An attempt to select the best management practice using the DNDC model

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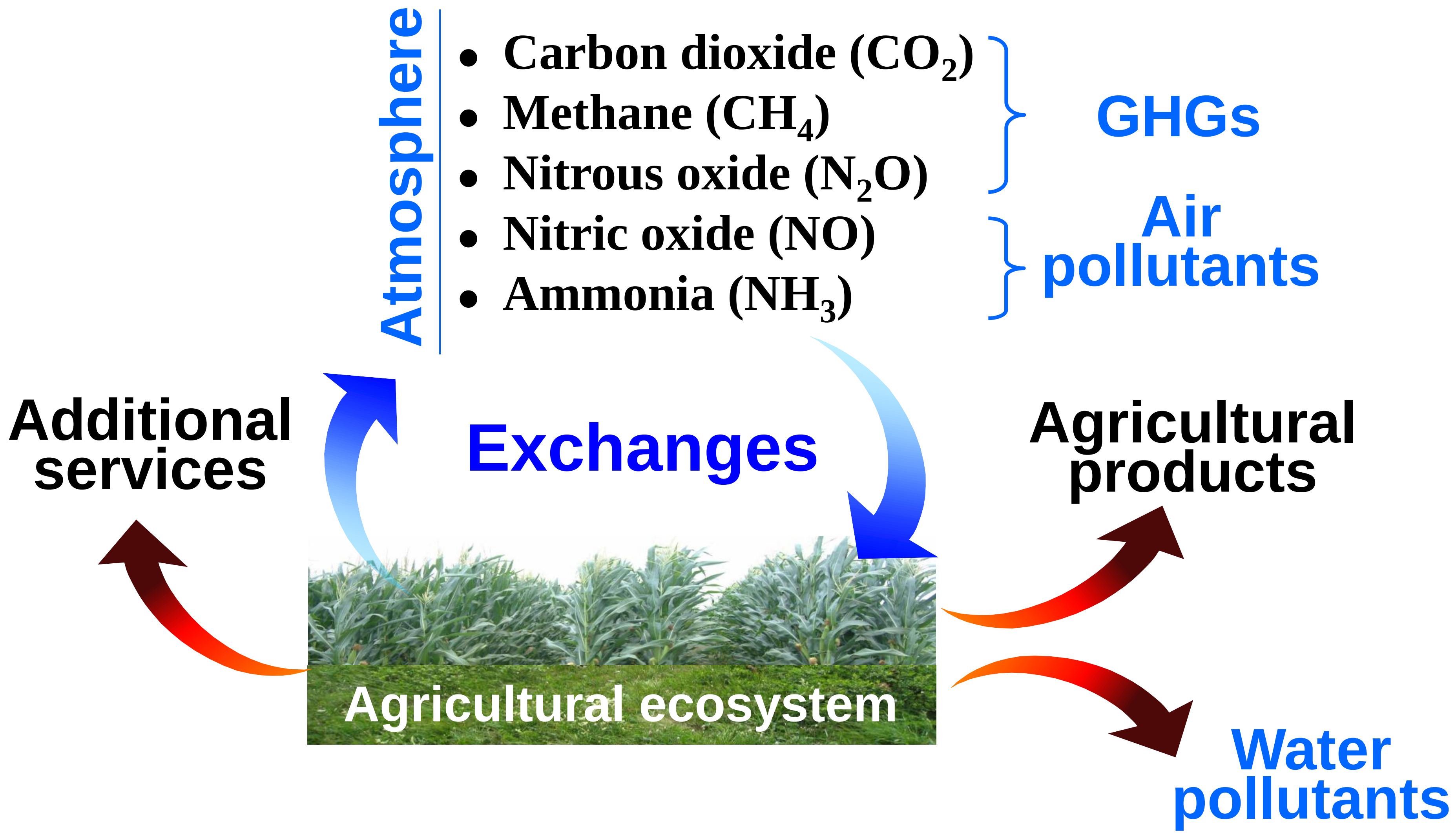
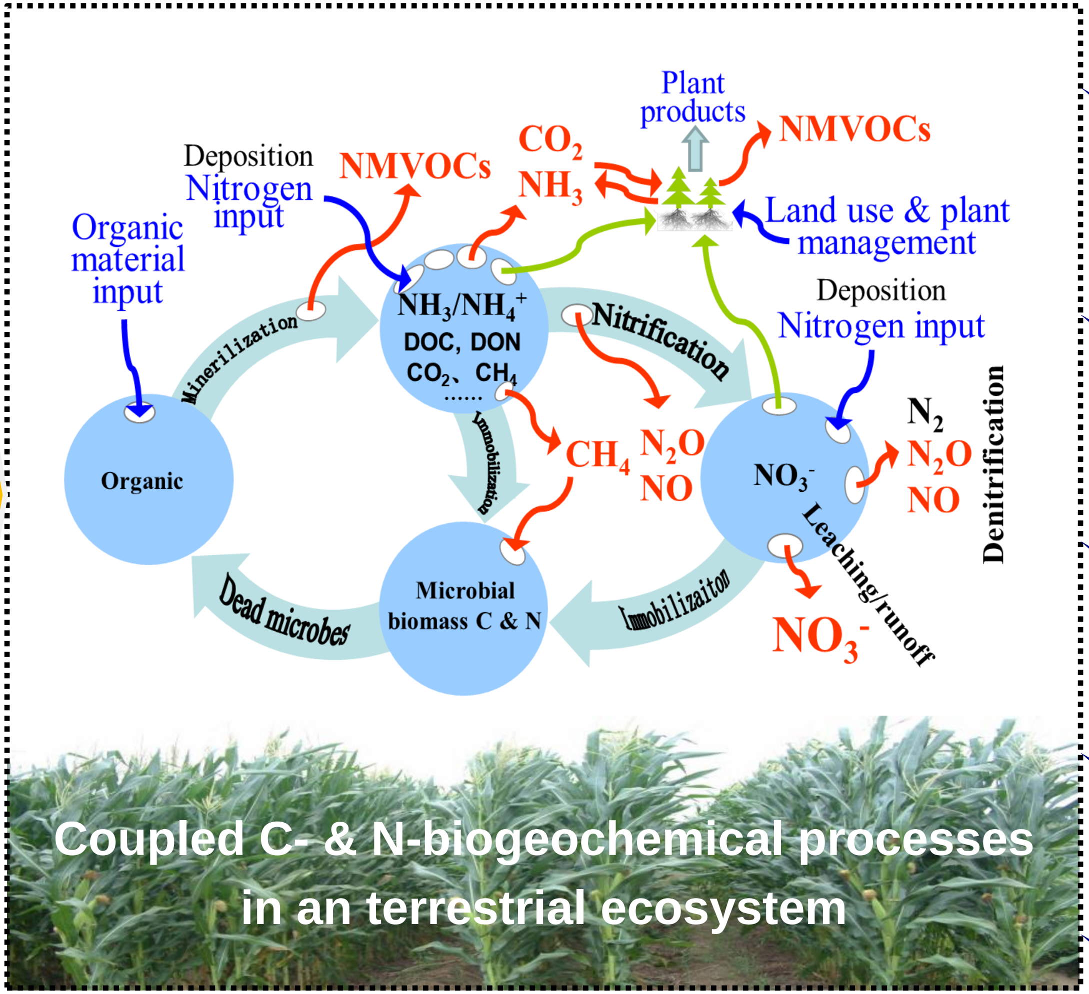
GHGs emissions linked with other services of an agricultural ecosystem



Aiming at identifying mitigation options of management practices to meet multiple goals

Management options



GHGs

NH_3 & NO

N leaching

Yields

Other services

The case study field site

Soil & climate

Type	Alluvial soil
pH (H_2O)	8.7
SOC	1.13%
TN	0.11%
Texture	Silt clay
Climate	Monsoon
Precipitation	580 mm
Mean temp.	14.4 °C

Field treatments for annual measurements

- **Residues retention:** **① full; ② zero**
- **Combined N & Irrigation practices:** **① conventional (flood; 430 kg N); ② improved (sprinkle, −30% water; −16% N)**
- **N addition rates:** **7 gradients (zero to 850)**
- **Nitrif. inhibitors:** **① control (urea); ② DCD; ③ DMPP**

Field measurements

- **Automatic chamber:**
  N_2O, CH_4, NO fluxes
- **Manual chambers:**
  N_2O, CH_4, NO fluxes
- **Eddy covariance:** **CO_2 (NEE) fluxes**
- **Micrometeor. method:** **NH_3 fluxes**
- **Other variables:**
  Meteor. factors, soil temp. & moist., yields, biomass, DOC, NH_4^+, NO_3^-

Main results from field measurements (1)

➢ Effects of crop residues retention:

Full retention of aboveground residues (8.1 ton C ha^{-1} yr^{-1});

Zero retention of aboveground residues: (0 ton C ha^{-1} yr^{-1})

Full vs. Zero retention:

- **Yields:** **+ 3%** (not significant)
- **Maize-season N_2O:** **+ 58%** ($p < 0.01$)
- **NO emission:** **+ 13%** (not significant)

EF_ds (residue-N vs. chemical-N):

- **N_2O: 0.75% vs. 0.69%;**
- **NO: 0.15% vs. 0.56%**

(Liu et al., 2011, AGEE)

Main results from field measurements (2)

➢ Effects of improved water and N practices:

Conventional practices: flooding 380-500mm; 430 kg N;

Improved practices: sprinkling −30% water; −16% N)

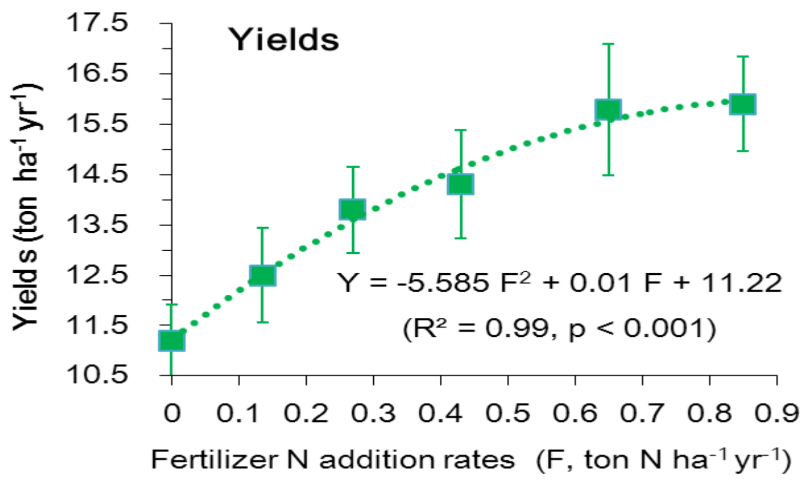
- **Improved vs. Conventional practices:**
- **Yields:** **+ 4–6%** ($p < 0.05$)
- **N_2O emission:** **− 7%** ($p < 0.05$)
- **NO emission:** **− 29%** ($p < 0.01$)

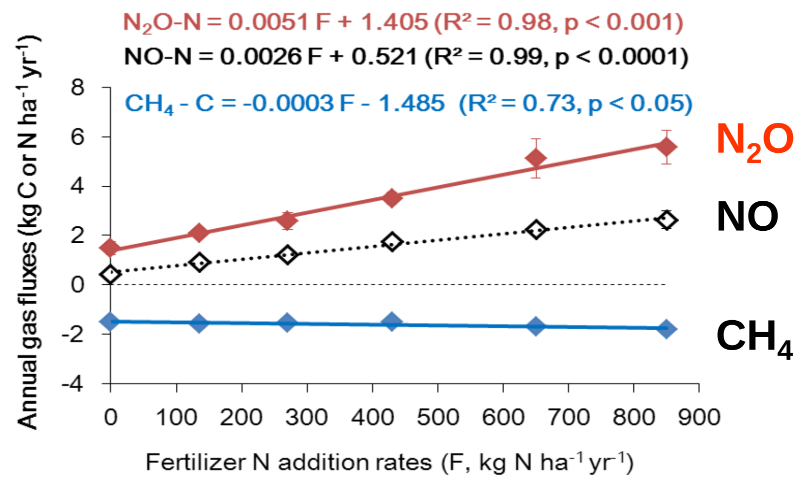
(Liu et al., 2011, AGEE)

Main results from field measurements (3)

➢ Effects of N gradients:

- yields: Increase stopped at > 600 kg N ha^{-1} yr^{-1}
- N_2O emission: Linearly increased ($p < 0.001$)
- annual CH_4 uptake: Slightly stimulated ($p < 0.05$)
- annual NO emission: Linearly increased ($p < 0.001$)
- N leaching: ?





(Liu et al., 2012, Biogeosciences)

Main results from field measurements (4)

➢ Effects of nitrification inhibitors (vs. control):

- annual yield:

  + 6-9% (not significant)

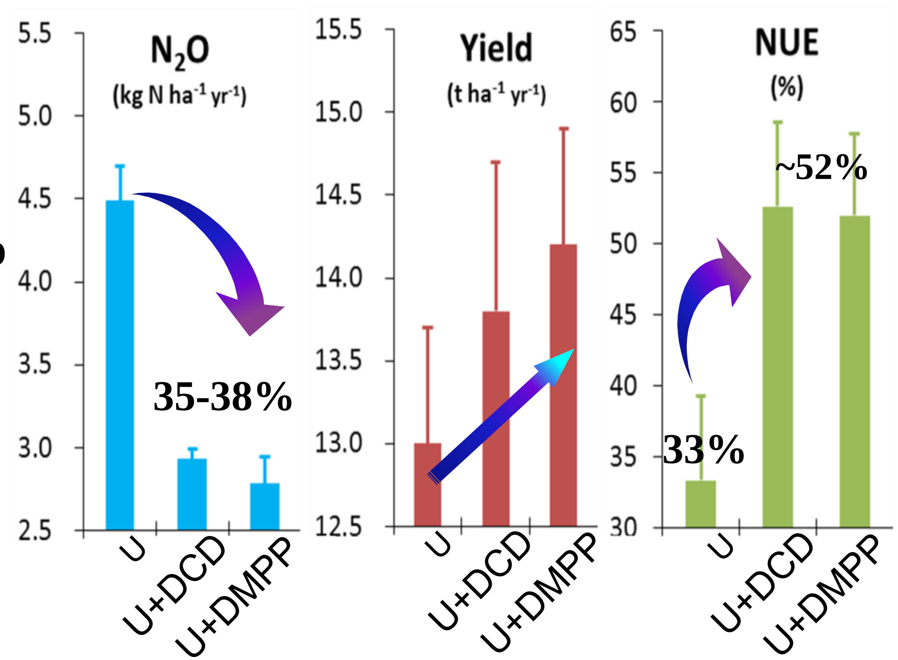
- annual NUE:

  Increased from 33% to ~52%

- annual N_2O emission:

  – 35~38% ($p < 0.05$)

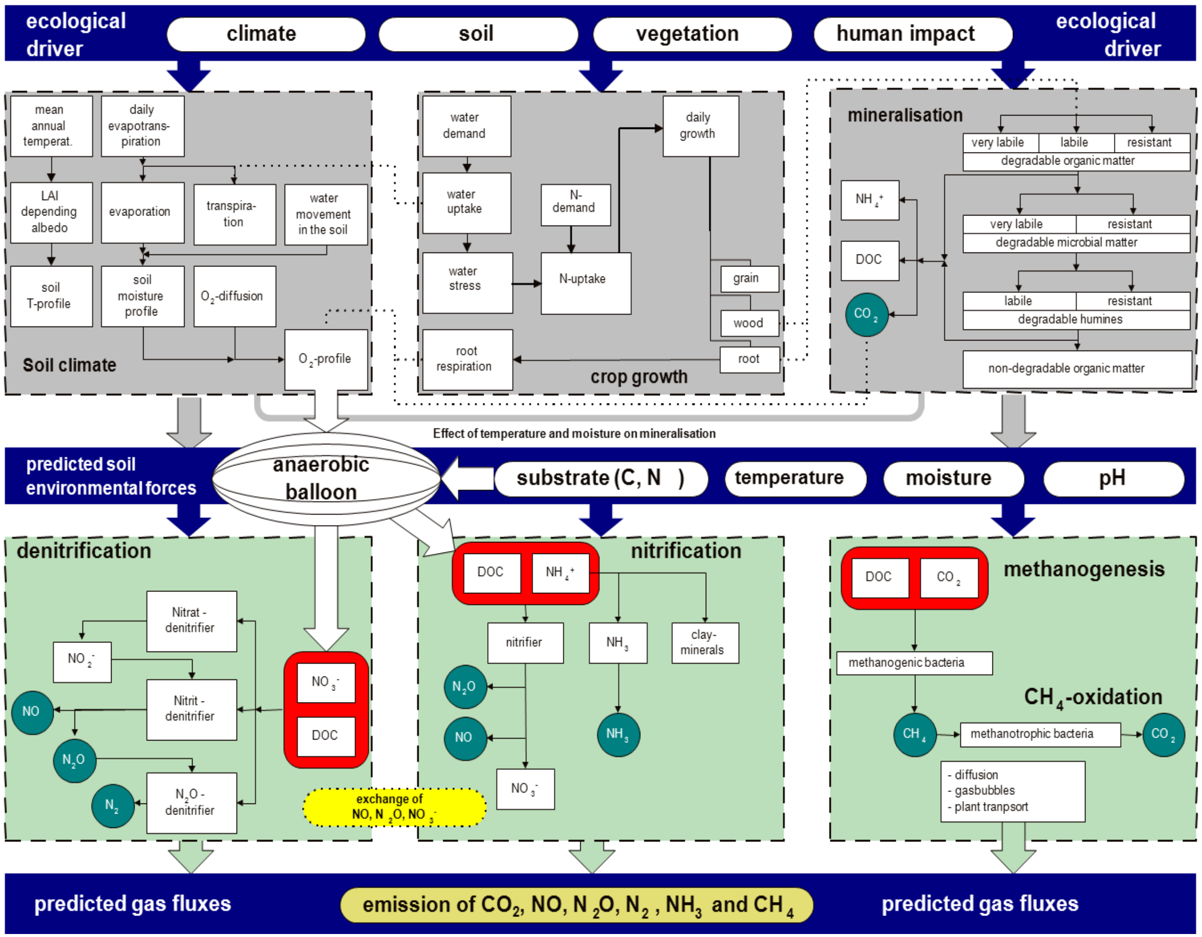
- NH_3 volatilization: ?



(Liu et al., 2013, Biogeosciences)

DNDC validation (Brief model introduction)

DNDC95 (a biogeochemical model)

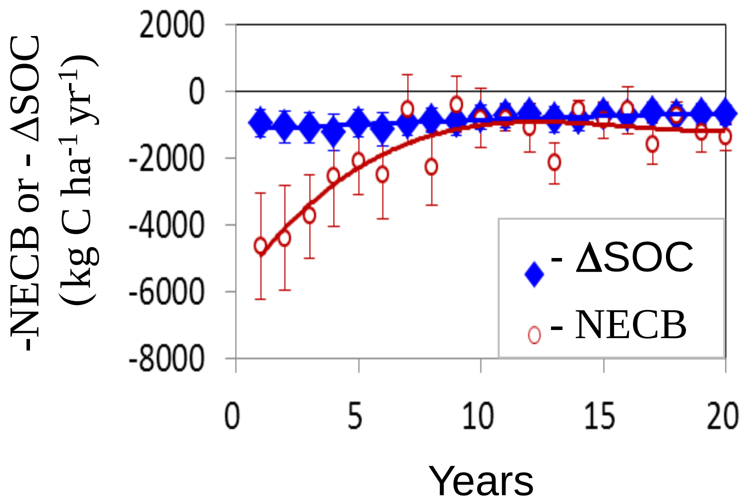


- Biomass
- Yields
- NEE fluxes
- ΔSOC
- Net CO_2 emis.
- CH_4 fluxes
- N_2O fluxes
- NO fluxes
- NH_3 fluxes
- N leaching
- ……

Modified ΔSOC definition and calculation

Original： ΔSOC = NECB = C_{end} - C_{ini}

Modified： ΔSOC = ΔHC+ ΔDOC+ΔSMC



Management change:

- Long-term change (≥ 10 yr)

ΔSOC ≈ NECB

- Short-term change (< 10 yr)：

ΔSOC ≈ 162.8 Ln (NECB) - 268.9

(Cui et al., 2013, Biogeosciences Discussions)

Modified ΔSOC definition and calculation

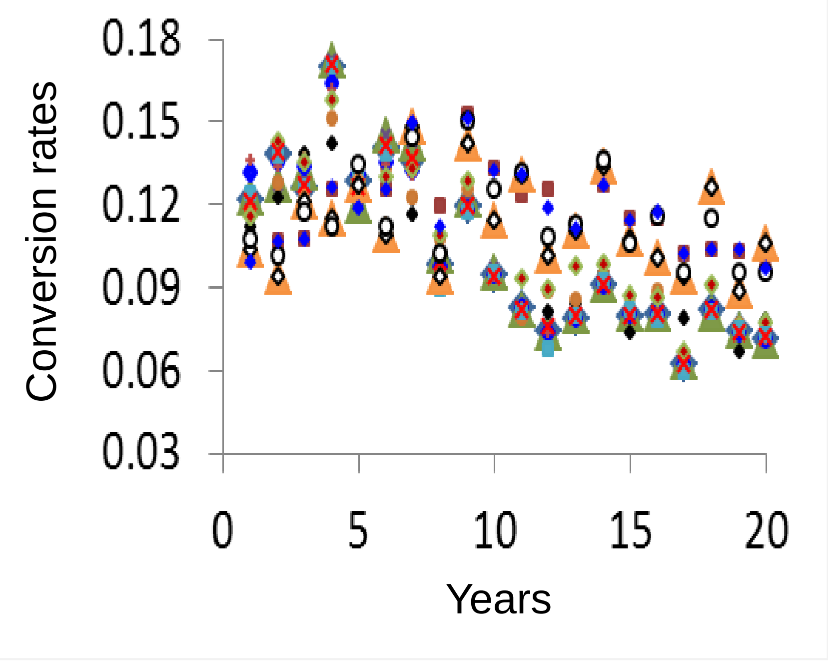
Simulated residue-to-SOC conversion rates:

11% ± 3% **(2SD, 20-yr mean)**

Measured residue –to-SOC conversion rates:

Northern China: **11% ± 2%** **(2SD)**

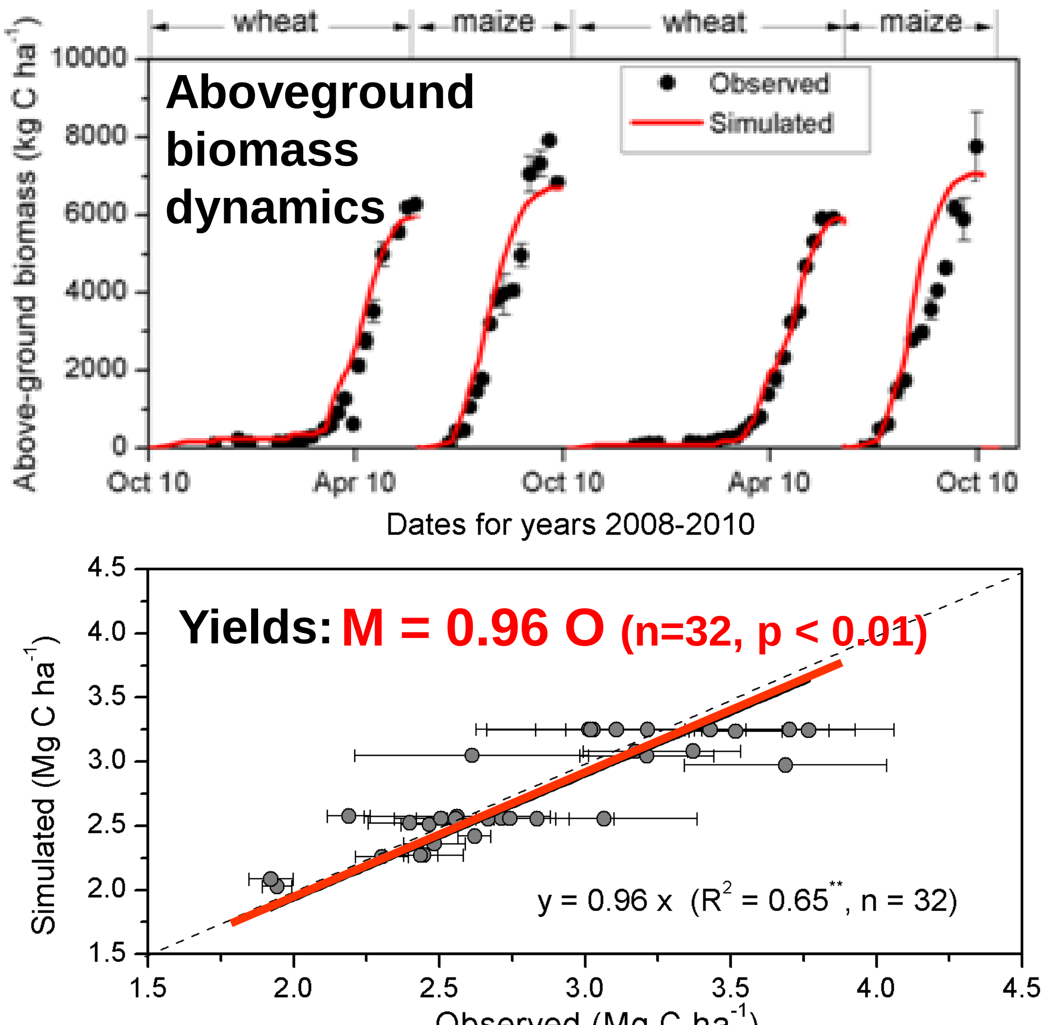
[Huang et al. (2007) and ref. therein]



Global dry lands : 6 - 31% (mean: 15%)

(Cui et al., 2013, Biogeosciences Discussions)

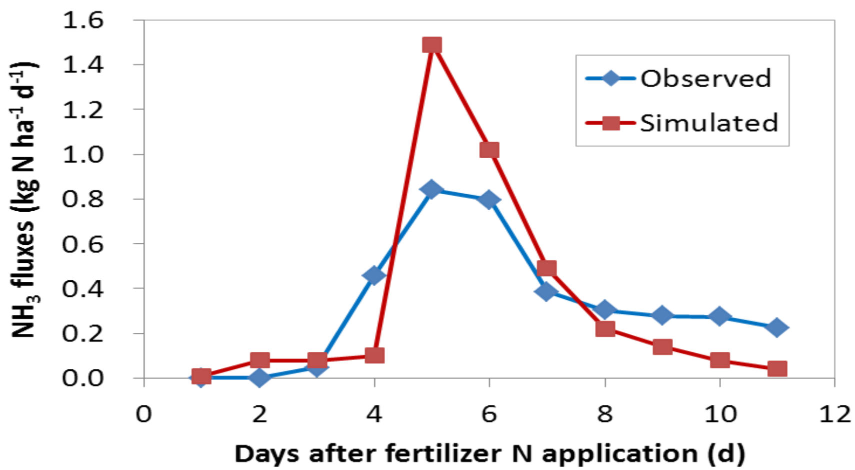
DNDC validation (Biomass & yields)

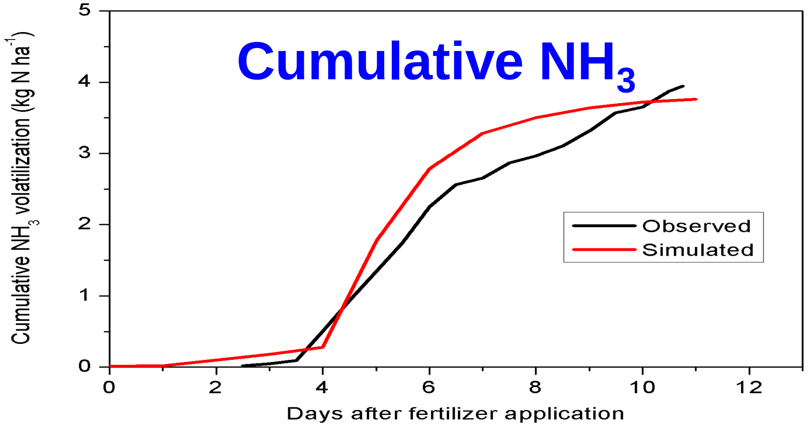


(Cui et al., 2013, Biogeosciences Discussions)

DNDC validation (NH_3)

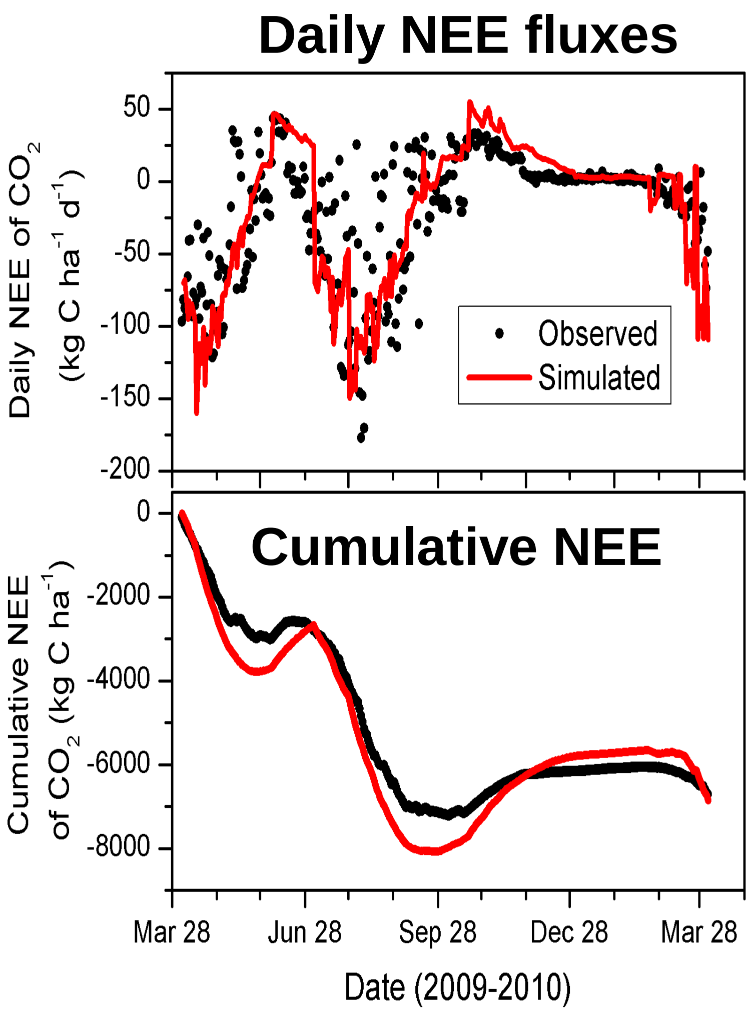
Daily NH_3 fluxes following a fertilization event





(Cui et al., 2013, Biogeosciences Discussions)

DNDC validation (NEE & net CO_2 emission)



$$NECB \approx \Delta SOC \approx -NEE - C_{harv.}$$

$$CO_2 = -\Delta SOC \approx (NEE + C_{harv.})/12 \times 44$$

Annual yields ($C_{harv.}$, ton C ha^{-1} yr^{-1}):

Observed: 5.7 ± 0.2

Simulated: 5.8

Annual net CO_2 emis. (ton CO_2 ha^{-1} yr^{-1}):

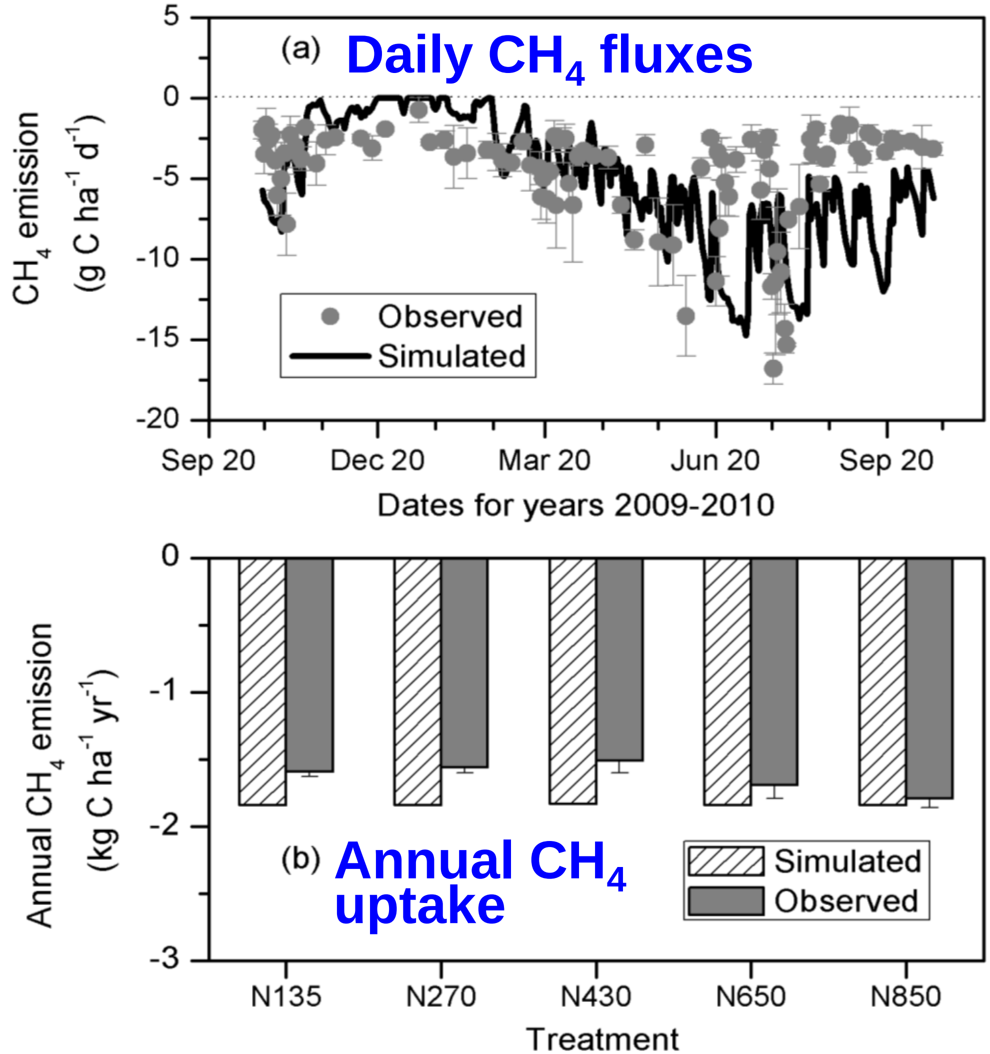
Observed: −4.3

Simulated: −5.0

Difference smaller than measurement error of NEE

(Cui et al., 2013, Biogeosciences Discussions)

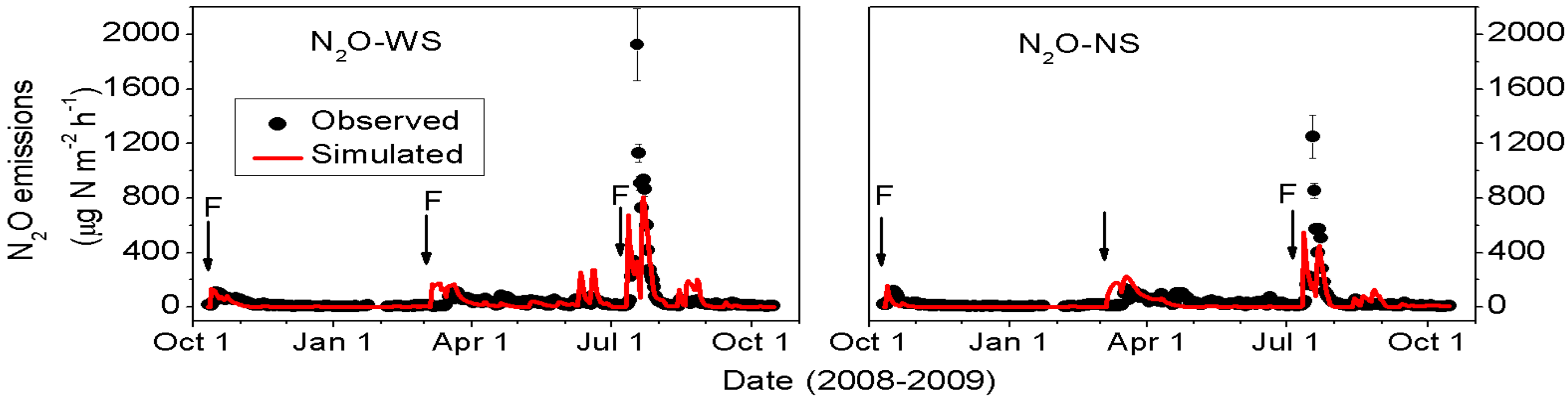
DNDC validation (CH_4 uptake)

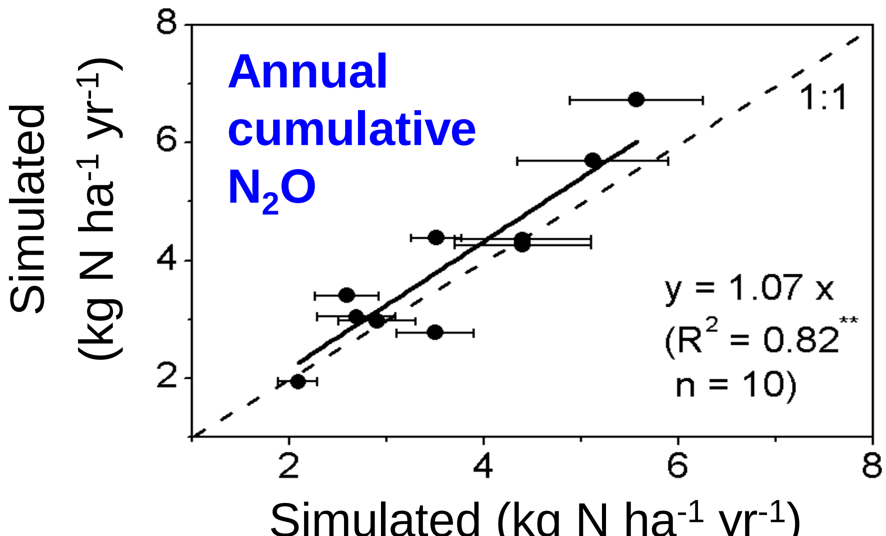


(Cui et al., 2013, Biogeosciences Discussions)

DNDC validation (N_2O emission)

Daily means of N_2O fluxes





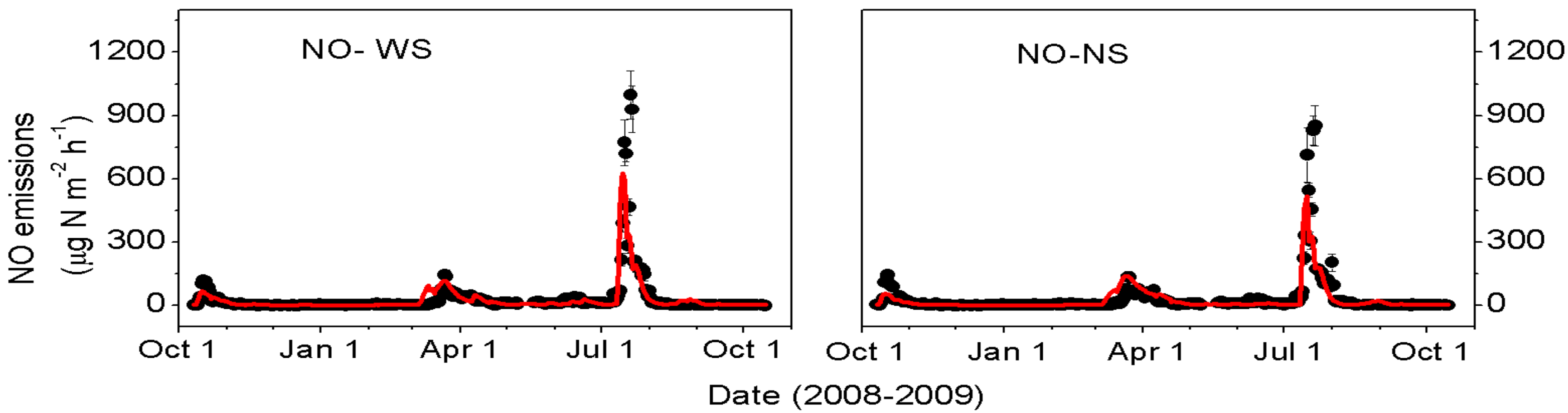
M = 1.07O

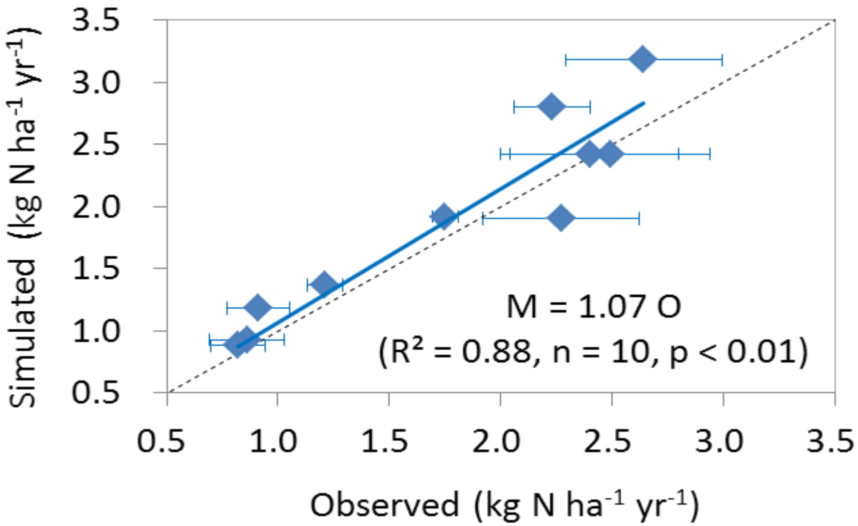
(n = 10, p < 0.01)

(Cui et al., 2013, Biogeosciences Discussions)

DNDC validation (NO emission)

Daily means of NO fluxes





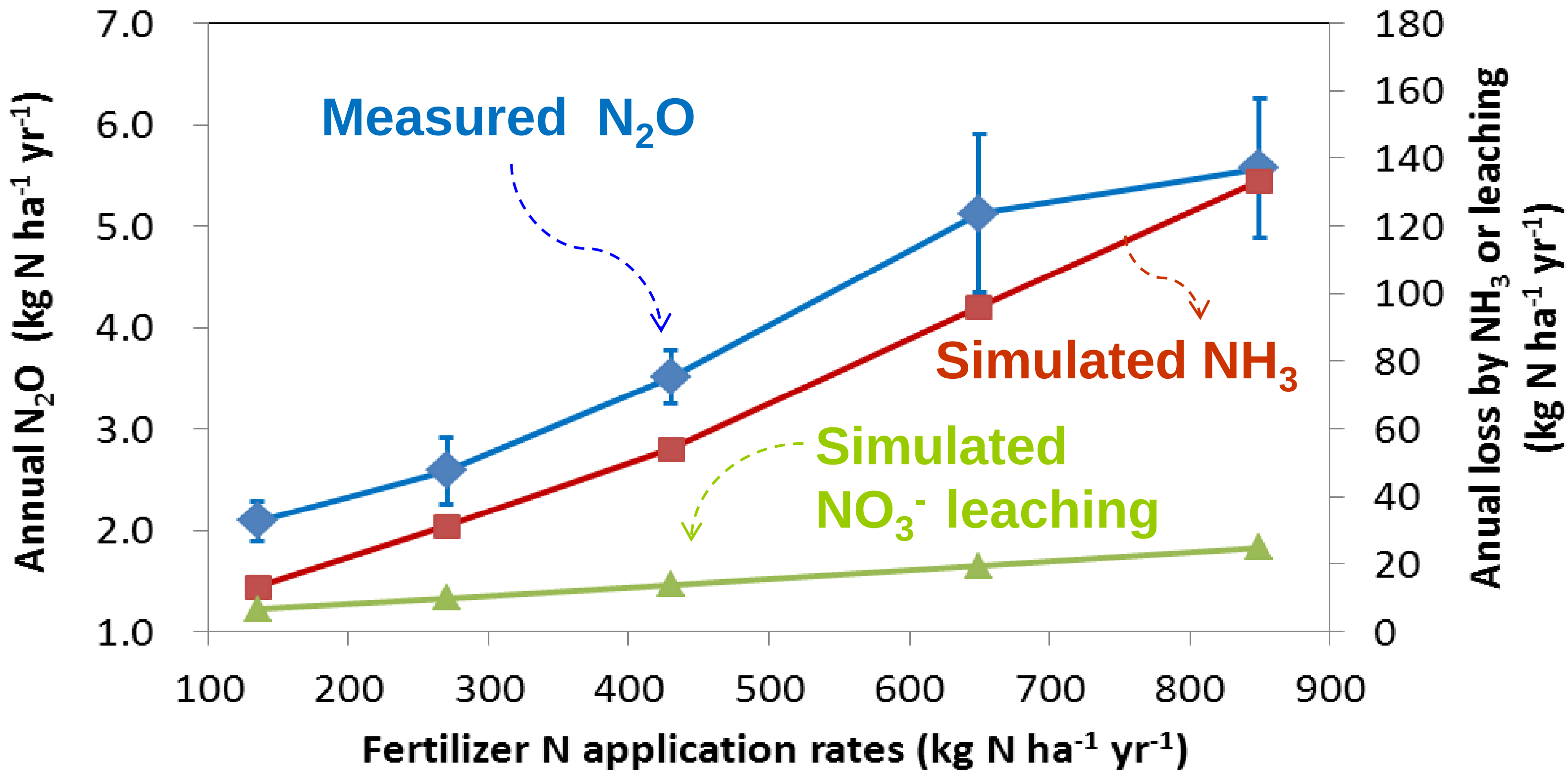
M = 1.07 O

(n = 10, p < 0.01)

(Cui et al., 2013, Biogeosciences Discussions)

DNDC simulation (N addition gradients)

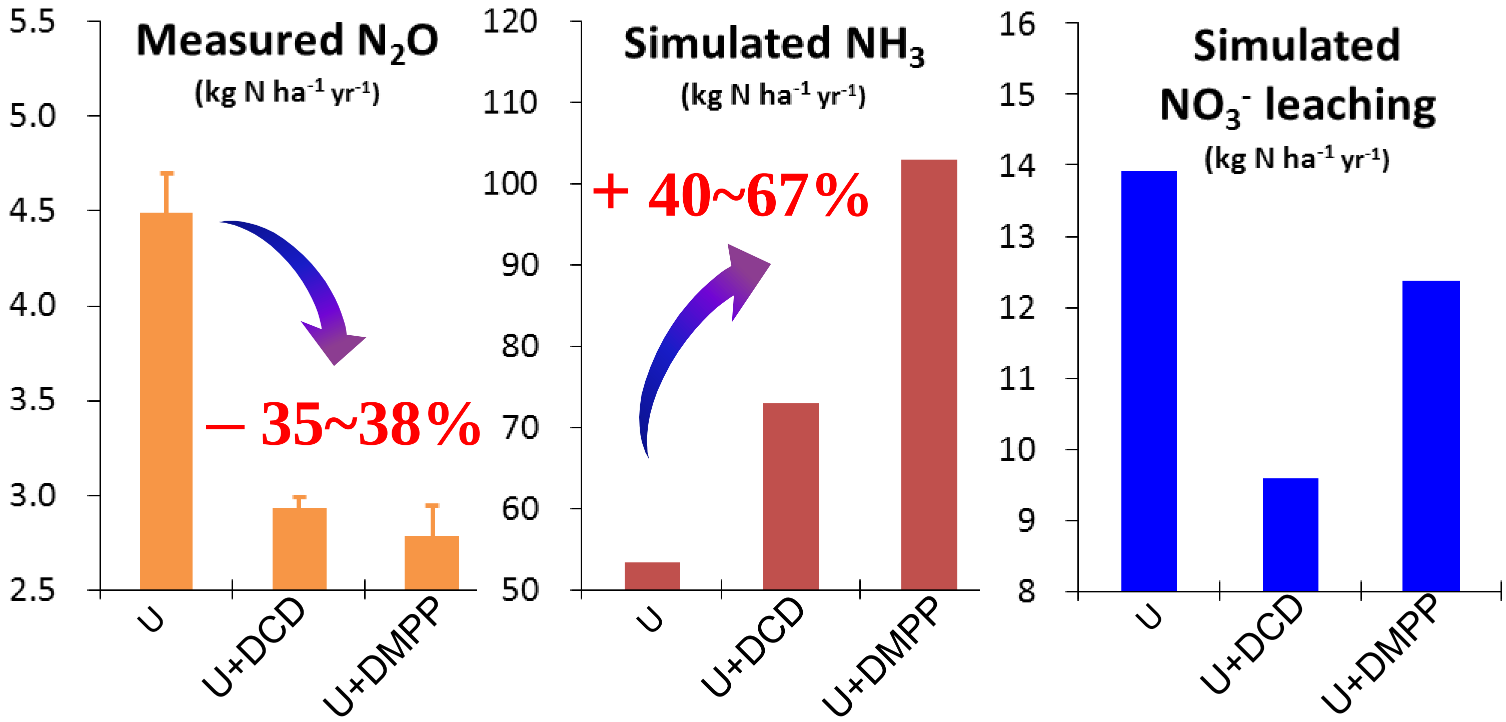
Implication: Applying N at a higher rate may stimulates more NH_3 volatilization than leaching



(Liu et al., 2012, Biogeosciences; Cui et al., 2013, Biogeosciences Discussions)

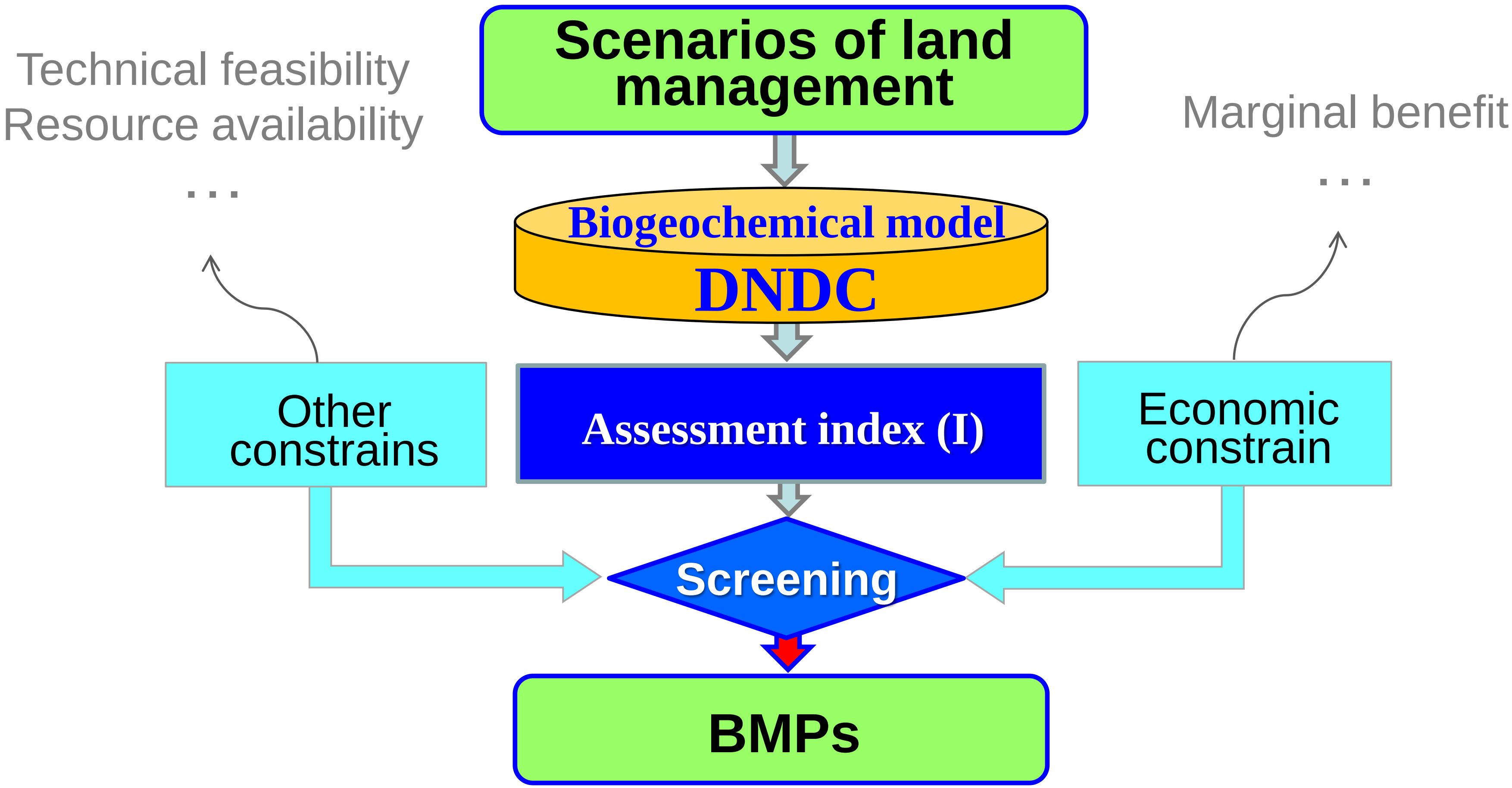
DNDC simulation (Nitrification inhibitors)

Implication: Use of nitrification inhibitors is not a good practice to mitigate N_2O emission from croplands with calcareous soils



(Liu et al., 2013, Biogeosciences; Cui et al., 2013, Biogeosciences Discussions)

Method to choose best management practice

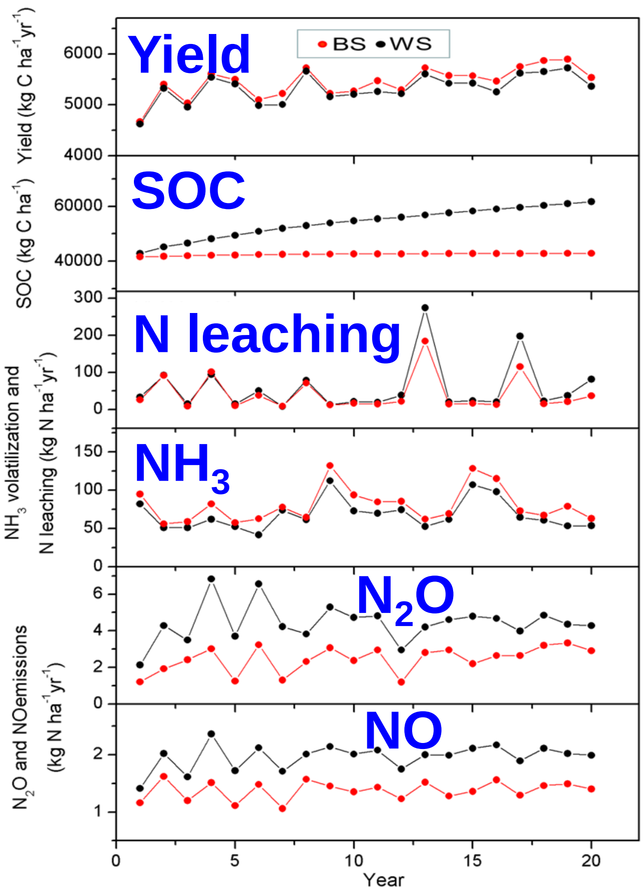


Screening: the scenario with the largest I value is the best under given constrains

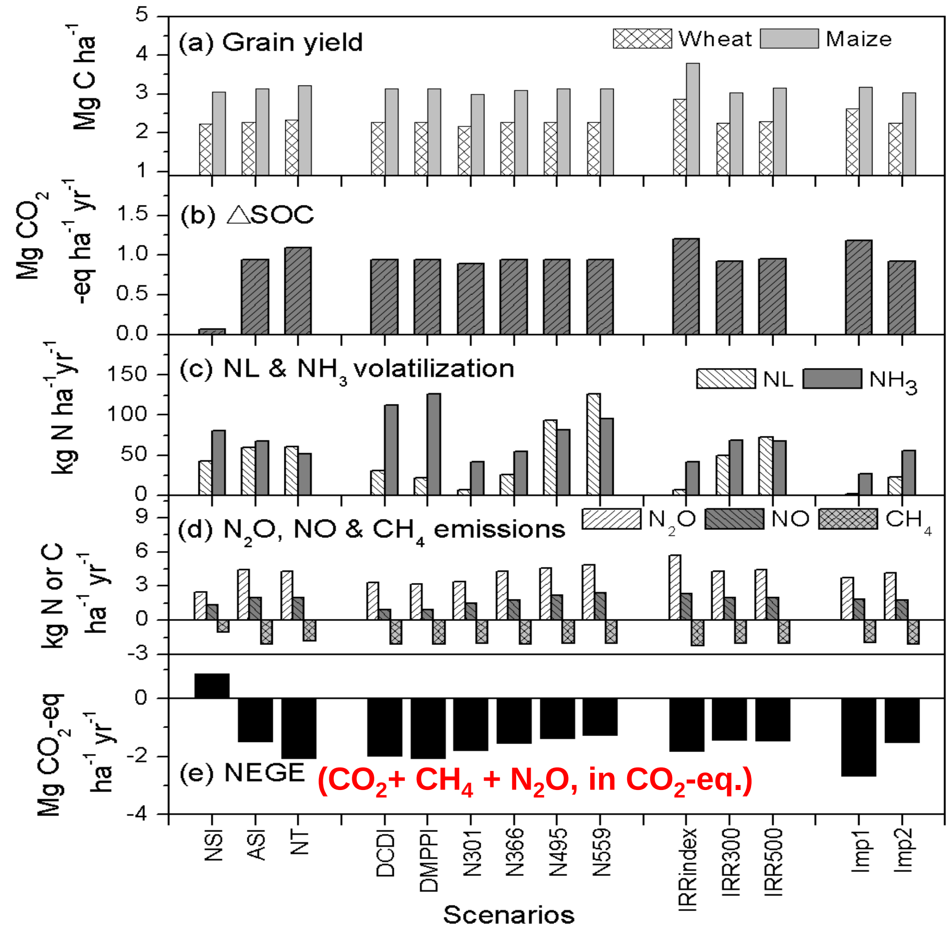
(Adapted from Cui et al., 2013, Biogeosciences Discussions)

Scenario study based on DNDC simulation

20-year simulation for With-straw & No-straw scenarios



Simulated results for 14 scenarios (as 20-year means)



(Cui et al., 2013, Biogeosciences Discussions)

Choosing potential mitigation options among a number of management scenarios

DNDC application: Looking for BMPs

Productivities (e.g. crop yield)

CO_2+CH_4+N_2O

Nitrate leaching

O_3-layer depletion matter

$$I = \sum_{i=1}^{n} a_i \cdot P_i - b \cdot NEGE - c \cdot NH_3 - d \cdot NL - e \cdot NO - f \cdot N_2O$$

a_1	891	\$ ton $^{-1}$ C	Referred to market prices
a_2	938	\$ ton $^{-1}$ C	of wheat and maize
b	7.00	\$ ton $^{-1}$ CO_2 eq	Referred to market price of carbon trade
c	5.02	\$ kg $^{-1}$ N	Birch et al. 2010
d	25.78	\$ kg $^{-1}$ N	Birch et al. 2010, Compton et al. 2011
e	1.92	\$ kg $^{-1}$ N	van Grinsven et al. 2010, Dodds et al. 2009
f	1.33	\$ kg $^{-1}$ N	Compton et al. 2011

Wheat-maize cropping regime

(Modified from Cui et al., 2013, Biogeosciences Discussions)

The best management practice (BMP)

Technical limits for irrigation

Reducing yields >5%

(current practice) Baseline

Best

Better

Worse

Scenarios	WY	MY	NEGE	NH_3	NO	NL	N_2O	I
IRRindex	2.87	3.79	-1.81	41	2.31	7	5.73	4190
Imp1	2.62	3.19	-2.68	26	1.83	2	3.71	3963
N301	2.16	2.99	-1.78	41	1.50	7	3.36	3110
Imp2	2.26	3.03	-1.52	56	1.75	22	4.13	2131
N366	2.28	3.11	-1.53	55	1.78	26	4.27	1976
DMPP	2.28	3.13	-2.06	126	0.93	21	3.14	1966
DCD	2.28	3.14	-1.98	113	0.95	30	3.33	1442
NSI	2.24	3.06	0.87	80	1.38	43	2.45	679
IRR300	2.26	3.04	-1.43	69	1.94	49	4.30	323
NT	2.33	3.23	-2.06	51	1.95	60	4.33	-96
ASI	2.28	3.14	-1.47	68	1.95	59	4.41	-225
IRR500	2.29	3.16	-1.46	68	1.97	72	4.47	-1037
N459	2.28	3.14	-1.39	82	2.17	93	4.58	-2493
N559	2.28	3.14	-1.27	95	2.39	126	4.83	-4693

The identified BMP (Imp2): ① full residues retention; ② sprinkler, 25% less water; ③ urea alone, 16% less N; ④ current cultivar, other management and schedules.

(Cui et al., 2013, Biogeosciences Discussions)

Summaries (1)

- **A case study was carried out, which combined multi-year, multi-factorial field experiments and model simulation.**
- **A price-based index was defined as the criteria to assess the biogeochemical effects of management alternatives, in terms of GHGs emissions, gaseous pollutants releases, N leaching and crop growth (yields), and thereby to identify potential BMPs.**
- **Nitrification inhibitors significantly reduced N_2O emission, enhanced NUE and crop yields; however they most likely stimulated intensive NH_3 volatilization from a calcareous soil.**

Summaries (2)

- **The identified potential best management practice (BMP) for maize-wheat cultivation on a irrigated calcareous soil with a silt clay texture has features of:**
  ① full residues retention;
  ② sprinkler of 25% less water than 380-550 mm yr^{-1};
  ③ using urea alone < 16% N than 430 kg N ha^{-1} yr^{-1};
  ④ adopting the crop cultivar, other management and schedules being applied currently at the study site.


Thanks for your attention !
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