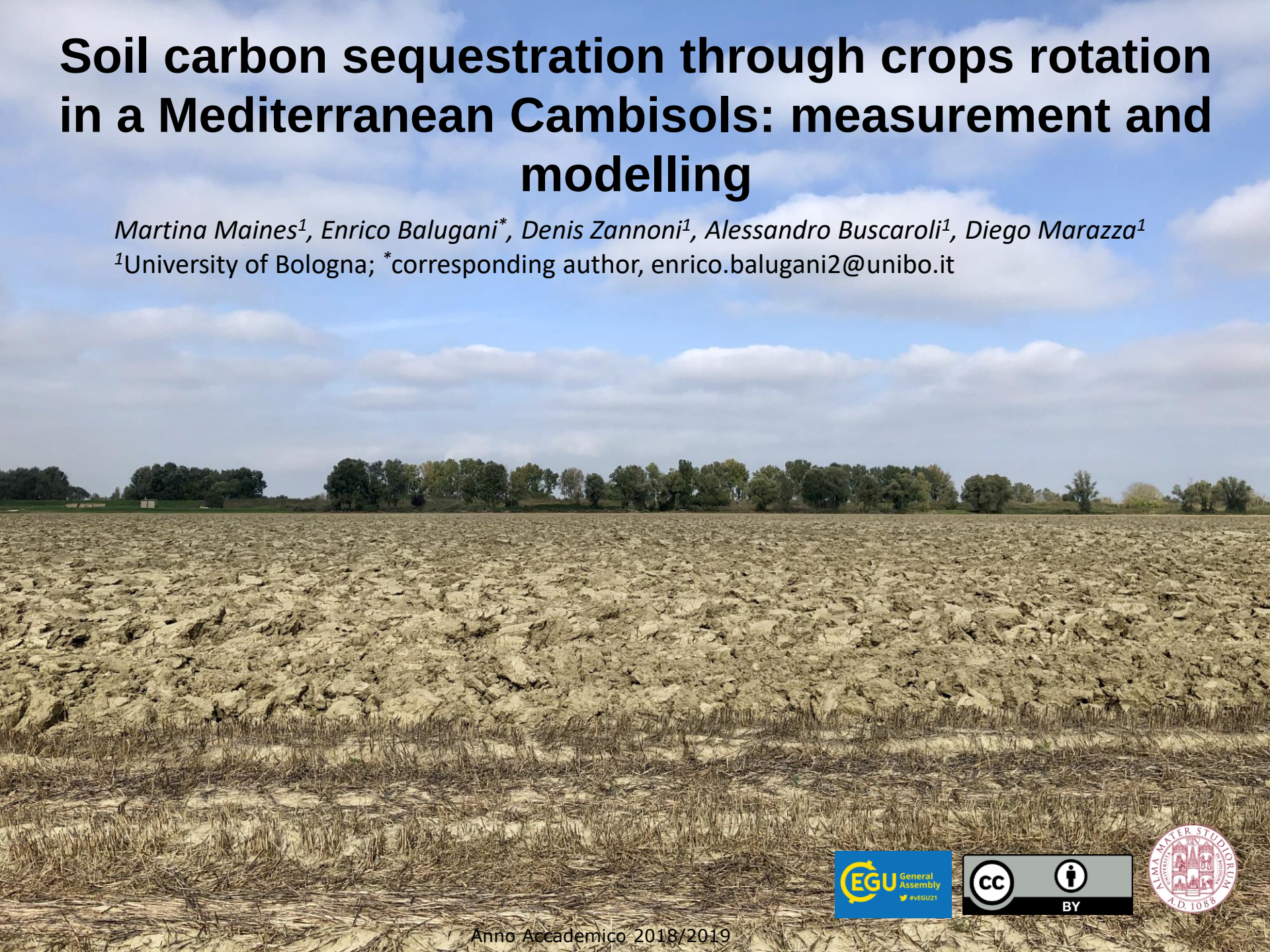

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1.1

CONVENTIONAL AGRICULTURE

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Characterized by:

- Elevated production levels
- Large energy demand
- Soil quality degradation

1.2

SUSTAINABLE AGRICULTURE

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- Aimed at conserve natural resources
- Food production directed toward:
  1. **Being economically viable for farmers**
  2. **Sustain development opportunities**
  3. **Protect human rights**
- Find and use agricultural practices able to maintain soil ecosystem services; among them, Carbon sequestration in soils to maintain soil quality and decrease climate change due to CO2 worldwide
- Soil crop rotation is a key principle to preserve soil health and increase soil C sequestration

1.3

SOIL ORGANIC CARBON – SOC

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- SOC has a fundamental role in maintaining soil functions and quality
- SOC is a measurable component of soil organic matter (SOM)
- SOC variation due to:
  - Climatic factors
  - Soil properties
  - Soil (land) use

1.3.1

HOW TO MODEL SOC DYNAMICS

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- **Modelling** useful to estimate SOC dynamics and generalize them to large areas or to project them to the future for different scenarios:
  - With changing climatic conditions (IPCC climate change scenarios)
  - Land Use Change scenarios
- Modelling may help in developing strategies to increase soil C sequestration and to support policy makers decisions
- Here, we used the model **RothC**

OBIETTIVO STUDIO

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The effect of different agricultural practices has not been yet studied in detail (large variety of practices, soils, climates, vegetations to take into consideration)

Here, we wanted to give our small contribution by:

- Assessing the effect of different crop rotation on SOC content on the short term by field experiment (2016-2020) and project the effects on the long term by modelling.

STUDY AREA

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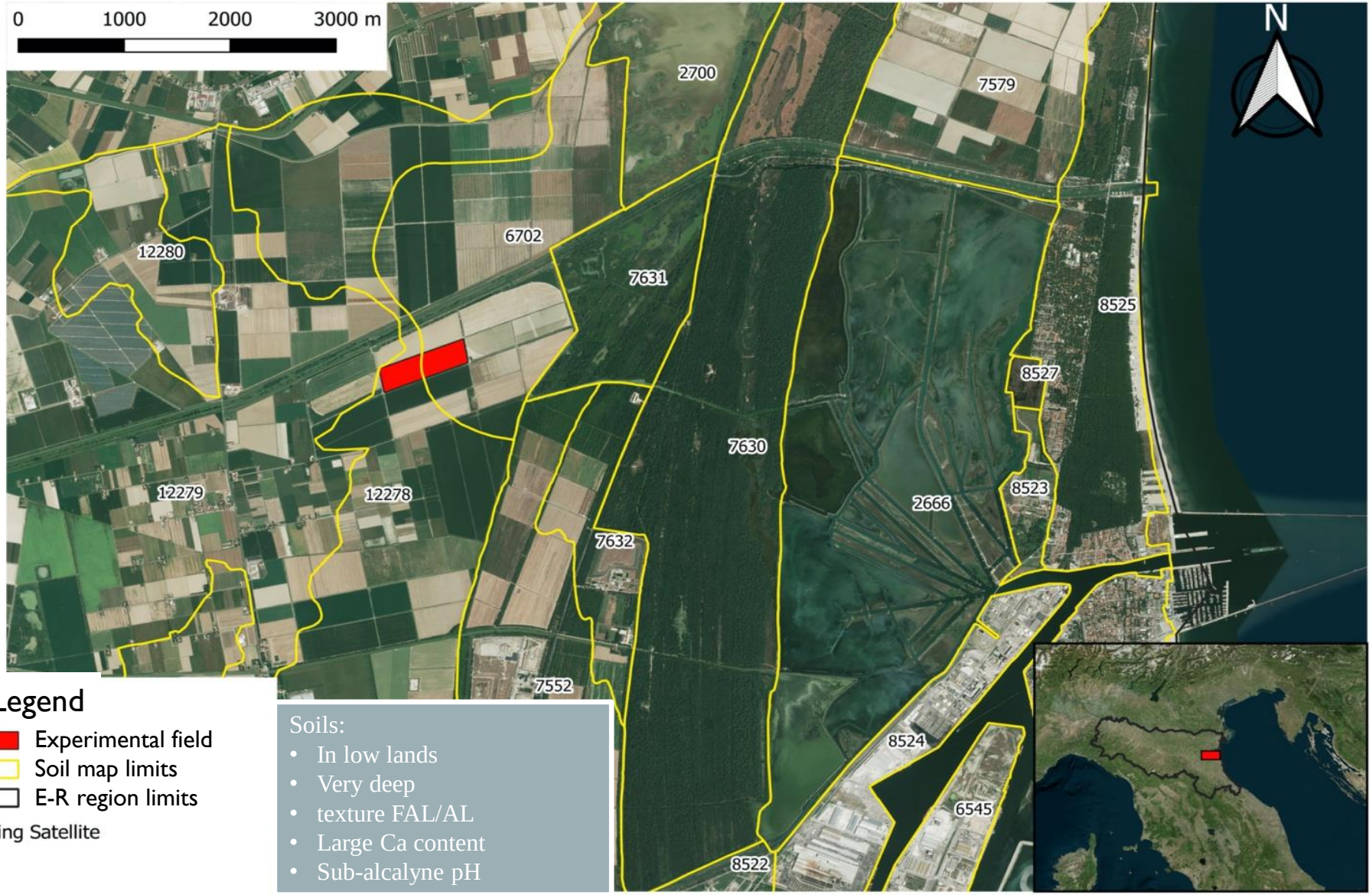

SAMPLING

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Two soil samples collected at the beginning of the experiment, when the whole field was kept under corn cultivation

3 samples collected every sampling point, then mixed for representativeness

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SOC ANALYSIS

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- *Method VII.1 (dry oxydation)*: adopted by law DM n.185 13/09/1999, Supp. Ord. n° 248, derived from ISO 10694
- Sample was crushed and mixed
- Pretreated with HCl 1.5N
- CHN analyzer

Thermo Fischer FLASH 2000 CHNS/O

4.2

ANALYSIS

Sample	N [%]	TOC [%]
TE1	0.146	0.953
TE2	0.121	0.893
TE3	0.122	0.905
TE4	0.117	0.830
TE5	0.125	0.892
TE6	0.106	0.755
TE7	0.114	0.840
TE8	0.118	0.833
TE9	0.117	0.832
TE10	0.118	0.777
TE3BIS	0.128	0.874
TE7BIS	0.110	0.821

Organic Carbon content	
Evaluation	%
Very low	< 0.45
Low	0.45 – 0.90
Average	0.91 – 1.36
High	1.37 – 1.81
Very high	> 1.81

Errors		
Total Perc. Error [%]	Sampling error [%]	Analytic error (precision) [%]
7.08	4.84	2.24

$$SOC\ (tC/ha) = \frac{TOC\ \%}{100} \cdot 5120$$

ROTHC

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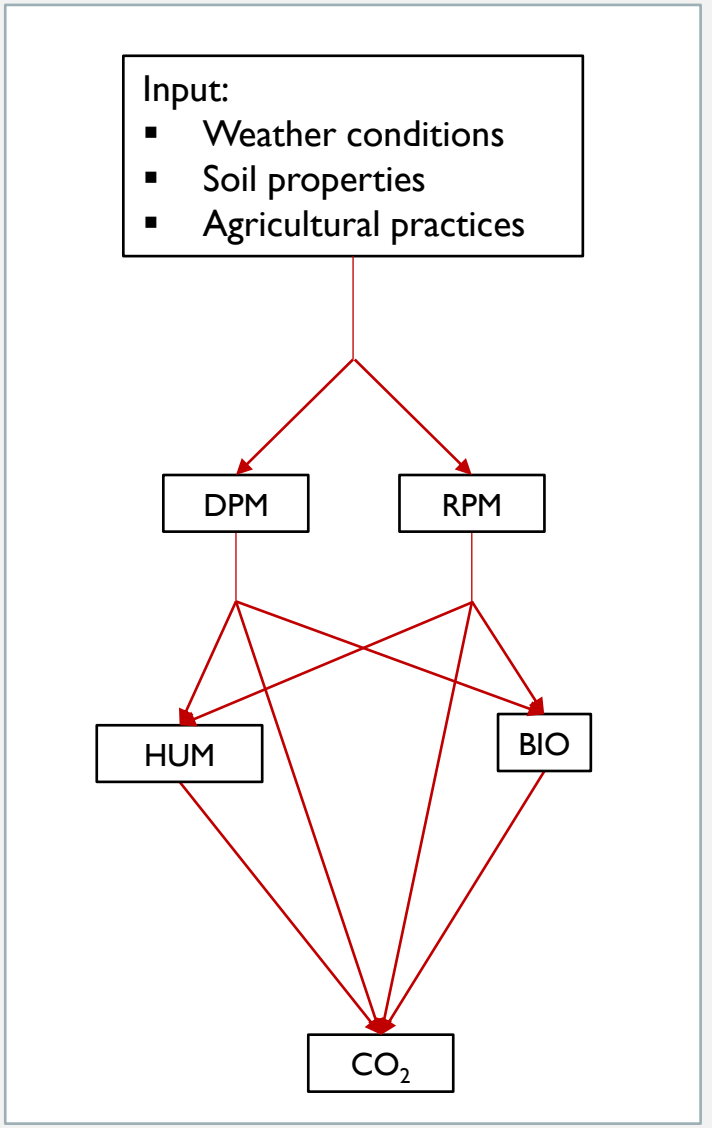
- Simulate SOC turnover in shallow soils
- SOC divided into 5 carbon pools:
  - **DPM**: decomposable plant material
  - **RPM**: resistant plant material
  - **HUM**: humified organic matter
  - **BIO**: microbic biomass
  - **IOM**: Inert organic matter
  - The mineralized SOC ends up as **CO_2**
- We implemented the RothC algorythm and equations on VensimPLE software



Vensim RothC

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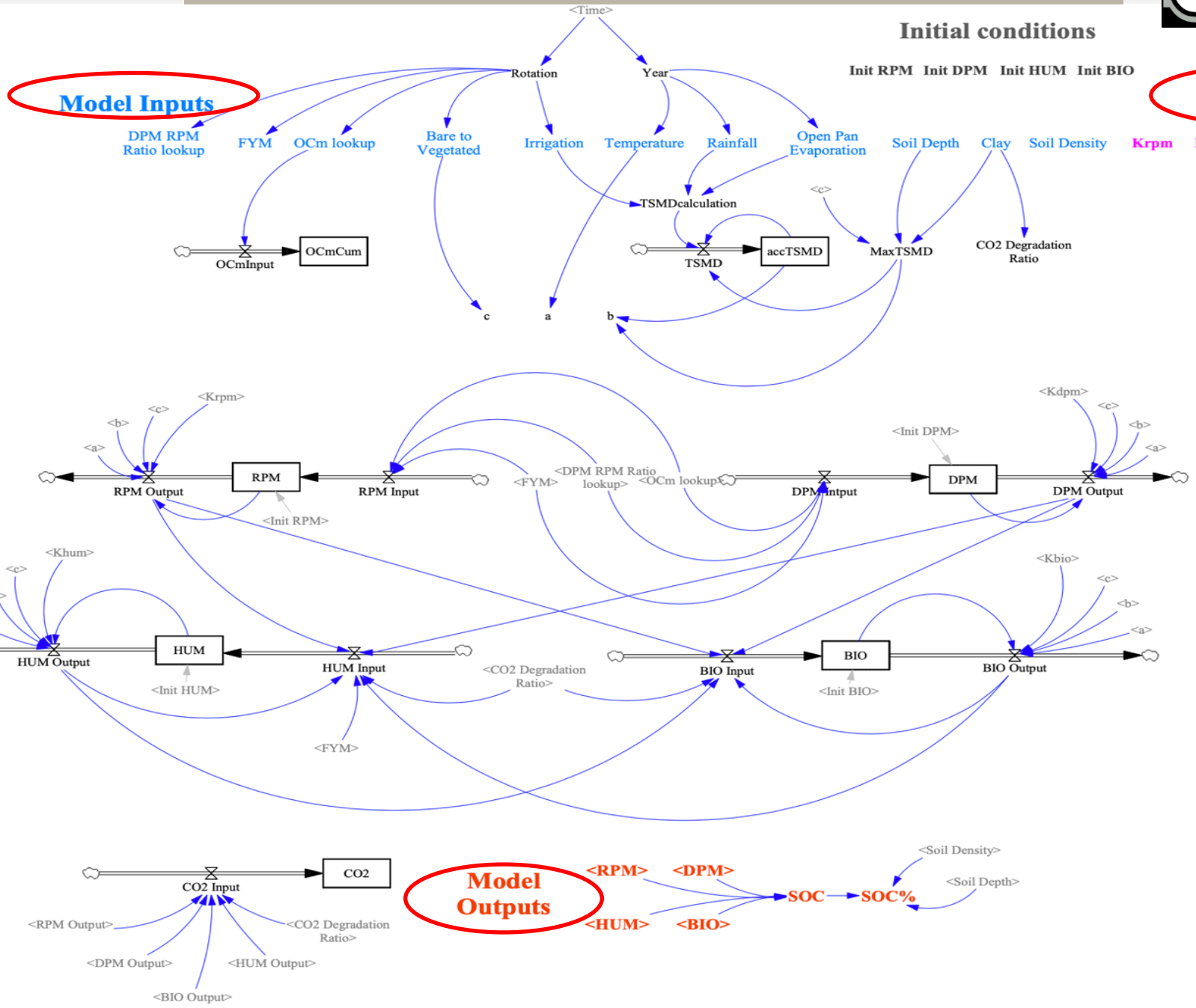

5.1

SINGLE CROP MODELS

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Spin run:

- Initial conditions: all pools to 0
- Crops: tilled wheat, untilled wheat, corn, tomato, soy
- Single annual cycle
- 10000 simulation month (833 years, till equilibrium reached)
- Input:
  - Weather variables→ Meteo station in the study area and data from Dext3r platform
  - Soil → 36% clay, 40cm depth (tillage depth)
  - Input practices:
    - *Irrigation*: only for tomato and corn
    - *Bare to vegetate:* as observed
    - *Ocm*: agricultural residues from harvested quantities (above ground) or from crop models (belowground)
    - *FYM*: not used
    - *DPM/RPM*: 1.44, as for other grass cultures

SINGLE CROP MODELS

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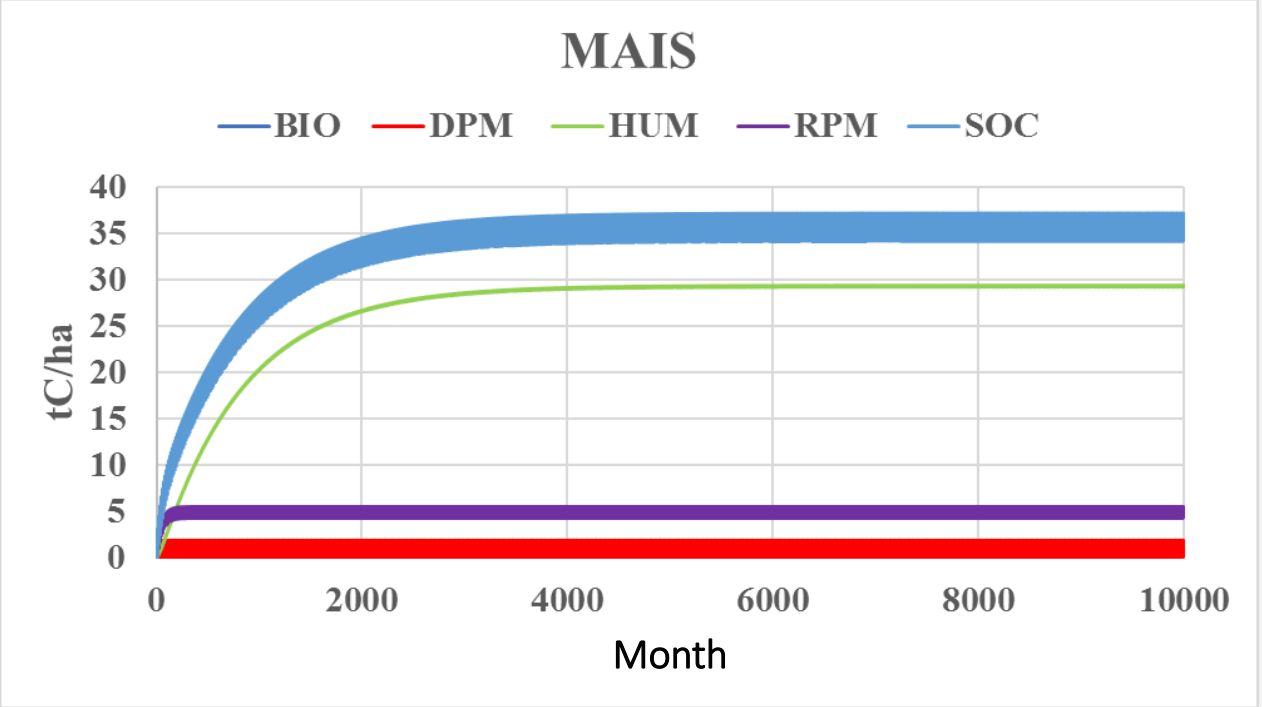
Crop	Ocm [tC/ha]	Period
Tomato	5.06	September
Soy	4.64	October
Corn	2.99	September
Wheat (till)	0.78; 0.36	June; September
Wheat (untill)	0.03; 0.80	All year

- Output of the single crop simulation
- Here only Corn shown due to:
  - Representativeness (most common crop)
  - TOC % values obtained very similar to those obtained in laboratory analyses



5.2

CROP ROTATION MODELS

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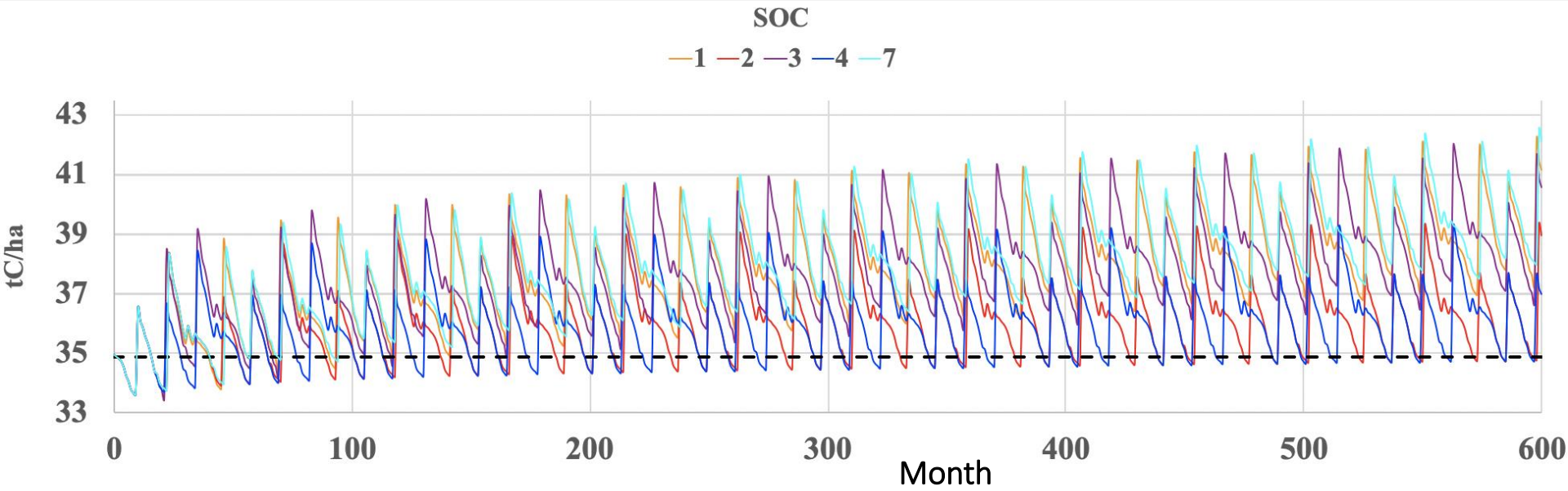
- 8 simulations (one for each rotation)
- 4-year cycles
- 600 simulation months (50 years)

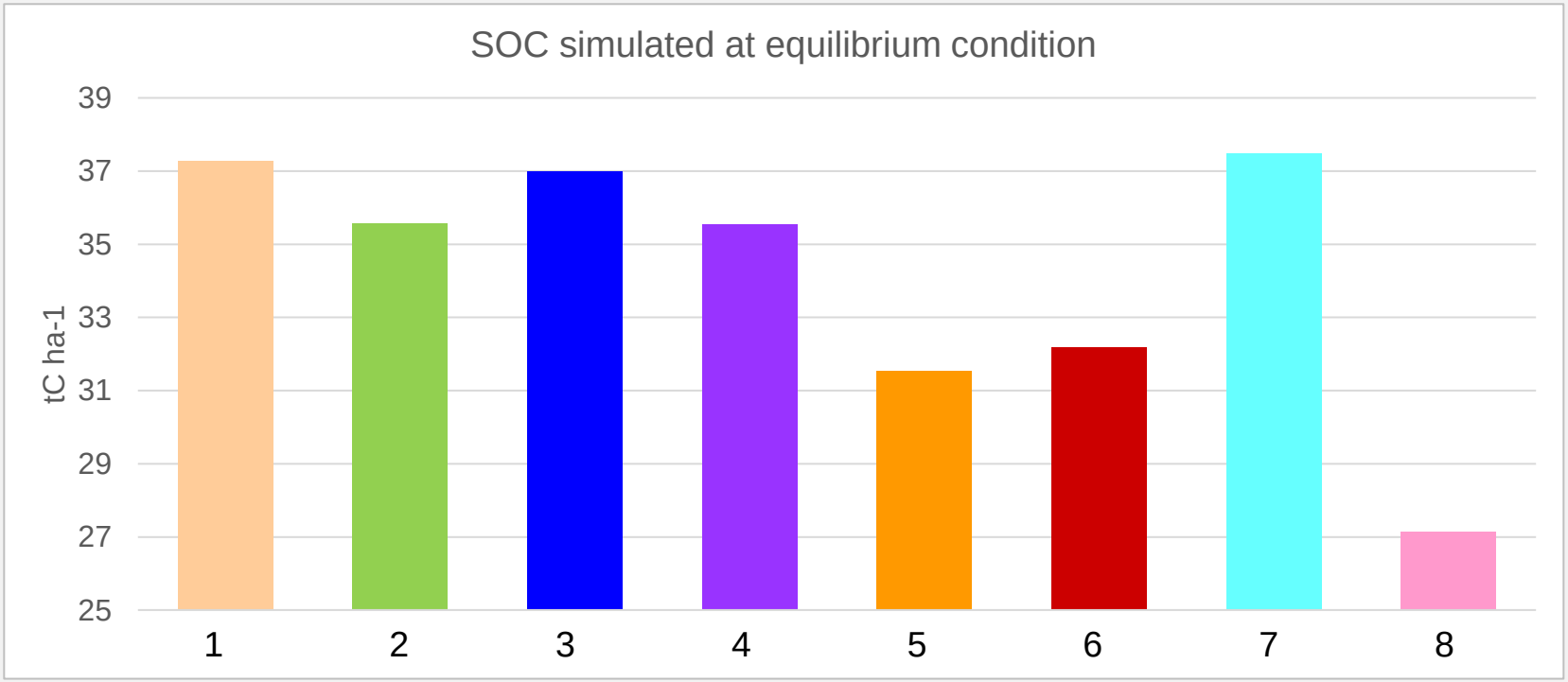
Rotazioni	2016-2017	2017-2018	2018-2019	2019-2020
1	CORN	TOMATO	WHEAT (TILL)	TOMATO
2	CORN	SOY	WHEAT (TILL)	CORN
3	CORN	TOMATO	SOY	WHEAT (TILL)
4	CORN	CORN	SOY	WHEAT (TILL)
5	CORN	WHEAT (TILL)	CORN	WHEAT SODO
6	CORN	WHEAT (TILL)	CORN	WHEAT (TILL)
7	CORN	SOY	WHEAT (TILL)	SOY
8	CORN	WHEAT (TILL)	WHEAT (TILL)	WHEAT (UNTILL)

CROP ROTATION MODELS



- Output of the crop rotation model shows clear fluctuations
- Initial conditions are set equal to the corn equilibrium spin-run conditions, adapted to measured SOC at beginning of the experiment
- After 5 rotation cycles, the SOC is increasing (due to very low initial values)

CROP ROTATION MODELS



- The largest SCS, at equilibrium condition, is reached by crop rotation 7, closely followed by 1 and 3
- The lowest SCS is reached by crop rotation 8

SOC AT EQUILIBRIUM

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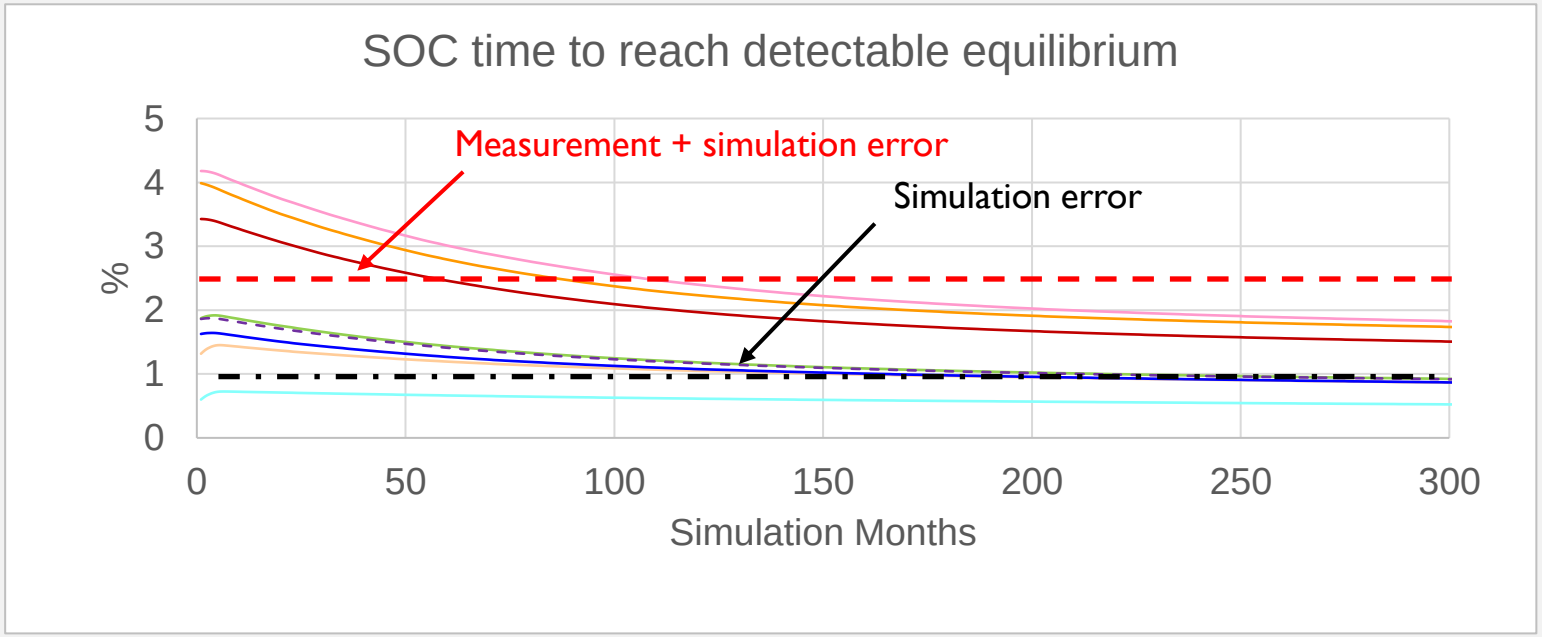
- Equilibrium (experimental) is reached when the moving average of the simulation SOC timeseries changes less than a threshold given by the observable change in carbon stock in the field (analytical error) plus the fluctuations of SOC in time in the simulation, and is given in percentage

$$\boldsymbol{Equilibrium = \frac{SOC_{t=0} - SOC_{t=N}}{SOC_{t=0}} \cdot 100 < e}$$

Where:

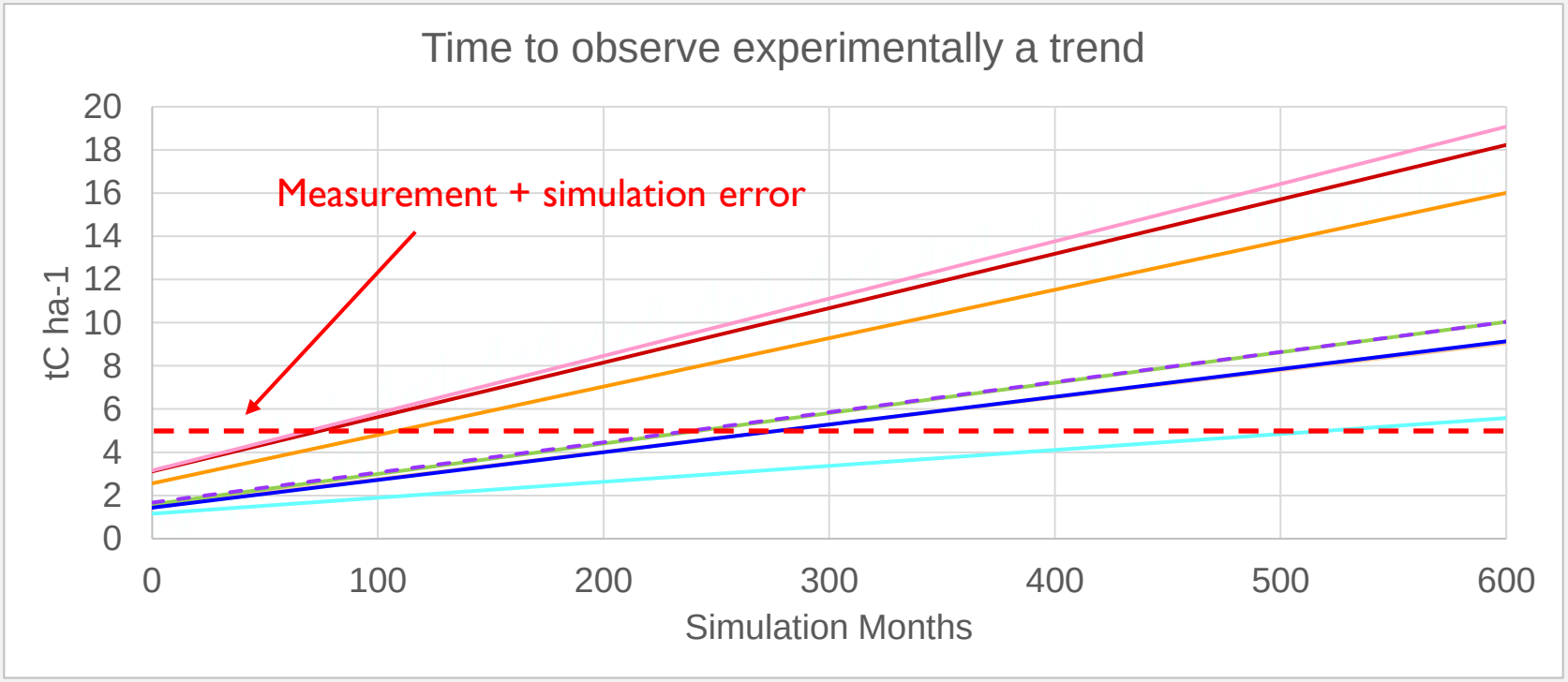
$$\boldsymbol{e = 0.01 \cdot 100 = 1\%}$$

SOC AT EQUILIBRIUM



- Time to reach an observable equilibrium, from the initial conditions of only corn yearly cultivation, goes from 50 months (<5year) to 100 months (<9 years)
- Some crop rotations do not change SOC enough to have an observable effect
- Simulation equilibrium takes much longer to reach (200-300 months)

SOC AT EQUILIBRIUM



- Another interesting question is how long does it take to observe experimentally a trend in the SOC measurements, depending on yearly SOC fluctuations and on the analytical error
- The shorter time is around 70 months (5.8 years) and the longer is around 500 months (41 years). Generally, to observe a statistically relevant SOC trend should require around 16 years.

5.3.1

POOL COMPARISON FOR CROP ROTATIONS

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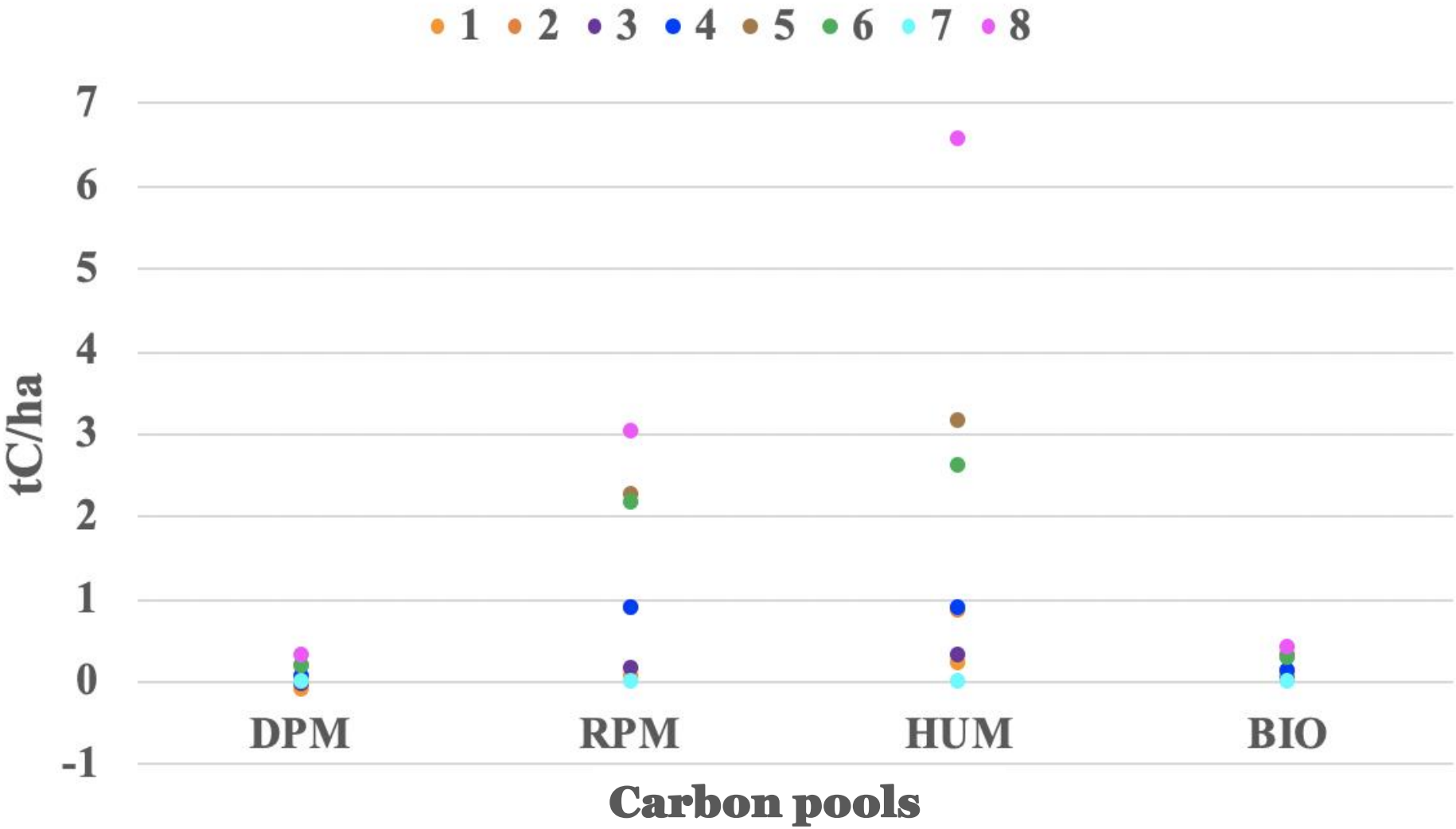

5.3.2

SOC EQUILIBRIUM COMPOSITION

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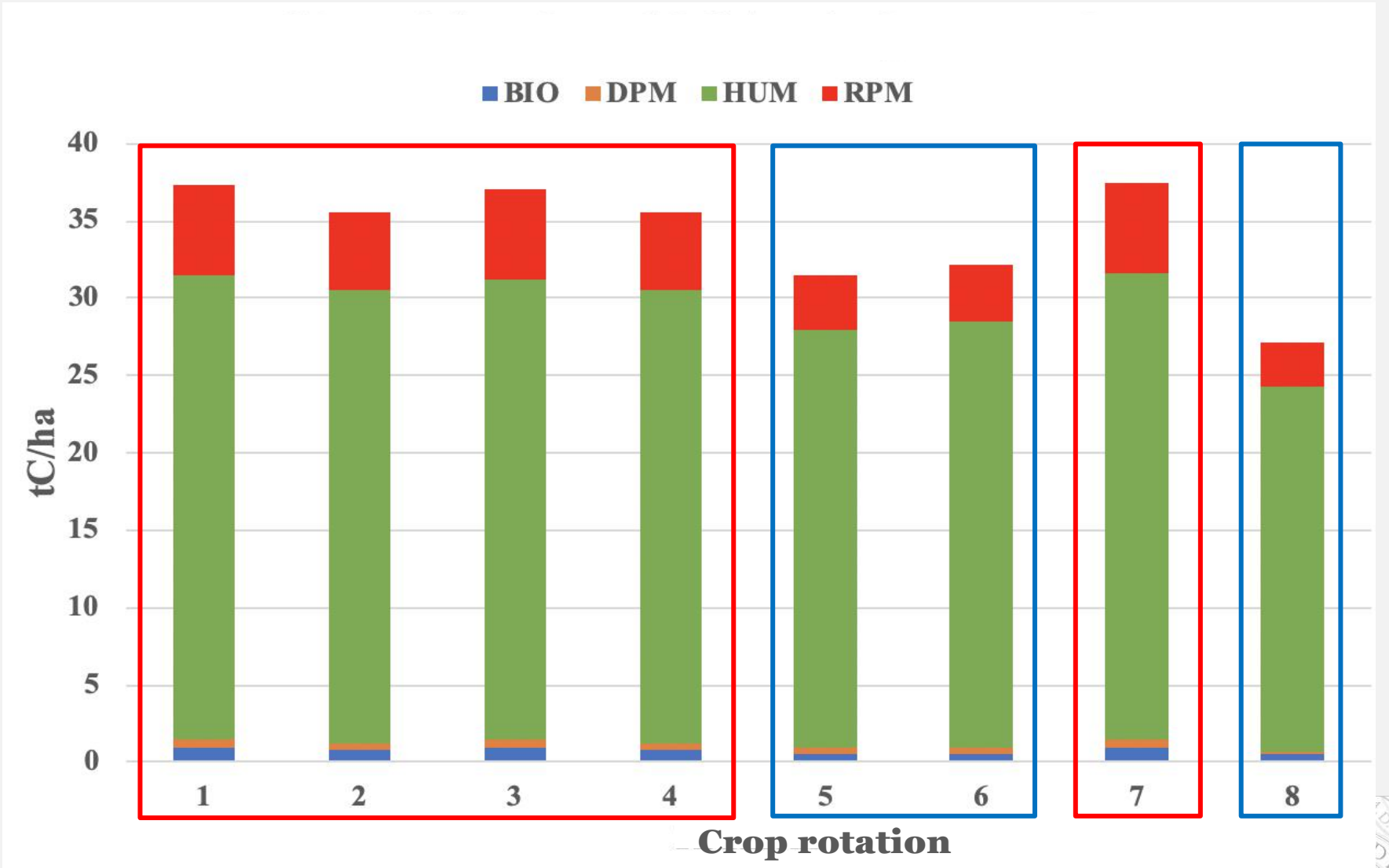

CONCLUSIONS

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- SOC sequastration influenced by vegetation residues input from each crop

(tomato > soy > corn > wheat)

- However, it is even **most important *when*** the residues enter the soil

(Autumn/Winter > Summer)

- SOC increase is extremely slow, and it slows in time, reaching (observable) equilibrium only after 50+ years.
- To detect a SOC increase trend in the field, 8-12 years of experiment are needed.
- The best crop rotation to increase SOC content was: Corn, Soy, tilled wheat and Soy
- Limits of the study:
  - Experiment too short in time (will return on the field in next years)
  - Large experimental error

Thank you for your attention!

This work was part of Martina Maines MSc thesis

For questions:

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