Faculty of Life Sciences

Simulating soil N_2O and CO_2 emissions from arable organic and conventional systems using MoBiLE-DNDC

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Presentation outline

- Introduction
- Field measurements
- Compare field measurements and model simulations
- Summary of findings
- Future model development
- Acknowledgments

Introduction

- Soils sources and sinks to N_2O and CO_2.
- High temporal and spatial varibaility of GHG emission.
- Field measurements and process-based models useful for estimating soil GHG emissions.
- Models integrate multiple factors.
- Models limited; need further development and testing.
- Field measurements expensive but critical for further development and testing of models.

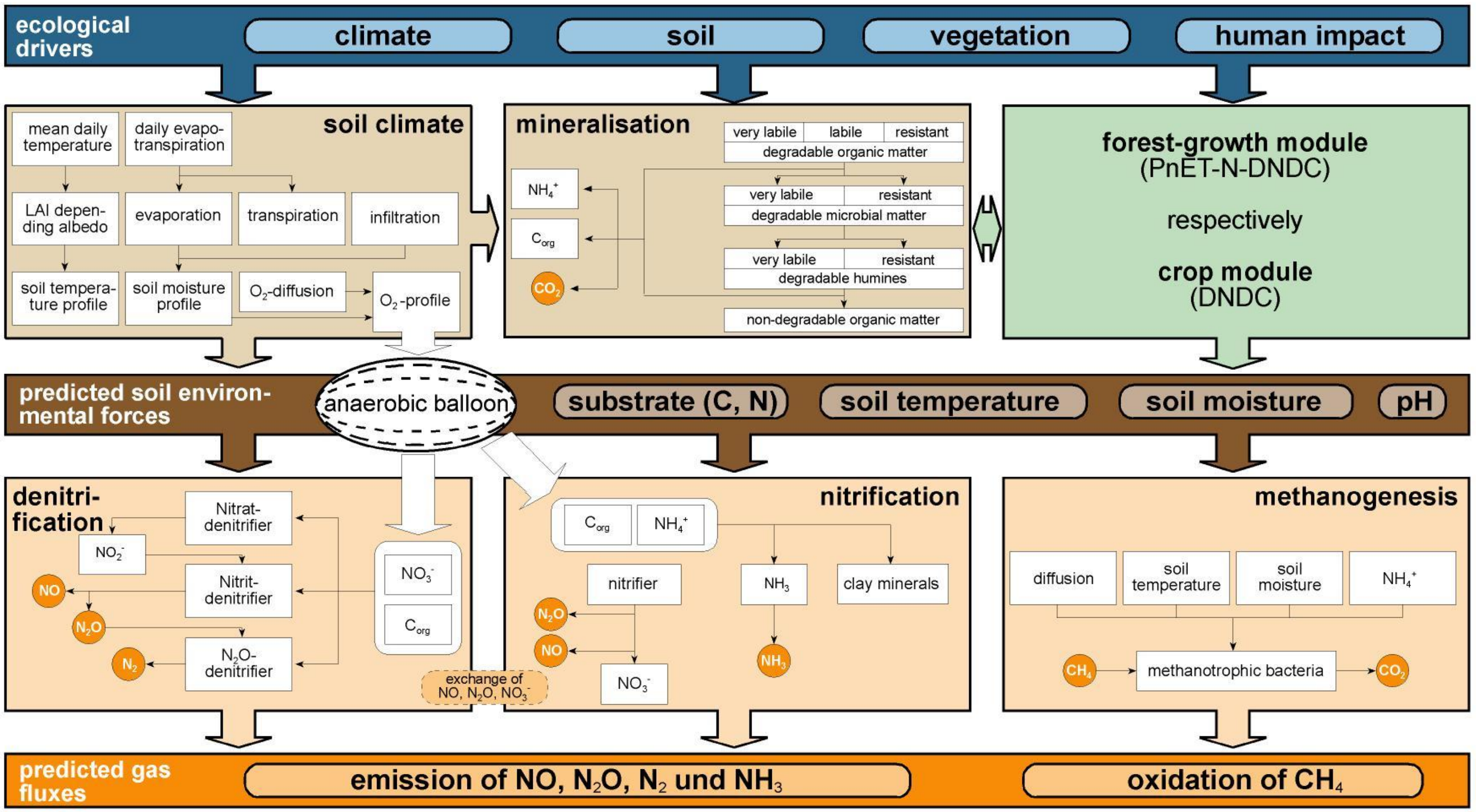
MoBiLE-DNDC model

- Modular Biosphere Simulation Environment (MoBiLE) framework, developed in Germany, enables flexible integration of different sub-models within the same software.
- Sub-models from various DNDC models run within the MoBiLE.
- Sub-models used:

  - soil physics, water cycling and biochemistry (PNET-N-DNDC)

  - crop growth and management (agriculture-DNDC 9.2)
- One-dimensional daily time steps process-oriented biogeochemical model (MoBiLE-DNDC).
- Uses sub-daily routines for C and N turnover in soil-plant system and gas diffusion

MoBiLE-DNDC model stucture



Calibration of MoBiLE-DNDC

Crop dry matter partitioning differs with cultivars and environmental conditions.

Dry matter partitioned to grain increased from 40% to 42%.

Dry matter partitioned to roots reduced from 17% to 15%.

These conservative adjusts particularly improved simulation of root dry matter accumulation.

Site description

- Long-term experiment at Foulum in western-Denmark, started in 1997
- Factorial design included three factors, two replicate blocks
- Soils: sandy loam (Typic Hapludult)
- 23 g SOC kg^{-1}
- 1.8 g total N kg^{-1}
- pH 6.5 ($CaCl_2$)
- Bulk density, 1.35 g cm^{-3}
- Mean annual rainfall, 704 mm
- Air temperature, 7.3^{o}C

Field measurements

- Soil N_2O emissions (over 12 months), static chambers.

- CO_2 emissions (sowing-harvest)

from collars inserted to 8 and 38 cm depths: differentiated roots from soil respiration

- Soil moisture (TDR)

- Soil Mineral-N

- Shoot dry matter accumulation

- Roots dry matter at anthesis

Conv C4-CC

spring barley → faba bean → potato → winter wheat

Org O4-CC

spring barley → faba bean → potato → winter wheat

Org O4+CC

spring barley → faba bean[CC] → potato → winter wheat[CC]

Org O2+CC

spring barley[CC] → grass/clover → potato → winter wheat[CC]

Effects	Systems
Conventional (min. fert.) vs. Organic (pig slurry)	C4-CC vs. O4-CC
Catch crops (grass-clover mixtures)	O4+CC vs. O4-CC
Rotation (leys: grass-clover mixtures)	O2+CC vs. O4+CC

Cropping system	Total N (kg N ha^{-1})
C4-CC	165
O4-CC	108
O4+CC	108
O2+CC	102

Hypothesis

In its current stage of development, MoBiLE-DNDC is capable of adequately predicting both soil N_2O and CO_2 emissions from conventional and organic cropping systems

Objectives

To validate the MoBiLE-DNDC model for simulating both soil N_2O and CO_2 emissions from three organic and one conventional cropping system.

To assess simulations of other variables that influence soil N_2O and CO_2 emissions, namely:

- soil water
- soil ammonium-N
- soil nitrate-N
- winter wheat shoot dry matter accumulation
- winter wheat root dry matter accumulation

Model Initialization

- The model was intialised using the following data:

  Soil property (e.g. bulk density, pH, hydraulic parameters, clay, C and N content).

  Management data (e.g. sowing, harvesting, tillage, fertilization, irrigation).

  Climate (e.g. rainfall, air temperature)

- Model run over two years for plots under potato and winter wheat.
- Simulations used here are from winter wheat plots (2007-2008).

Model evaluation

Coefficient of variation (r^2): model precision

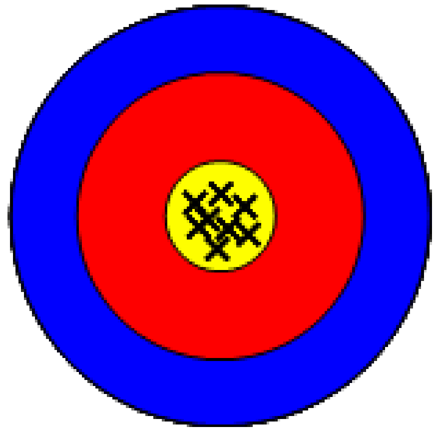
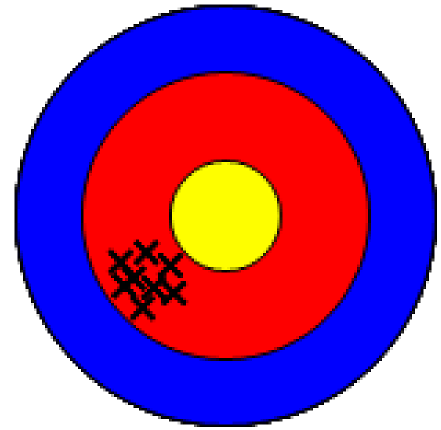
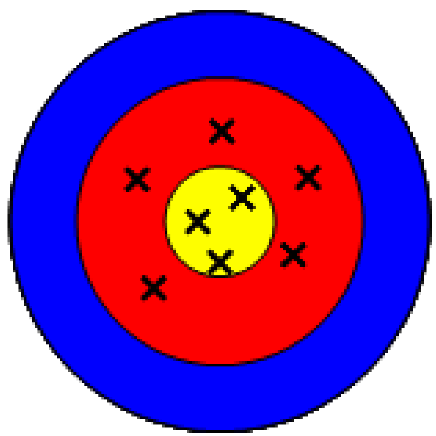
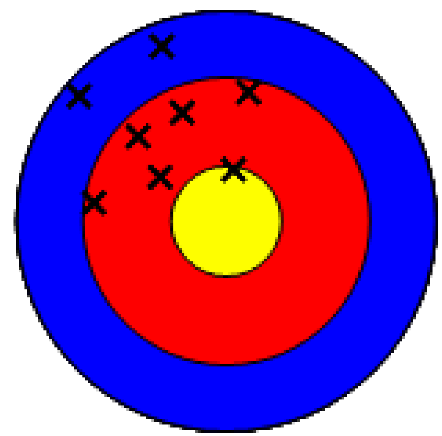
$$r^2 = \frac{\left(\sum (x_{mod} - \bar{x}_{mod}) * (x_{meas} - \bar{x}_{meas})\right)^2}{\sum (x_{mod} - \bar{x}_{mod})^2 * \sum (x_{meas} - \bar{x}_{meas})^2} \qquad 0 \le r^2 \le 1$$

Model efficiency (r^2_{eff}): model accuracy

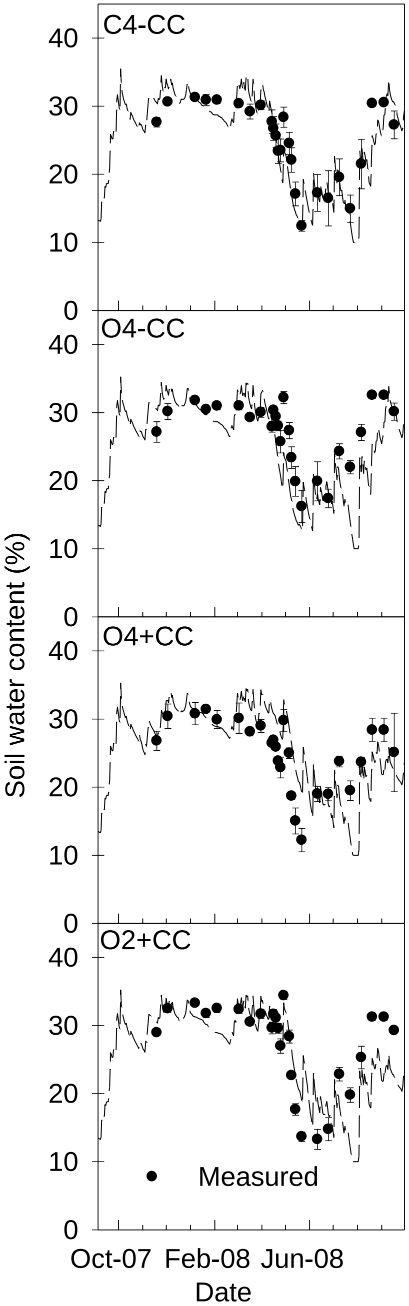
$$r^2_{eff} = 1 - \left(\frac{\sum (x_{mod} - x_{meas})^2}{\sum (xmeas - \bar{x}meas)^2} \right) \qquad -\infty \le r^2_{eff} \le 1$$

Normalized root mean square prediction error: model error

$$RMSPE_n = \frac{\sqrt{\frac{\sum (x_{mod} - x_{meas})^2}{n}}}{SD}$$

	Accurate	Inaccurate (systematic error)
Precise		
Imprecise (reproducibility error)		

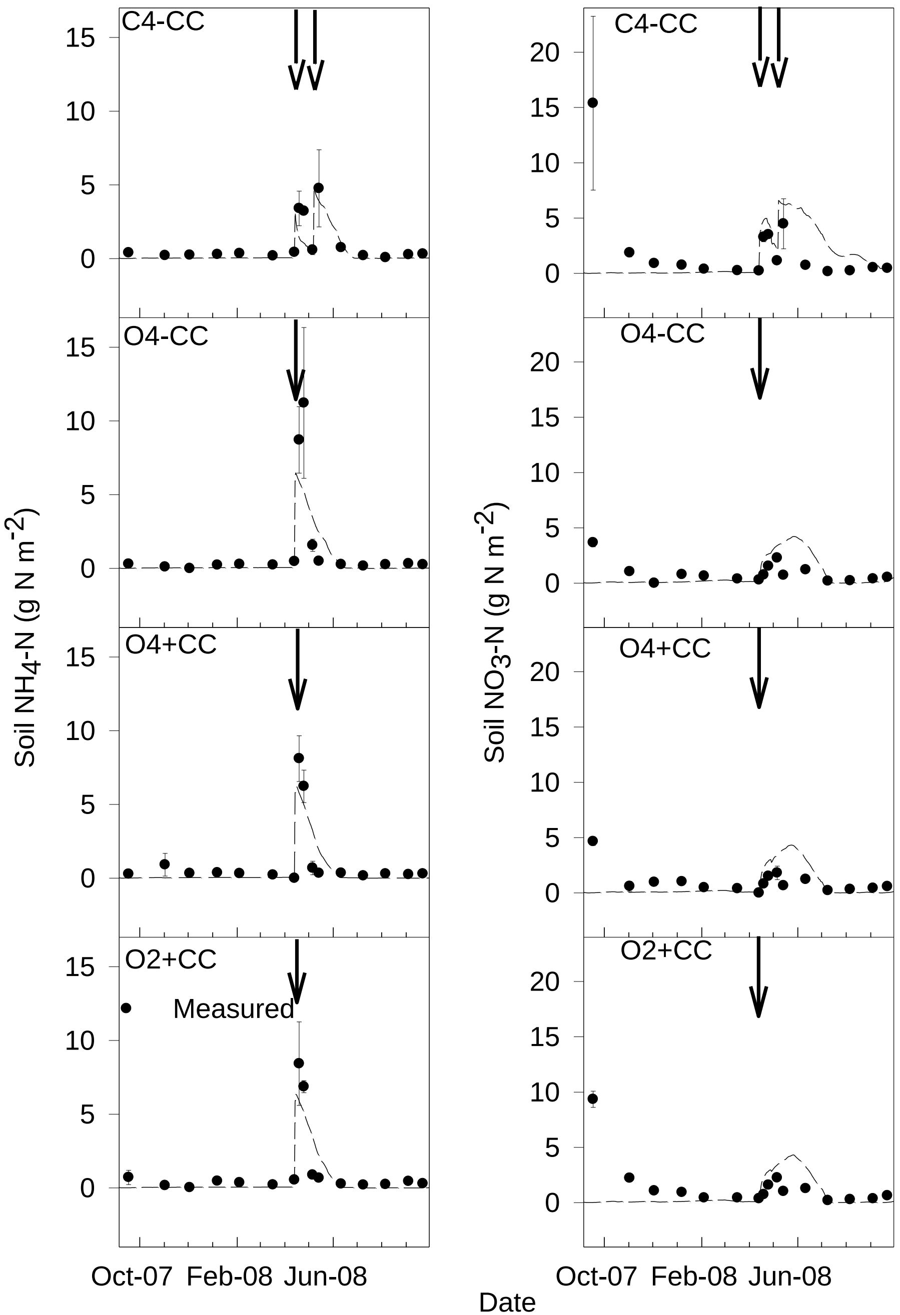
Volumetric soil water content, 0-30 cm depth



Volumetric soil water content, 0-30 cm depth

Cropping system	$RMSPE_n$	r^2	r^2_{eff}
C4-CC	0.42	0.85	0.79
O4-CC	0.86	0.68	0.11
O4+CC	0.79	0.51	0.25
O2+CC	0.57	0.64	0.61

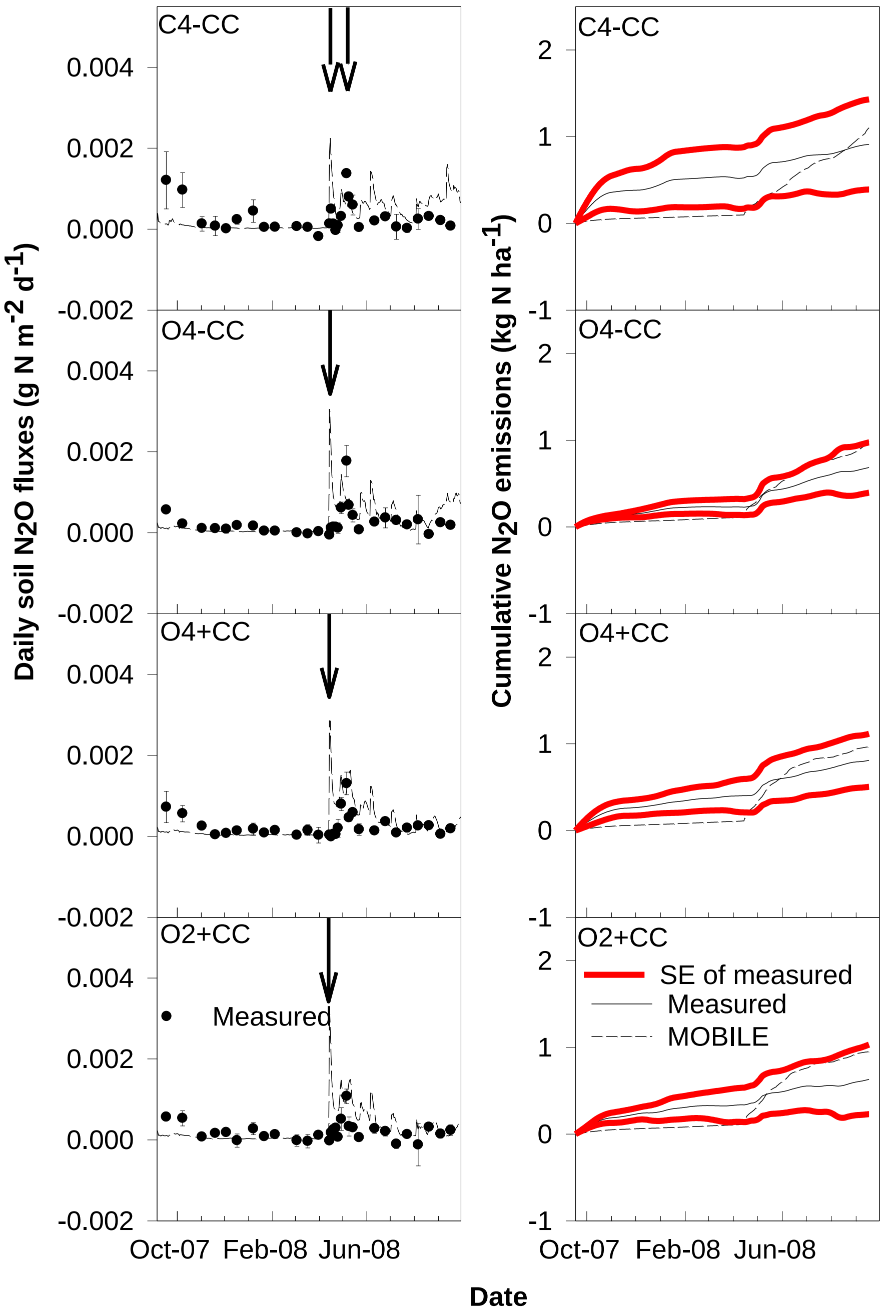
Soil mineral-N 0-30 cm depth



Soil mineral-N 0-30 cm depth

	Cropping system	$RMSPE_n$	r^2	r^2_{eff}
NH_4-N				
	C4-CC	0.56	0.82	0.67
	O4-CC	0.54	0.79	0.69
	O4+CC	0.44	0.80	0.79
	O2+CC	0.45	0.81	0.79
NO_3-N				
	C4-CC	1.10	0.002	-0.30
	O4-CC	1.56	0.07	-1.61
	O4+CC	1.54	0.02	-1.52
	O2+CC	1.20	0.001	-0.53

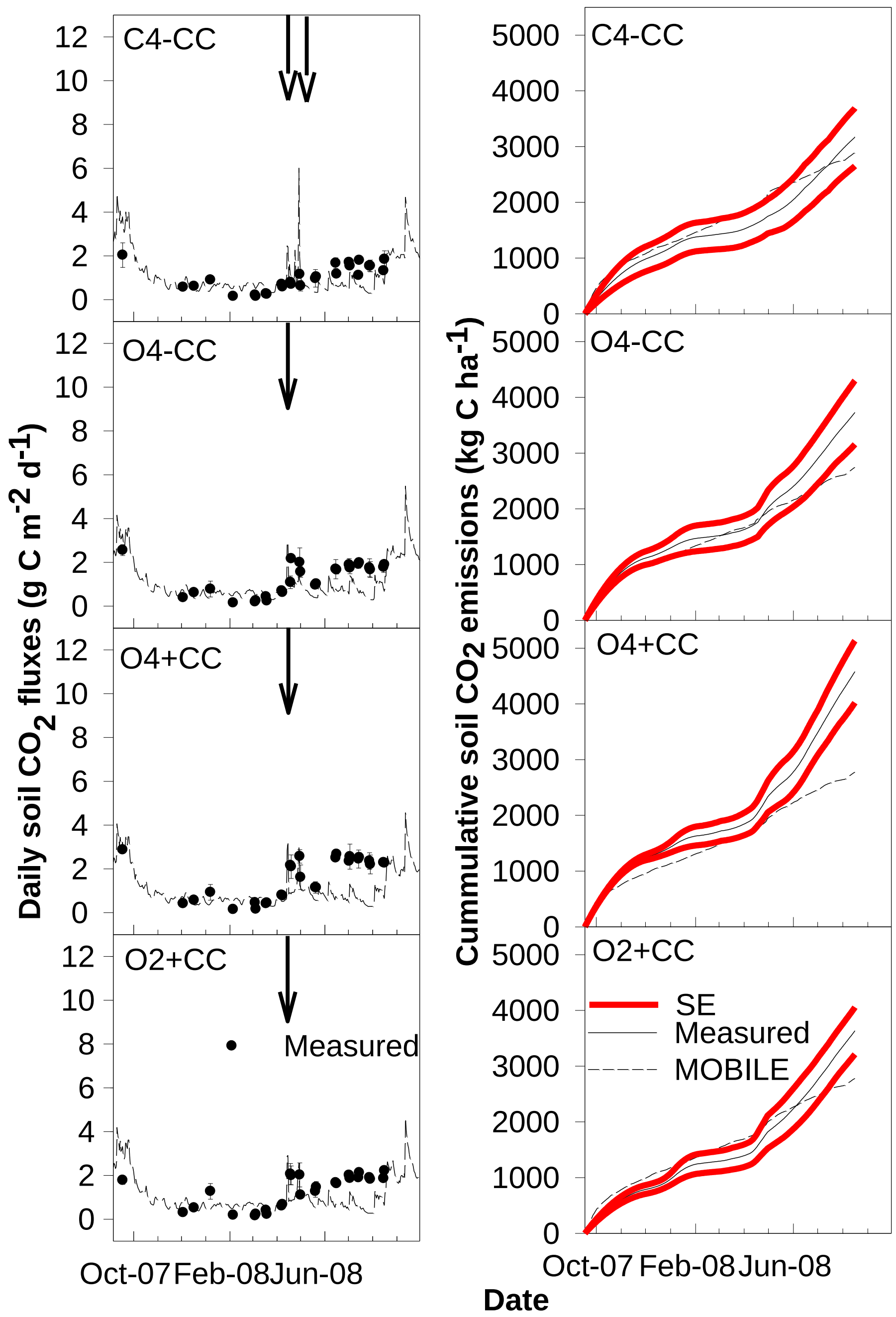
Soil N_2O-N emissions



Soil N_2O-N emissions

Cropping system	$RMSPE_n$	r^2	r^2_{eff}
C4-CC	1.64	0.01	-1.78
O4-CC	2.23	0.01	-4.13
O4+CC	2.57	0.03	-5.83
O2+CC	3.38	0.01	-10.82

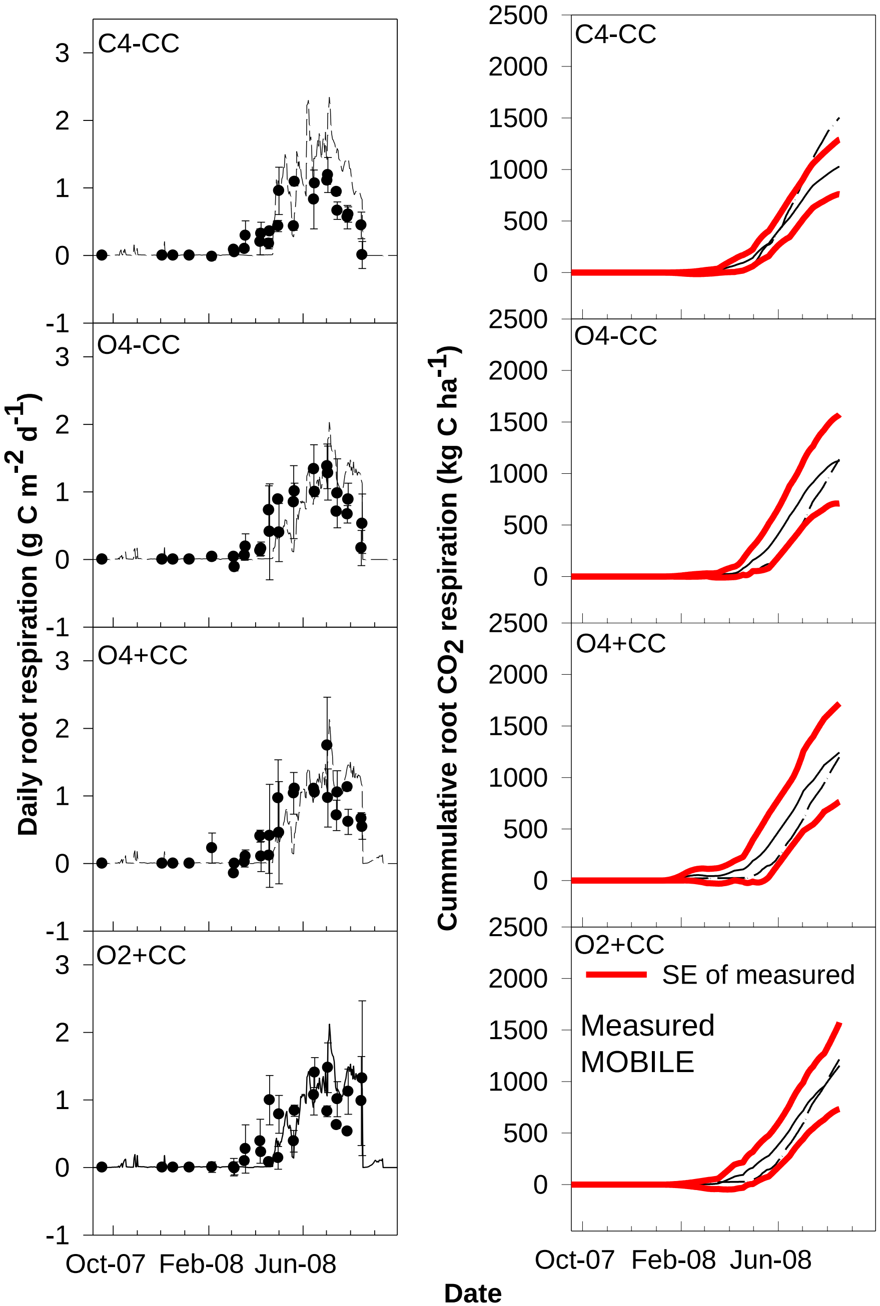
Soil heterotrophic CO_2 respiration



Soil heterotrophic CO_2 respiration

Cropping system	$RMSPE_n$	r^2	r^2_{eff}
C4-CC	1.32	0.12	-0.82
O4-CC	1.13	0.27	-0.32
O4+CC	1.29	0.18	-0.74
O2+CC	1.37	0.05	-0.95

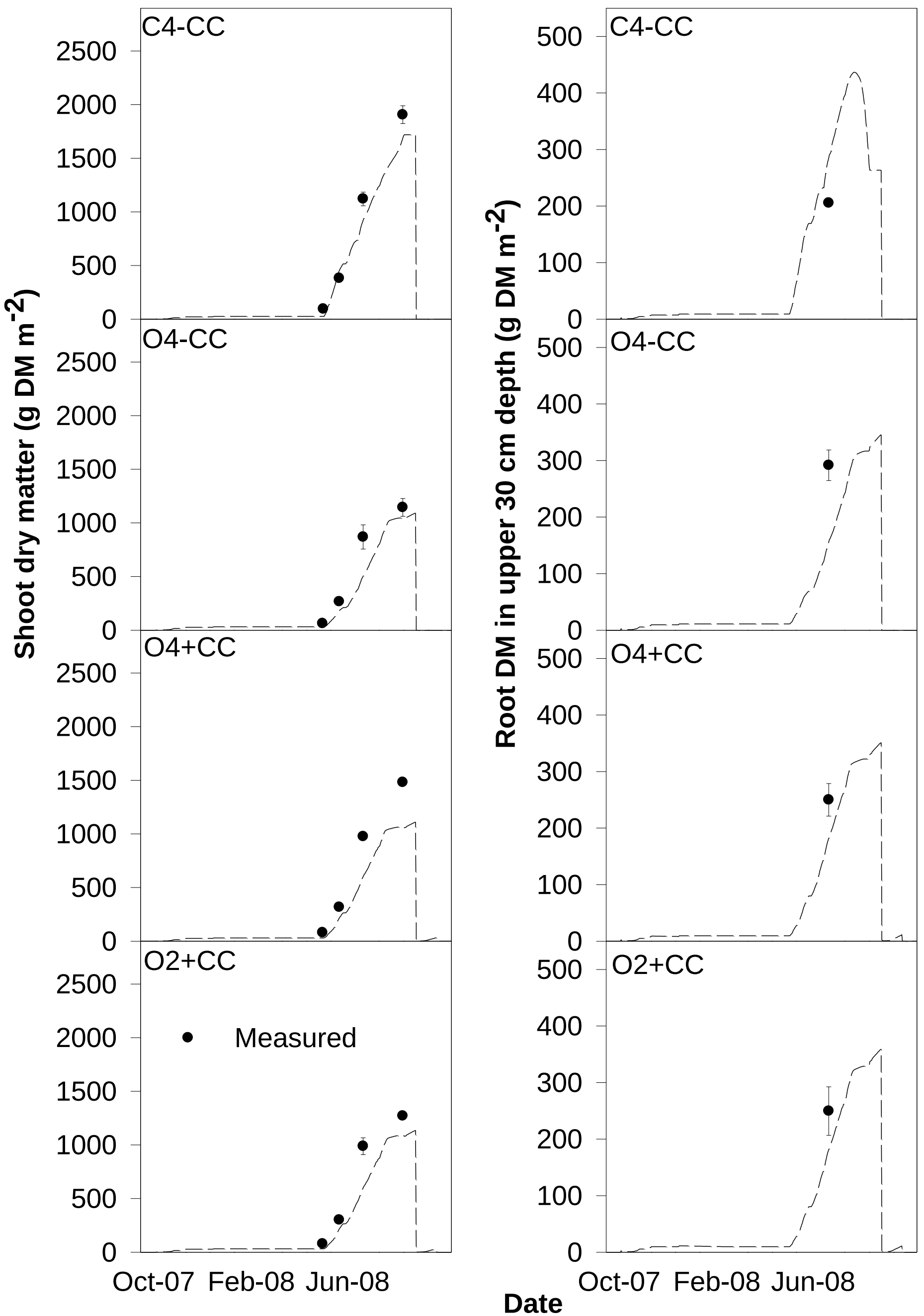
Winter wheat root CO_2 respiration



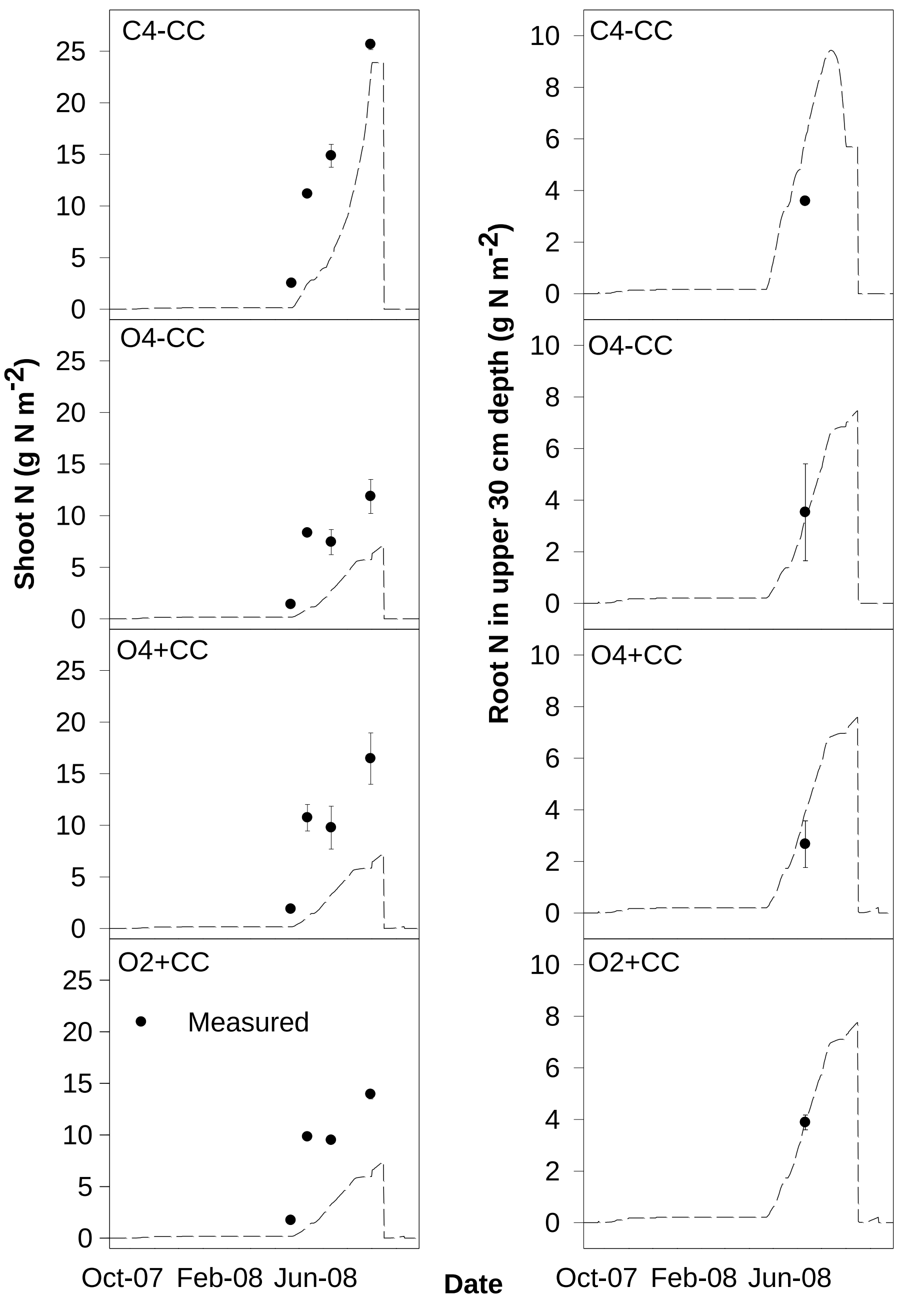
Winter wheat root CO_2 respiration

Cropping system	$RMSPE_n$	r^2	r^2_{eff}
C4-CC	1.16	0.66	-0.39
O4-CC	0.92	0.46	0.13
O4+CC	0.85	0.50	0.26
O2+CC	0.72	0.64	0.47

Winter wheat shoot and root dry matter accumulation



Winter wheat N uptake



Summary of findings

- Fairly satisfactory predictions of, annual soil N_2O emissions and root CO_2 respiration, soil water and ammonium-N.
- Model failed to predict annual soil hetrotrophic respiration within measurement uncertainity range particularly in organic systems.
- Several problems in predicting daily soil N_2O and CO_2 emissions.
- Limitations in modelling soil NO_3-N, crop shoot growth and nitrogen uptake, most severe in organic systems.
- Continuous partitioning of dry matter to roots post-anthesis too high, especially in conventional system.

Future model development

- Post-anthesis DM partitioning to roots and shoots needs improvement, especially for conventional systems; adjustment may improve simulations of root respiration.
- Shoot plant C:N may need modification to improve plant N
- Enhancing carbon availability for microbial activity could enhance heterotrophic CO_2 respiration and, consequently, improve simulations of soil NO_3-N and also N_2O and CO_2 emissions
- Inclusion of sub-models allowing for consideration of undersown catch crops, necessary.

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