Leibniz-Zentrum für Agrarlandschaftsforschung (ZALF) e.V.

ETH zürich

# An integrated crop and mechanistic soil organic matter model for arable cropping systems

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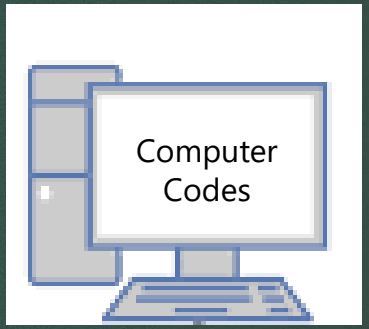



**Inès Astrid Tougma** (inesastrid.tougma@zalf.de) ,
Dr Marijn Van de Broek, Prof. Dr. Heidi Webber,
Prof. Dr. Johan Six

# Presentation plan

- Context
- Objectives
- Model description
- Model calibration/ validation
- Model applications
- Conclusion

# Challenges of optimal SOM management in agroecosystems

**Soil Organic Matter (SOM)** processes are critical for soil fertility, structure and climate changes mitigation;

These processes **vary a lot** with soil properties, weather conditions, and management practices (Neve et al., 2004, Follett et al., 2012);

**Weather variability** and **extremes** have large effect on N, crop growth and N-uptake and SOC processes which together makes managing challenging (high uncertainty).

# Limitations of current agroecosytem models

Inadequate representation of multiple stressors effect
(Webber et al., 2022)

Limited consideration of management
(Basso et al., 2006)

Limited consideration of pest and disease damages
(Whish et al., 2015)

Outdated representation of C and N cycles
(Campbell & Paustian, 2015)

# Recent SOM modelling

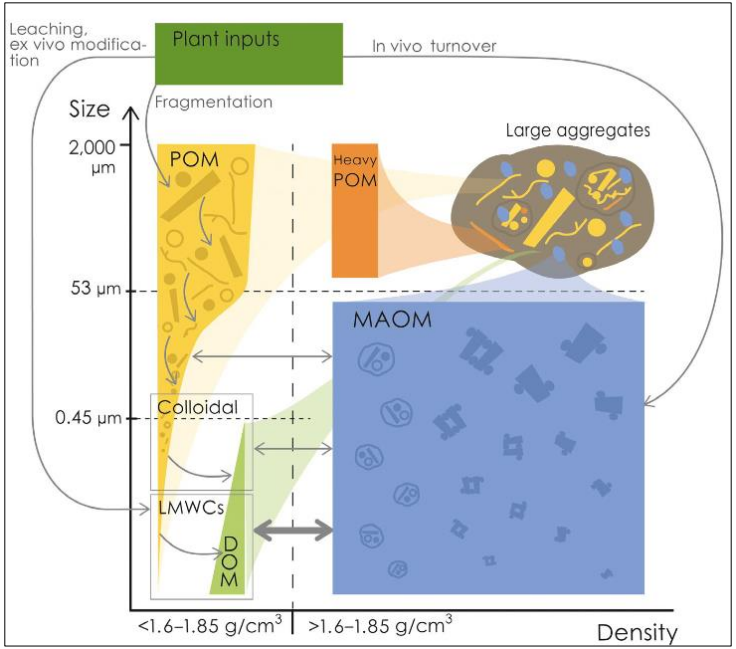
Simulate measurable SOM pools with contrasting physical and chemical properties;

**POM** and **MAOM** can be separated with density or size fractionation (Six et al., 1998, 2000, 2002);

Possible to validate against C and N of **each pool**

Inclusion of **14C dynamics** to reduce equifinality during model calibration (Van de Broek et al., in prep, Braakhekke et al., 2014)

Opportunity? Such a model can be applied in an agricultural context and may improve simulations




Conceptual representation of SOM components physically defined based on size and density (Lavallee et al., 2020)

# Objectives

Model development & integration

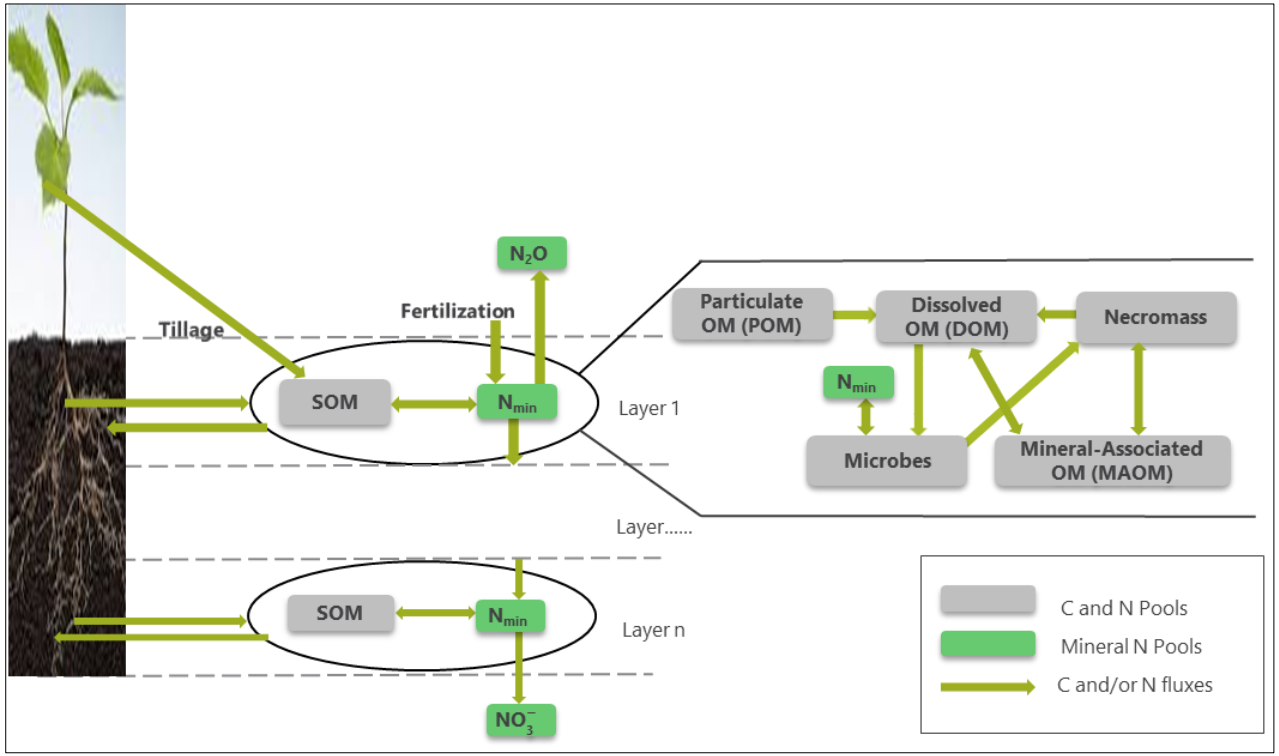
Develop a state-of-the-art SOC and N model

Integrate the state of the art SOM model developed to crop growth improve the simulation of crops yield, carbon sequestration, nitrate leaching and nitrous oxides emissions for different soil characteristics under uncertain weather drivers

Model applications

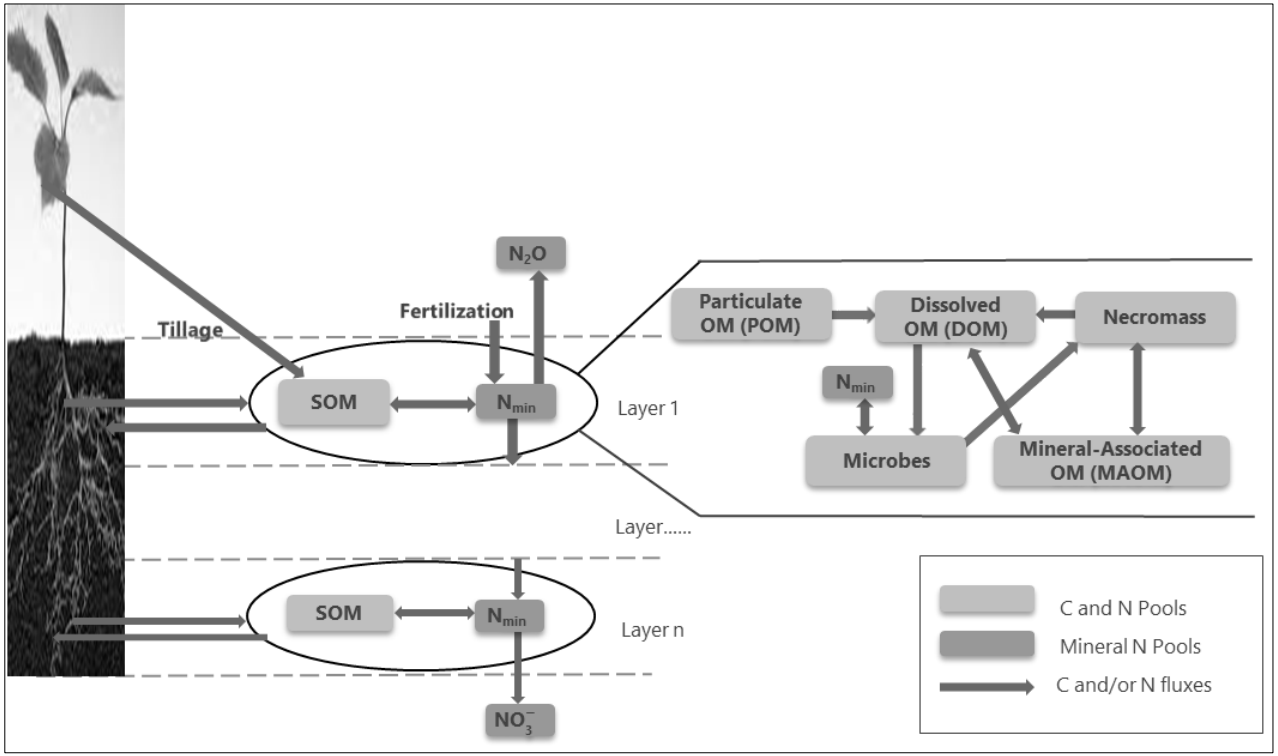
Improve agroecosystems management for different soil characteristics under uncertain weather drivers

# SOM model description




Schematics of the conceptual representation of SOM model

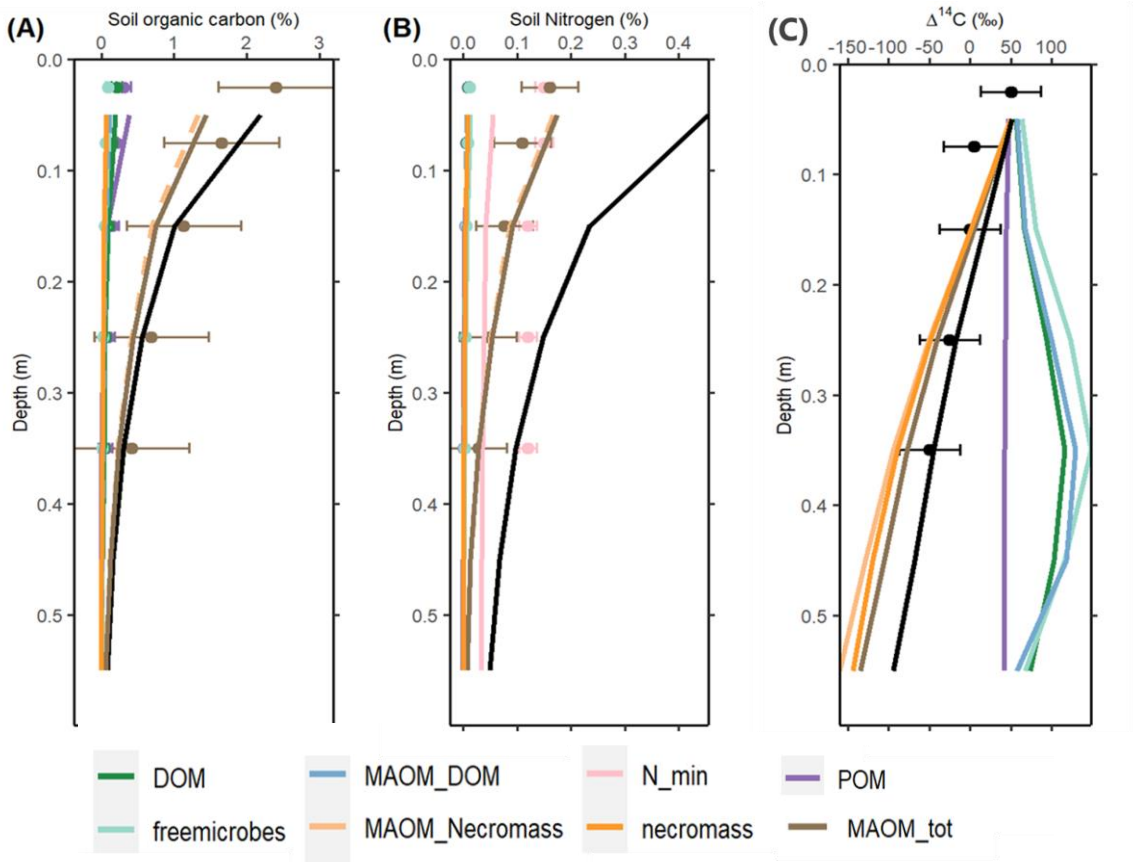
# SOM model description




Schematics of the conceptual representation of SOM model

- ✓ Daily time steps simulations
- ✓ Depth explicit model with decomposition and adsorption rates varying per layer
- ✓ Temperature and moisture effect on decomposition simulated
- ✓ Dissolved organic matter and mineral N leaching simulated
- ✓ Reverse Michaelis-Menten equations

# SOM model description




Schematics of the conceptual representation of SOM model

# Coupled crop and SOM model: SIMPLACE crop model solution

**SOM dynamics:**
State-of-the art SOM model developed

**Lintul 5**

**Biomass accumulation:**
RUE driven, modified by water, nitrogen & temperature

**Phenology:**
temperature and photoperiod driven

**Water demand: FAO-56**
ETo and partitioning based on LAI

**Water & nitrogen dynamics: SLIM**
Nitrate leaching, crop available water and crop water uptake

**Root growth: Slim Roots**
Seminal and lateral root growth

# Model calibration/ validation

**The patchCROP field experiment  landscape, Brandenburg, Germany**

- Date of crops emergence, flowering and maturity ;
- Crops LAI;
- Total 12C and N in POM and MAOM fractions of the soil ;
- Total C and N in soil microbial biomass ;
- Soil texture, water content and temperature ;
- Mineral N in soil and plant biomass
- 14C content of soil

# Model application 1: Risk-based scenario framework for spatial planning of crop rotations

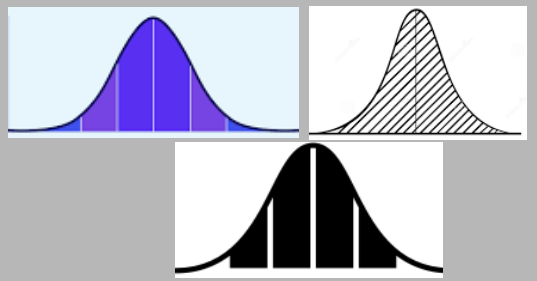
**Sample weather variability**

**Plausible rotations**
(Reckling et al., 2016 and Faye et al, 2022)

**Soil heterogeneities**
(texture, topography …)

simplace
modelling framework

**Model outputs**
Probabilistic trade-off between average yield, nitrate leaching and $N_2O$ emissions for a given rotation, weather conditions and soil proprieties



# Model application 2: Improving within-season N application

Run the model with real historical data

↓

N in the crop and N lost

Run the model with climate average data

↓

Estimate of the best application **time and rates** for remaining N fertilizer

Time

Before the current date

Current day

Rest of the season

# Conclusion: take home messages

The project aim is to assess if the use of a mechanistic measurable pool based SOM model can improve the simulation of organic matter dynamics, crop yield and N losses in agricultural systems

The results are relevant for the scientific community  to support agricultural management practices.

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# Thank you for your attention.

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