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Experimental databases and model of N_2O emissions by croplands Do we have what is needed to explore mitigation options?

Workshop of the GRA
17-19 March 2014, Paris

Oral presentations presented during the workshop

CROPLANDS GROUP
GLOBAL RESEARCH ALLIANCE ON AGRICULTURAL GREENHOUSE GASES

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Opening session

Chair: Alan Franzluebbers

Co-chair: Raia Silvia Massad

Introduction - Sylvain Pellerin, Pierre Cellier, Alan Franzluebbers

Introductory lectures:

- Klaus Butterbach-Bahl
- Pete Smith
- Mark Liebig and Pierre Cellier

Objectives of the workshop: Sylvain Pellerin, Pierre Cellier

Welcome address and introduction

Sylvain Pellerin, Pierre Cellier, Alan Franzluebbers

INRA, France

US Department of Agriculture - Agricultural Research Service

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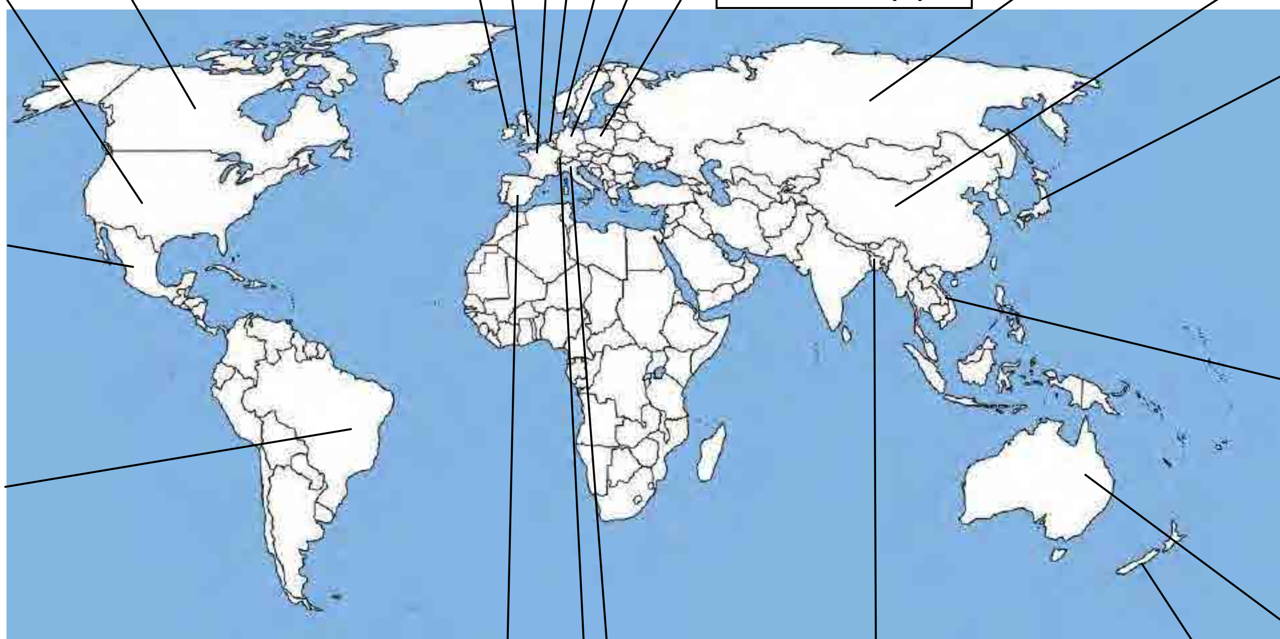
ON AGRICULTURAL GREENHOUSE GASES

62 participants, 21 countries



The Global Research Alliance on Agricultural Greenhouse Gases

- Aim: linking up efforts and achieve faster progress towards the solutions needed for reducing the contribution of agriculture to climate change.
- Launched in December 2009
- 40 member countries
- Founded on the voluntary, collaborative efforts of countries

GRA organisation

Alliance Council

Research Groups

Livestock	Croplands	Paddy Rice

Soil carbon & nitrogen cycling cross-cutting group

Inventory & measurement cross-cutting group

Alliance Secretariat

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Croplands Research Group

- Co-chaired by Alan Franzluebbers (USA) and Ladislau Martin-Neto (Brazil)

- Three components

    1. Quantifying net greenhouse gas emissions in cropland management systems (P. Cellier, France / C. Rice, USA)

    2. Assessing greenhouse gas emissions in agricultural peatlands and wetlands (L. Oygarden, Norway / A. Klemedtsson, Sweden / K. Regina, Finland).

    3. Modelling carbon and nitrogen emissions (N. Cavallaro, USA / S. Pellerin, France)

- The workshop “Experimental databases and model of N_2O emissions by croplands: do we have what is needed to explore mitigation options?” is co-organised by components 1 and 3.

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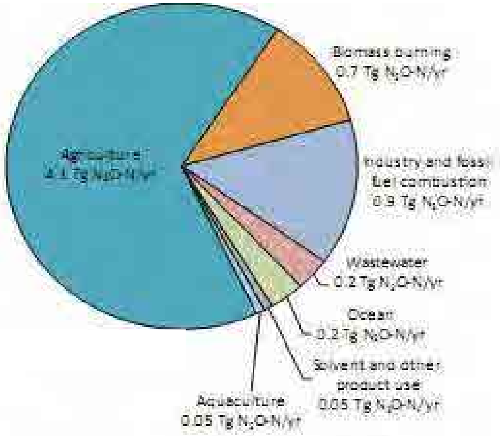
Why a workshop dedicated to the effect of management practices on N_2O emissions and modelling?

- 66% of gross anthropogenic N_2O comes from agriculture. N_2O is mainly produced by agricultural soils.

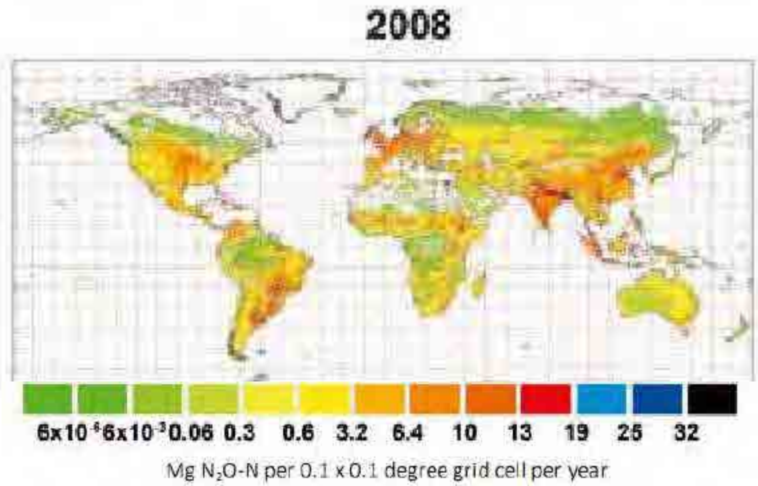
- Because of its global warming potential (296 times greater than that of the CO_2) N_2O strongly affects the global GHG budget of croplands

  ⇒ *e.g. in poorly aerated soils the benefit of the adoption of no-till on C sequestration could be offset by increased N_2O emissions*

- N_2O emissions are influenced by many agricultural management practices (N fertilisation rate, forms and placement, tillage, residue management,…), which in turn offer levers for mitigation



Origin of anthropogenic N_2O emissions in 2005 (UNEP, 2014)



Map of N_2O emissions from agricultural soils (UNEP, 2014)

General organisation of the workshop

-Three introductory lectures:

Basic processes of N_2O emissions from agricultural soils
State of the art of N_2O emission models
Experimental measurements and databases

- Objectives and expected outcomes of the workshop

- Four sessions dedicated to key management practices that influence N_2O emissions and offer levers for mitigation (1 key-note+3 volunteered presentations +discussion)

Fertilisation techniques
Soil tillage
Cover crop and residues management
Other management practices and combinations of techniques

- One session on cross-cutting issues

What are the key compartments/processes which must be considered in simulation models to account for the effect of management practices ? (key note)

Three slots of discussion on cross-cutting issues (short introduction+discussion)

- Final discussion and conclusion

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Introductory lecture

Nitrous oxide emissions from soils, current understanding of the processes and modelling

Klaus Butterbach-Bahl

KIT, Germany

Karlsruhe Institute of Technology

INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

Nitrous oxide emissions from soils, current understanding of the processes and modelling

Butterbach-Bahl K[1,2], Baggs EM[3], Dannenmann M[1], Kiese R[1] and Zechmeister-Boltenstern S[4]

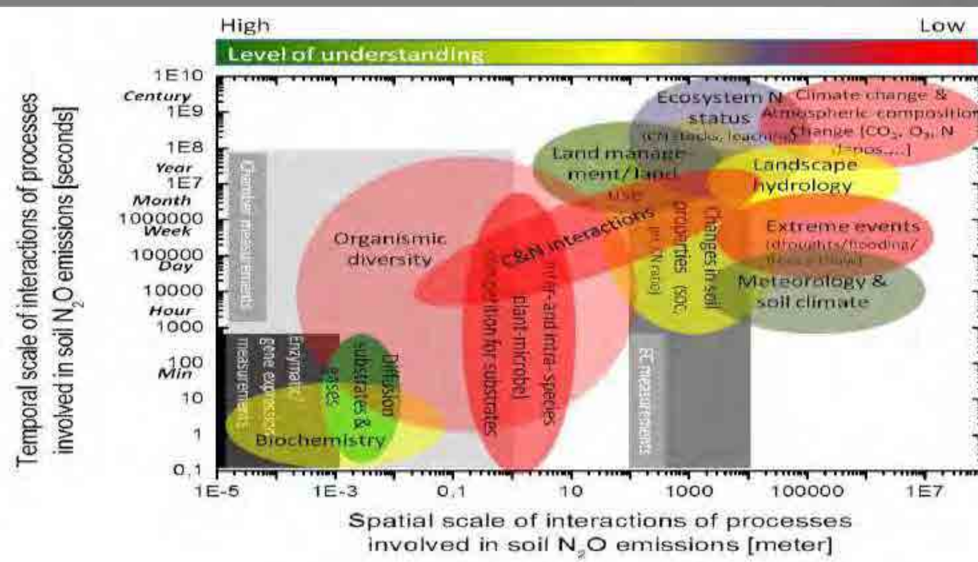
Institute for Meteorology and Climate Research, Atmosphere-Biosphere Interactions and Global Change, Biogeochemical processes

[1)] *Institute for Meteorology and Climate Research, Karlsruhe Institute of Technology, Garmisch-Partenkirchen, Germany*

[2)] *Interrnational Livestock Research Institute, Nairobi, Kenya*

[3)] *Institute of Biological and Environmental Sciences, University of Aberdeen, UK*

[4)] *University of Natural Resources and Life Sciences Vienna, Department of Forest and Soil Sciences, Institute of Soil Research, Austria*



Outline

(1) Nitrogen processes and N_2O production and consumption

(2) Techniques to characterize and quantify soil processes

(3) Environmental controls of N_2O fluxes at various spatial and temporal scales

(4) Shortcomings of available flux measurements techniques

(5) Modeling soil N_2O fluxes – present status and remaining uncertainties

(6) Conclusions

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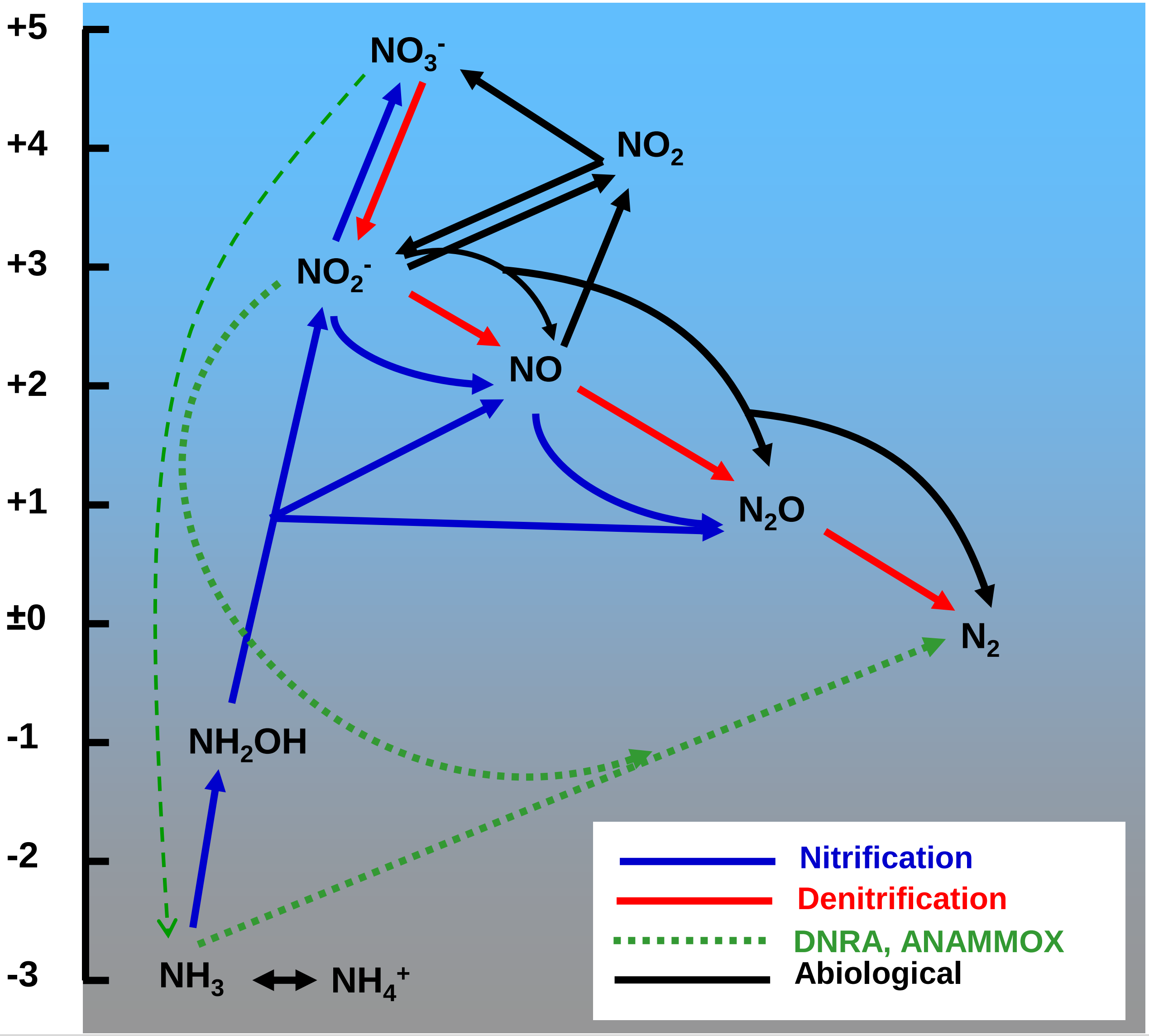
Major N_r transformation processes in soils



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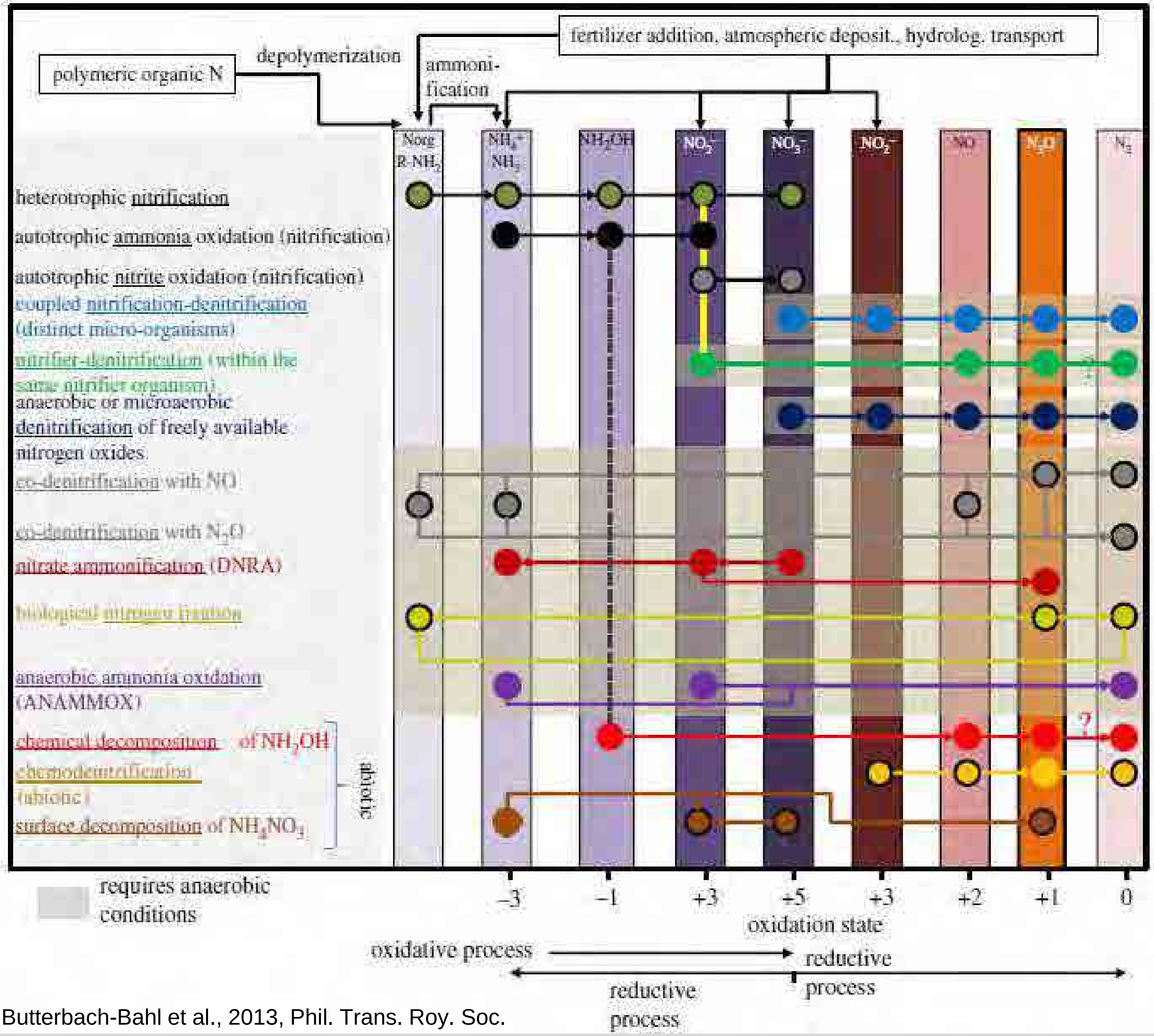
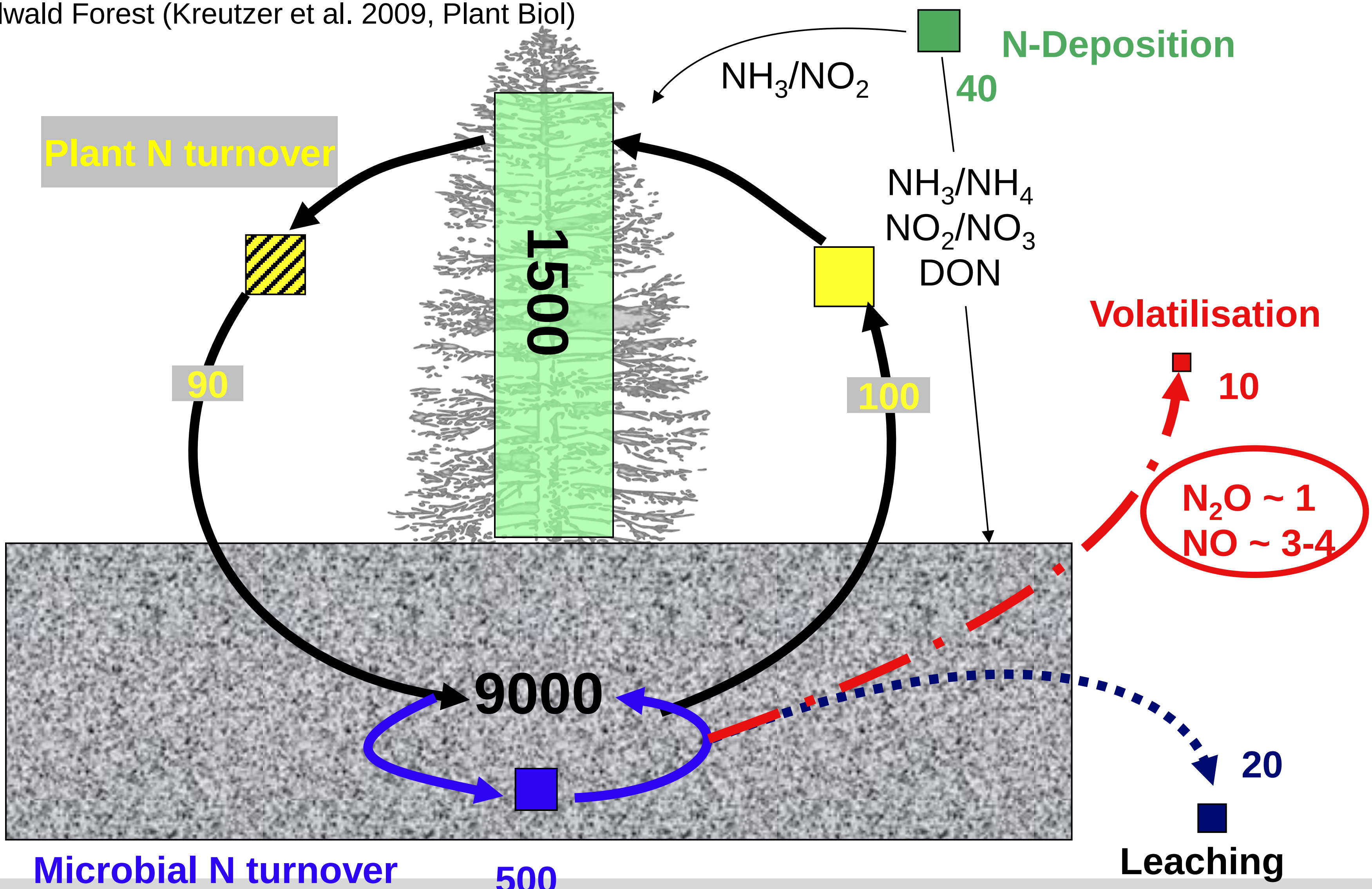


Butterbach-Bahl et al., 2013, Phil. Trans. Roy. Soc.

N_2O fluxes: a minor loss process of ecosystem N cycling

Höglwald Forest (Kreutzer et al. 2009, Plant Biol)



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Nitrification and denitrification genes and source partitioning of N_2O production

Karlsruhe Institute of Technology

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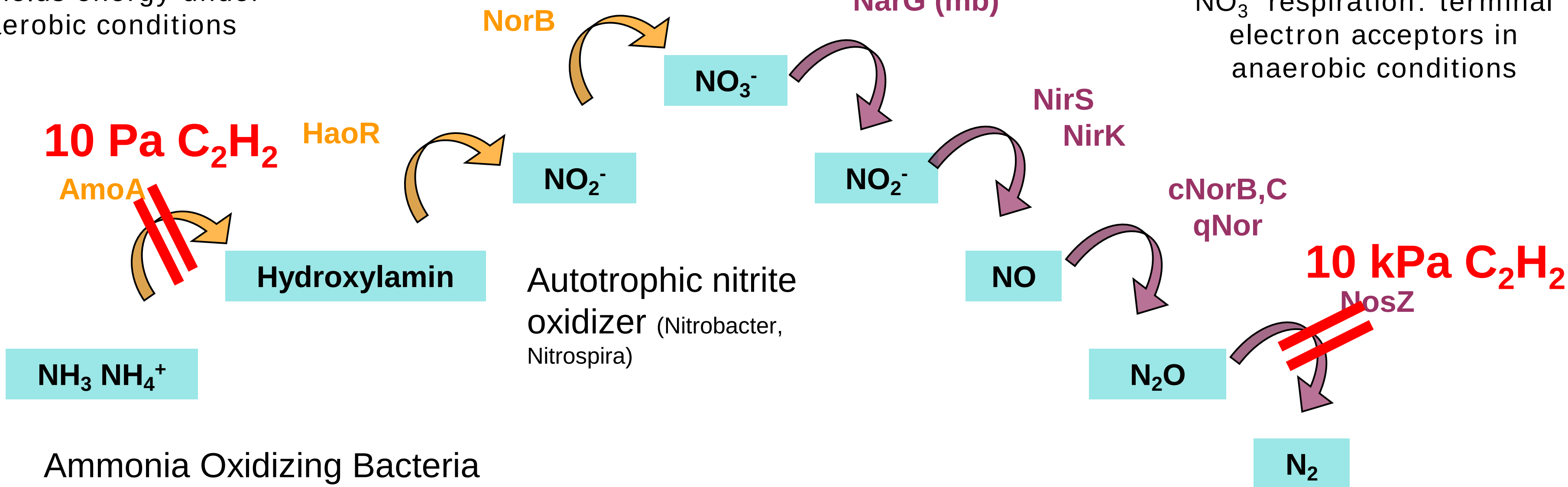
Nitrification

Yields energy under aerobic conditions

Denitrification

NO_3^- respiration: terminal electron acceptors in anaerobic conditions



Ammonia Oxidizing Bacteria
(β and γ-ProteoB (Nitrosomonas, Nitrosospira, Pseudomonas))

Ammonia Oxidizing Archaea
(Crenarchaeota)

ProteoB (α (Paracoccus, Ochrobactrum), β (Alcaligenes Achromobacter, Variovorax), γ (Pseudomonas))

Bacteroidetes (Flavobacterium)

Fibrobacteres (Acidobacterium)

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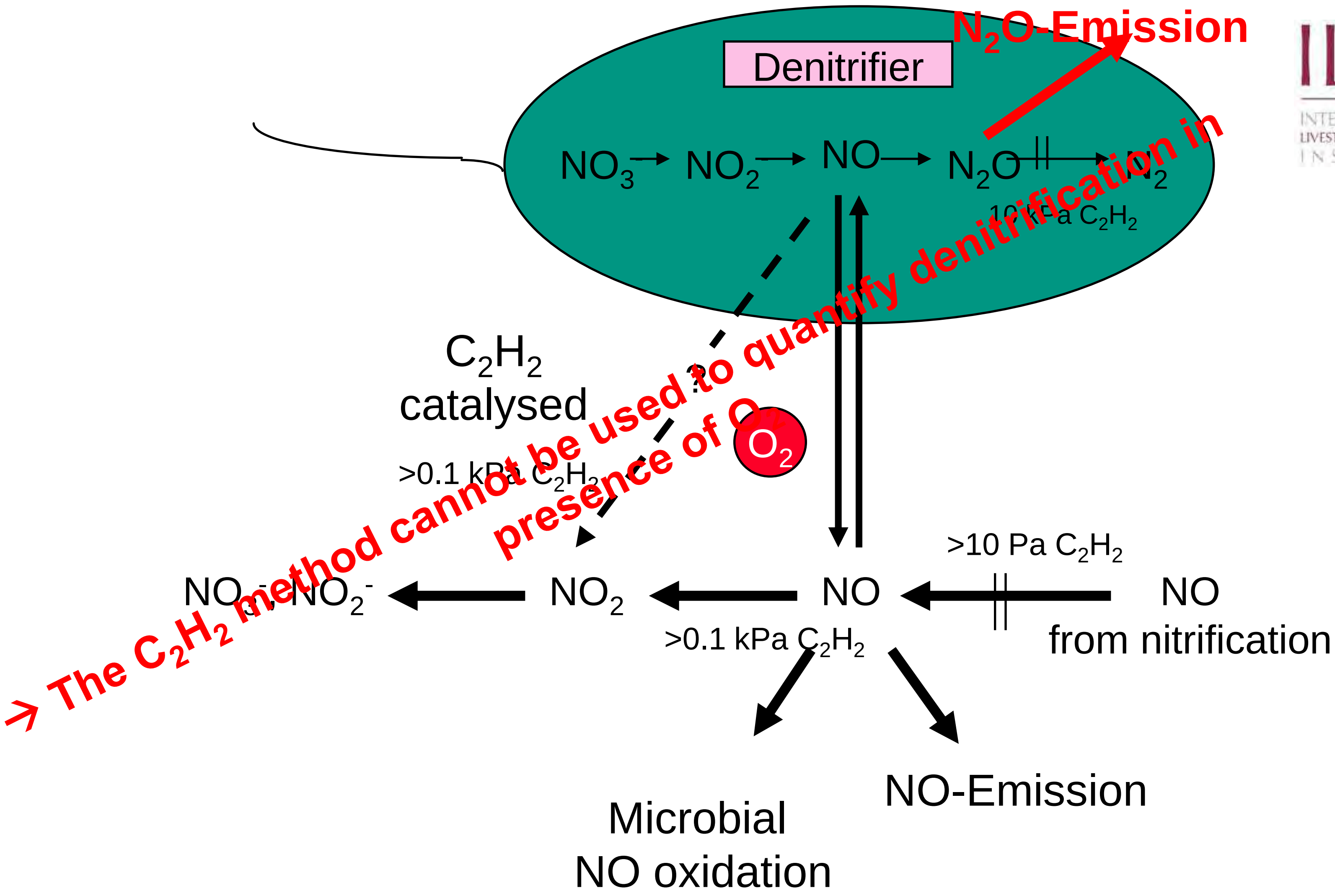
Draw backs of the acetylene method



Bollmann & Conrad (1997) Soil Biol. Biochem 29,7: 1067-1077

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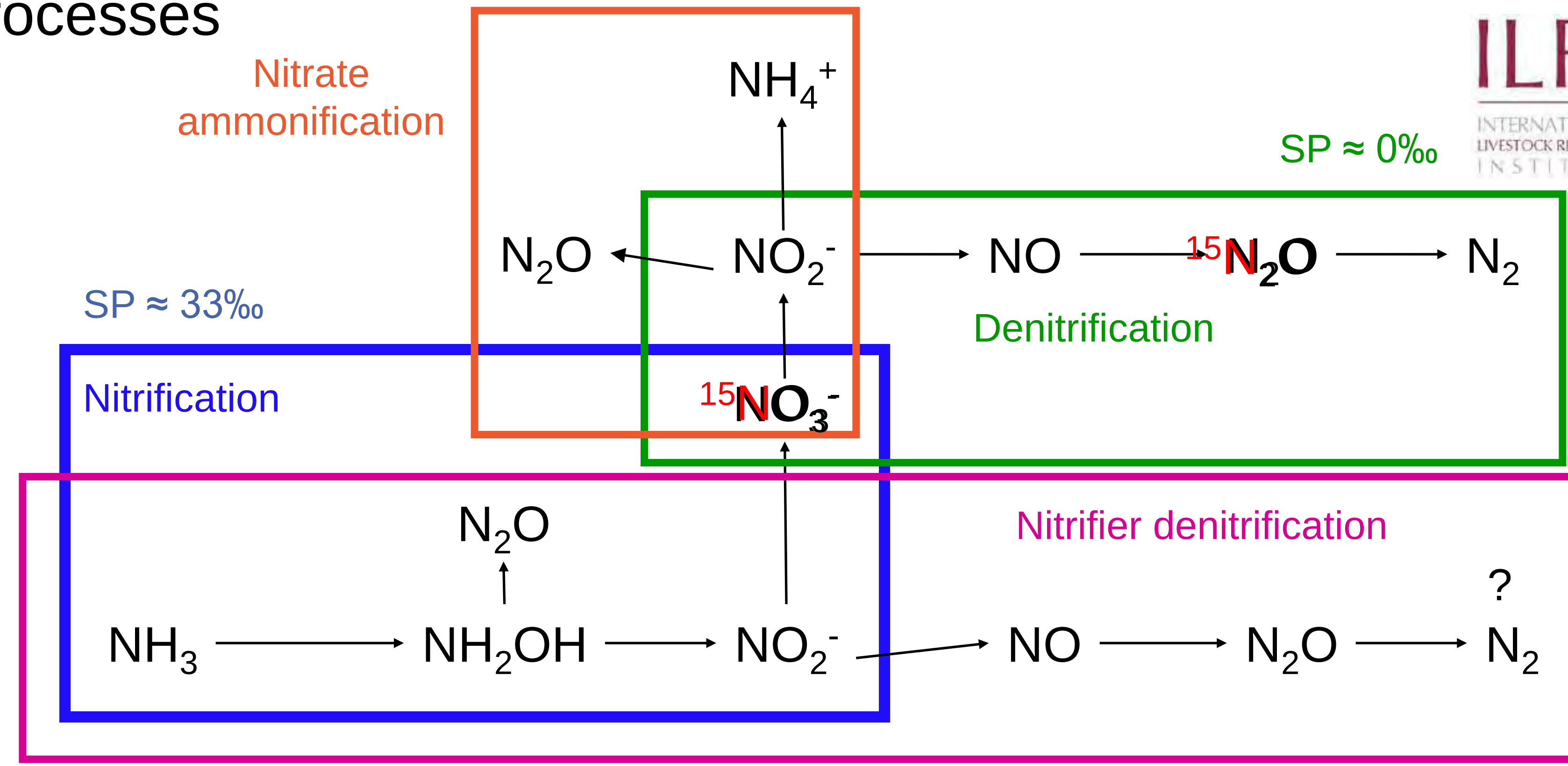
Quantification of microbial N_2O production-/consumption processes



$\underline{N_2O}$

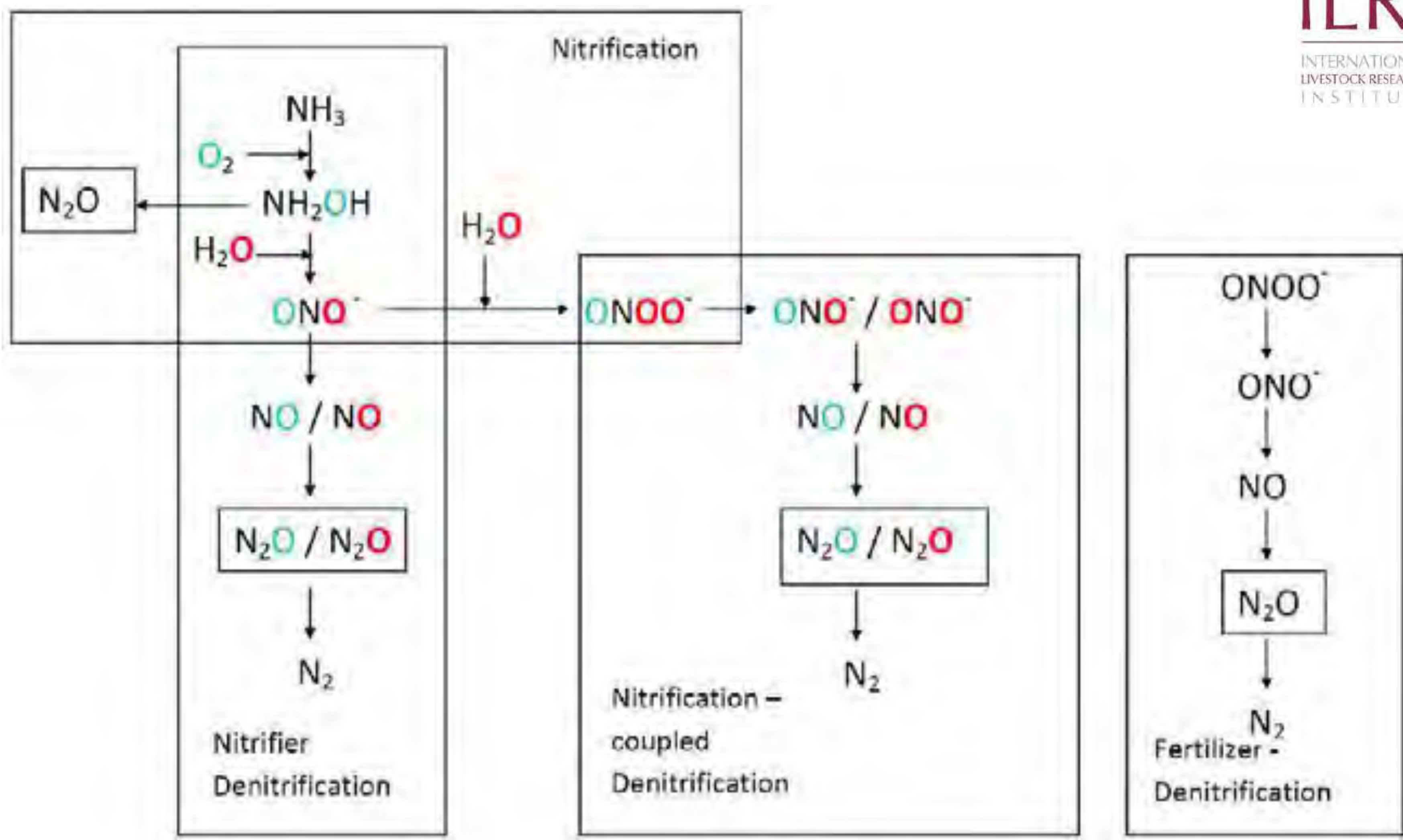
N – N – O
β α

^{15}N site preference = $\delta^{15}N^{\alpha} - \delta^{15}N^{\beta}$

^{15}N, ^{18}O enrichment

Wrage et al., 2005, RCM; Baggs, 2008, RCM

Major pathways of N_2O formation (Kool et al. 2009 Soil Biol. Biochem)



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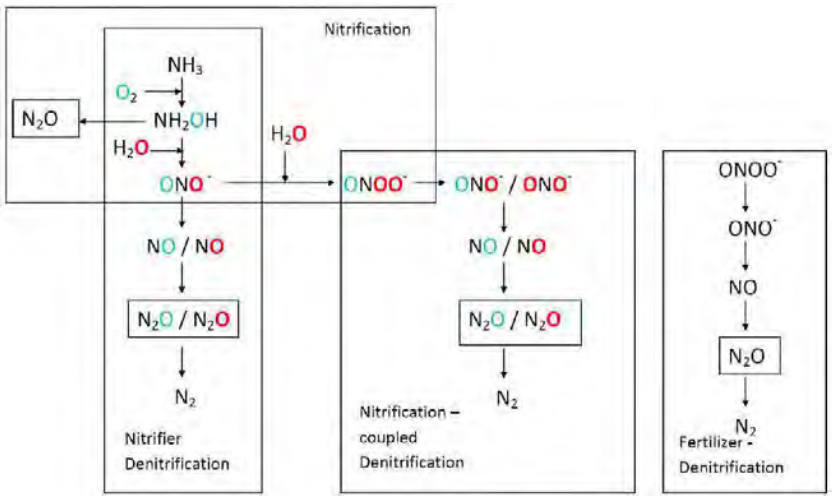
N_2O Isotopic signals vor various microbial groups and environmental conditions (Well & Flessa 2009, J Geophys res. G02020)

	$\Delta\delta^{18}O$ (‰)	ε_{bulk} (‰)	$\varepsilon_{SP}{}^{b}$ (‰)
Bacterial denitrifiers			
Pseudomonas chlororaphis Pseudomonas aureofaciens		−12.7 to −36.7	
Pseudomonas fluorescens	−3 to 32	−39 to −17	−22.2 to −24.1
Pseudomonas denitrificans Paracoccus denitrificans	4 to 23	−10 to −22	−5.1 to −5.7
Paracoccus denitrificans		−26.6 ± 1.2	
Paracoccus denitrificans		−26.9 ± 2.6	
Pseudomonas aureofaciens	40		
Fungal denitrifiers			
Fusarium. oxsporum		−6.6 to −74.7	36.9 to 37.1
Cylindrocarpon tonkinense			
Soils			
Tropical forest soils		−10 to −45	31 ± 8
Arable soil		11 to 29.4	
Sandy aquifer	−8	−15.9	

Source partitioning of N_2O production (Kool et al. 2010 Eur J Soil Sci)



<u>Soil incubations 16°C, 80% WHC</u>

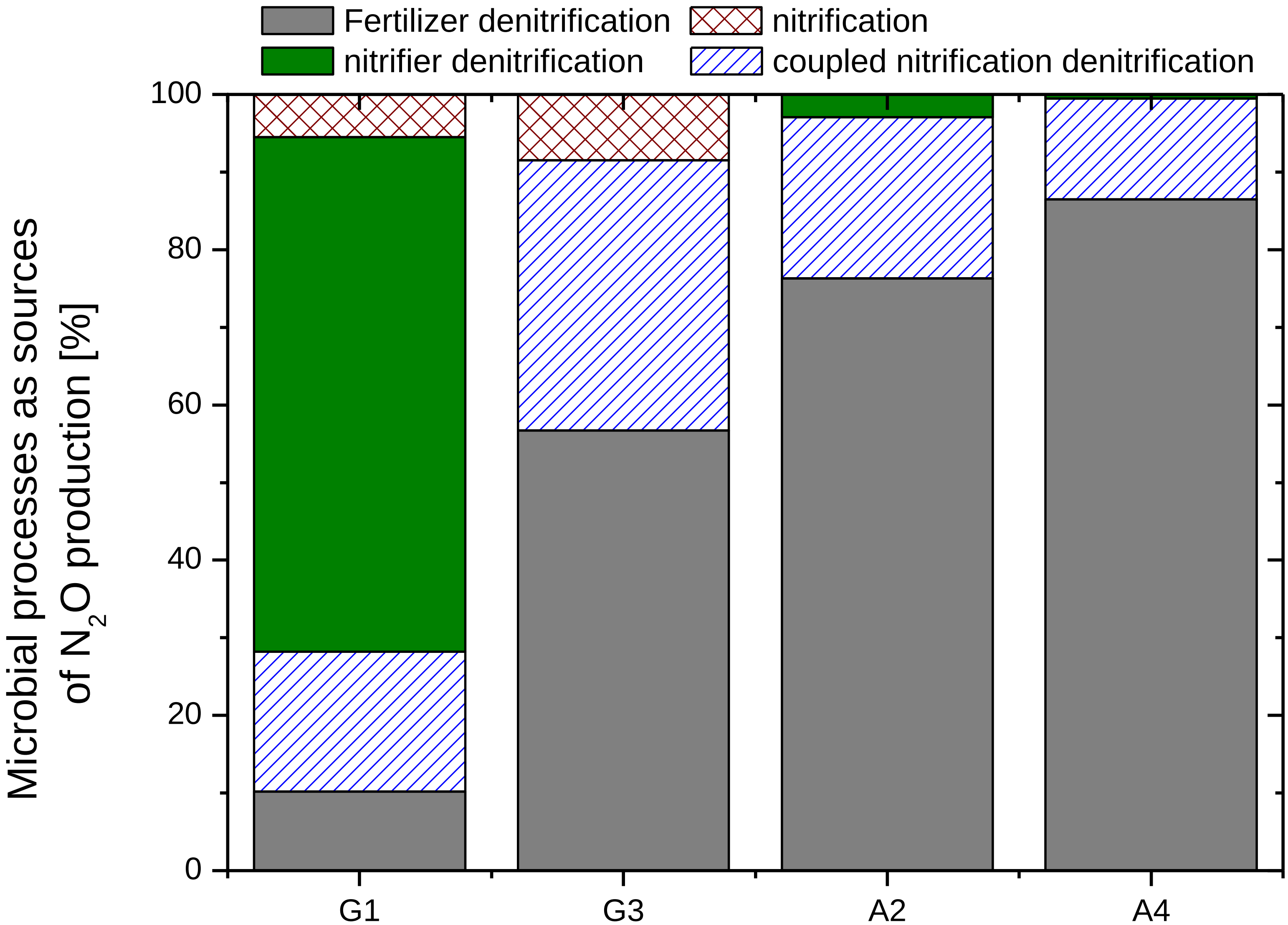
a) ^{18}O in H_2O enriched

b) ^{18}O in NO_3 enriched

c) ^{15}N in NO_3 enriched

d) ^{15}N in NH_4 enriched

Source partitioning of N_2O production (Kool et al. 2010 Eur J Soil Sci)



[G1, G3 = grassland soils]
[A2, A3 = arable soils]

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Isotope approaches for source partitioning of N_2O fluxes (Baggs, 2008, RCM)

	Advantages	Disadvantages
Natural abundance (d^{15}N, d^{18}O)	Non-obtrusive	Lack of quantification
	Potential for source partitioning over a large scale	Fractionation not known for all processes
	Less expensive than isotope enrichment approaches	Fractionation may differ between strains
Isotope enrichment (^{15}N, ^{18}O atom % excess)	Emissions can be related to input (e.g. fertiliser, residues, water)	^{18}O-H_2O not suitable under field conditions
	Potential to link source partitioning to nano-scale imaging	No discrimination of nitrate dissimilation processes
	Potential for elucidating interactions with other processes and cycles	Obtrusive →natural systems Undesirable fertilisation Homogeneous distribution
Site preference (d^{15}N$^{\alpha,\beta}$)	Precision > as natural abundance	Lack of quantification
	estimating nitrate ammonifier-N_2O	Denitrification = nitrifier denitrification Insufficient data for species and strains Overlapping SPs limit source partition. Lack of standard calibration

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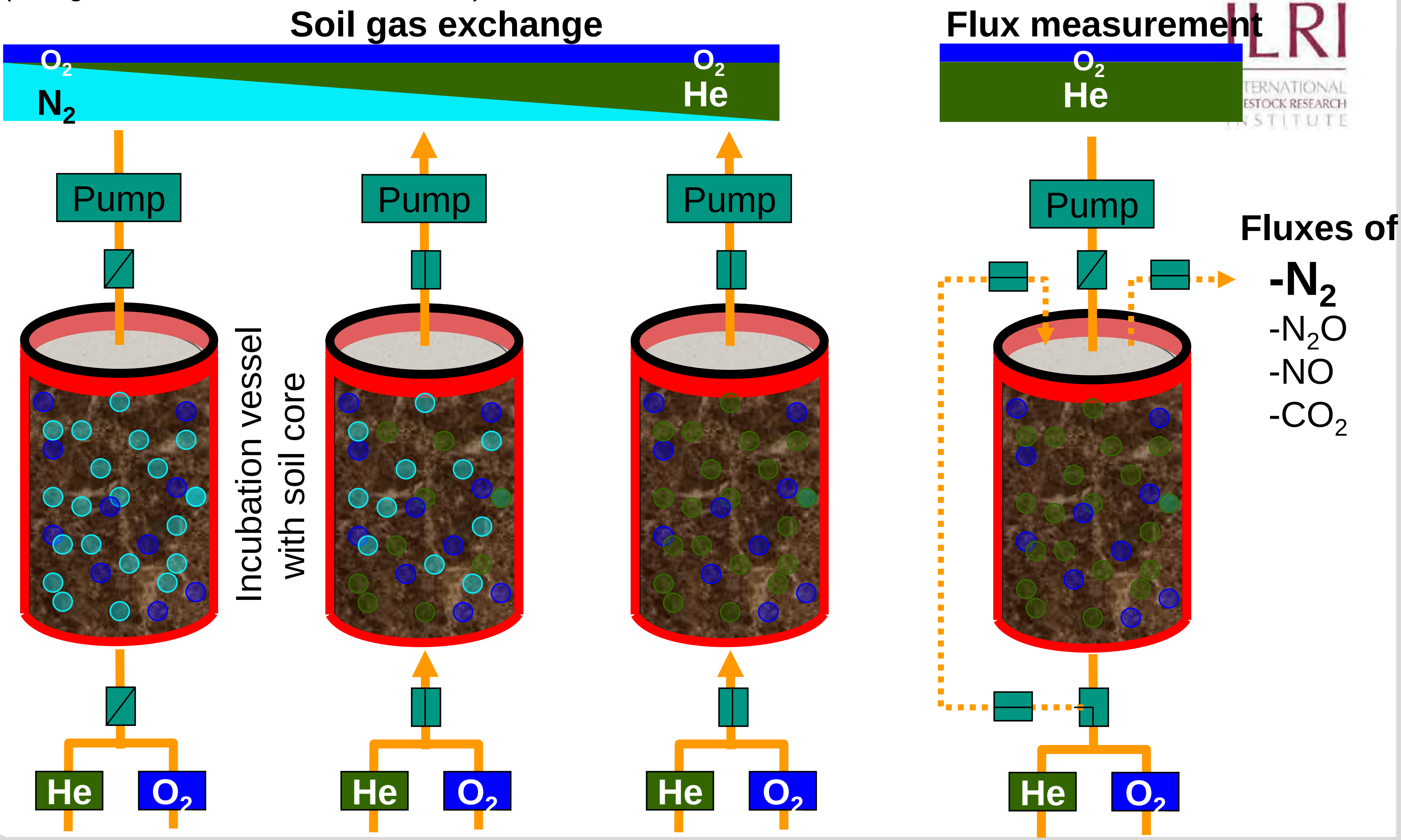
Measurement of N_2, N_2O and NO production

(Wang et al. 2011 Environm Sci Techn)



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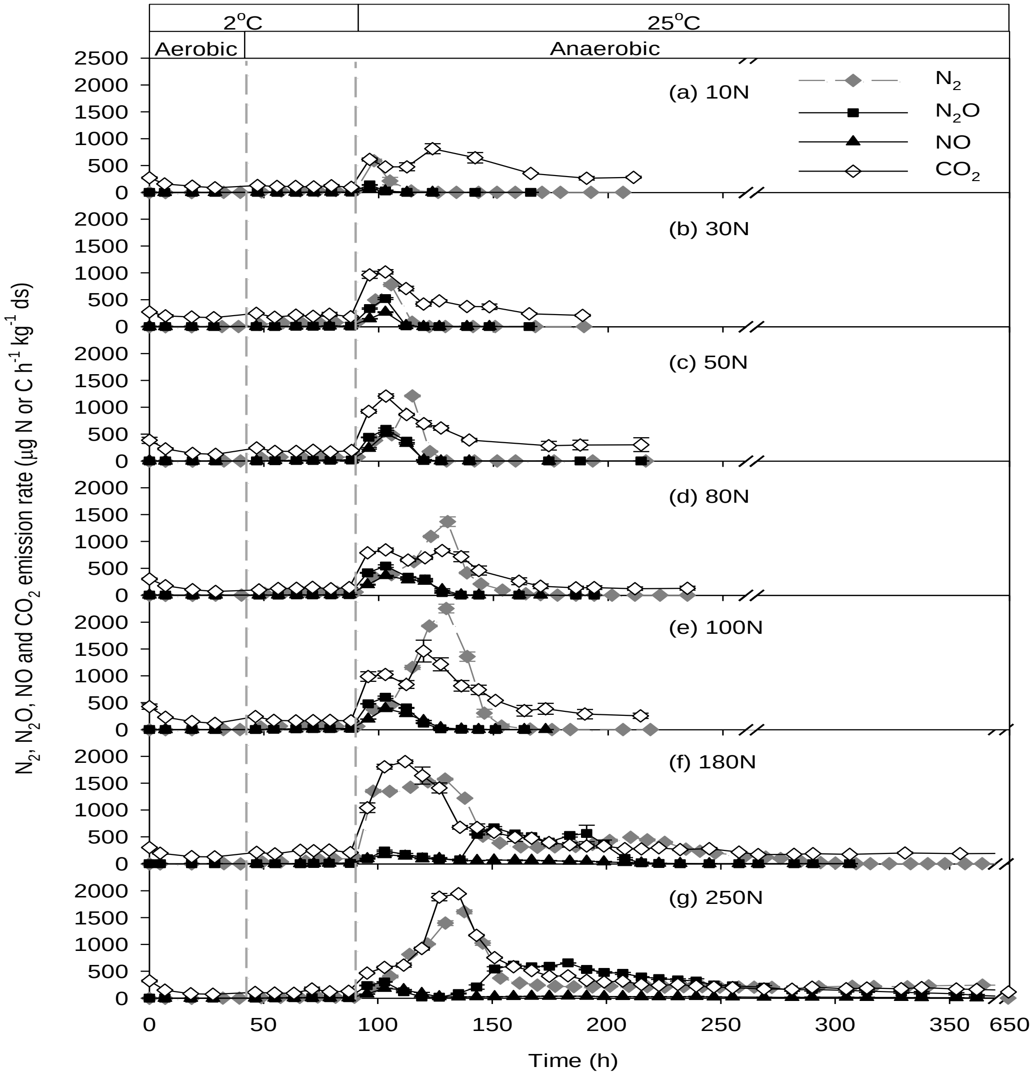
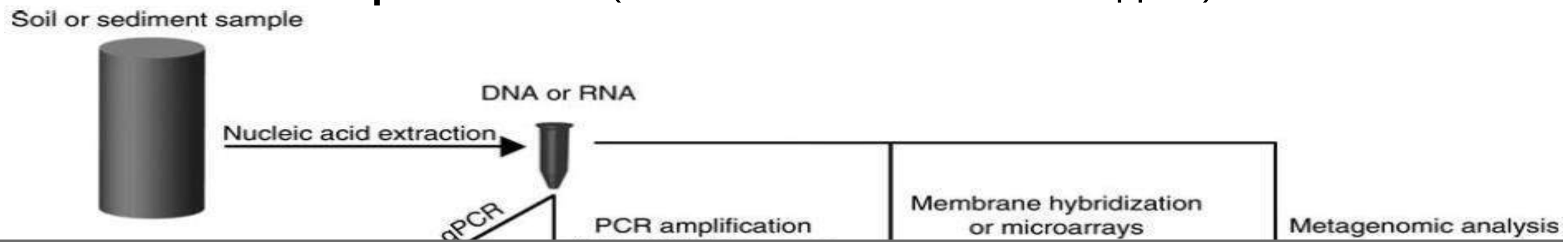
Measurement of N_2, N_2O and NO production

(Wang et al. 2013, Plant & Soil)



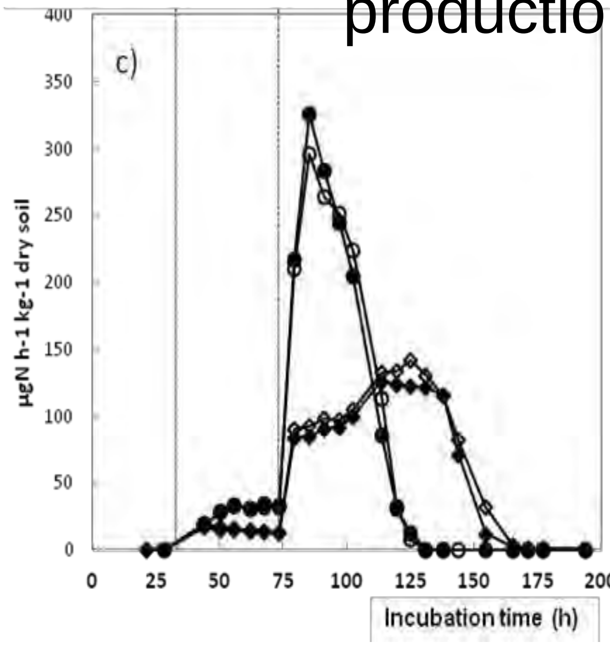
Relating N_2O production to microbial community composition (Wallenstein et al. 2006 Ecol.Applic.)

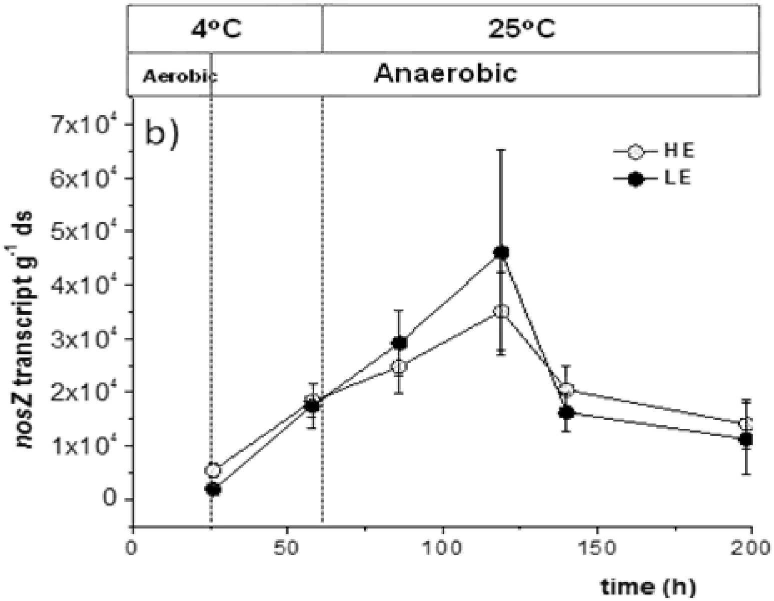


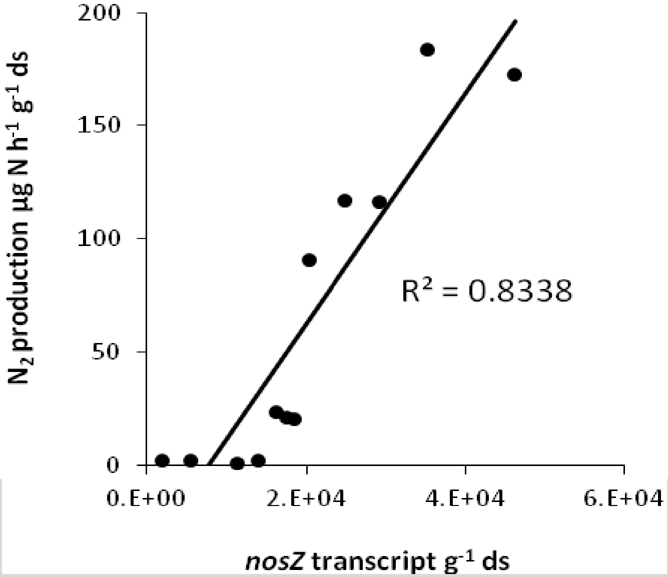
- Quantification of gene copies of relevant nitrification/ denitrification genes
    - Most studies failed to show significant relationships to N_2O fluxes
    - Gene coding for N_2O (norB/ norC) seldom studied (missing primer)
- Quantification of mRNA driving enzyme formation
    - Increasingly used, allows a direct link nitrification/ denitrification activity
    - Few studies only, even less for N_2O
- Combination of methods (enzymes, isotopes, mRNA/DANN)
    - pH effects on N_2O production (e.g. Cuhel et al., 2010, Appl. Environm. Microbiol.)

Quickly developing field, though methodological and scale problems needs to be solved, new insights in process regulation can be expected

Close correlation of nosZ gene expression and N_2 production in alpine grassland soils







Chen et al. Subm.

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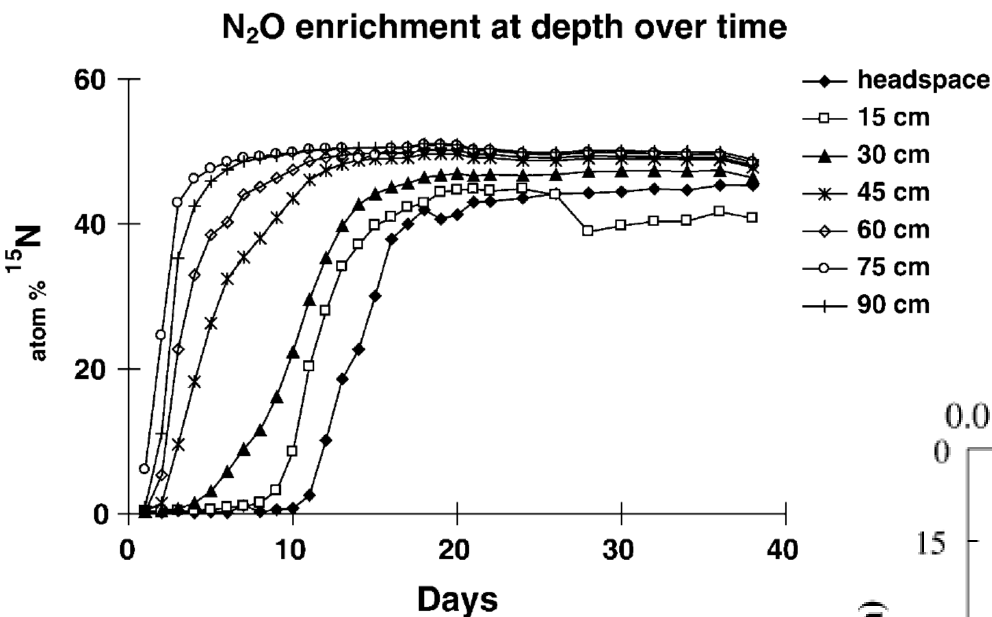
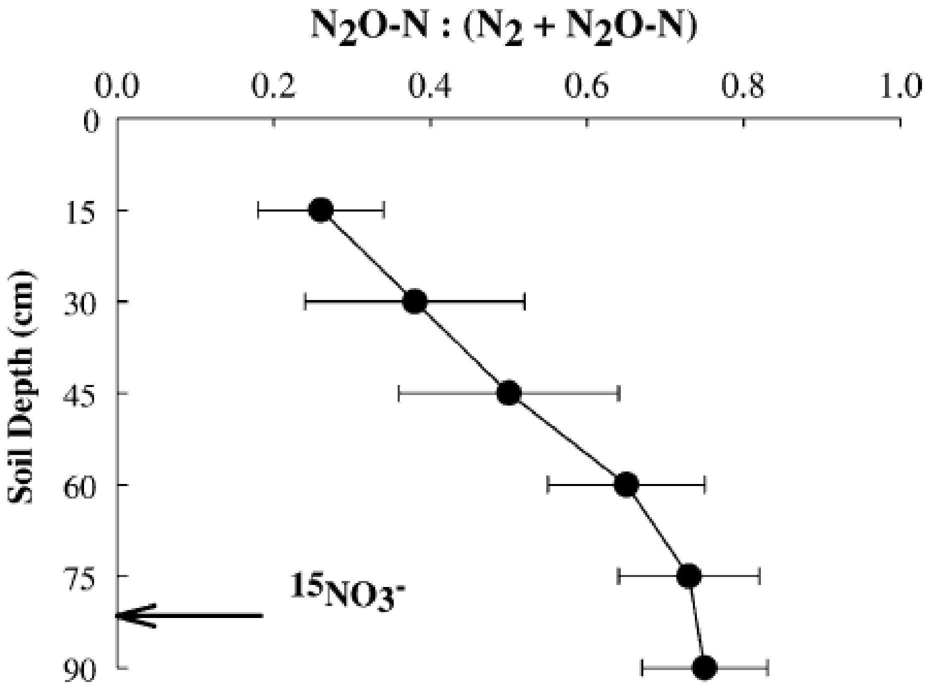
Soil surface flux N_2O = N_2O production – N_2O consumption





Clough et al. 2005 Nutr. Cycl Agroecosys

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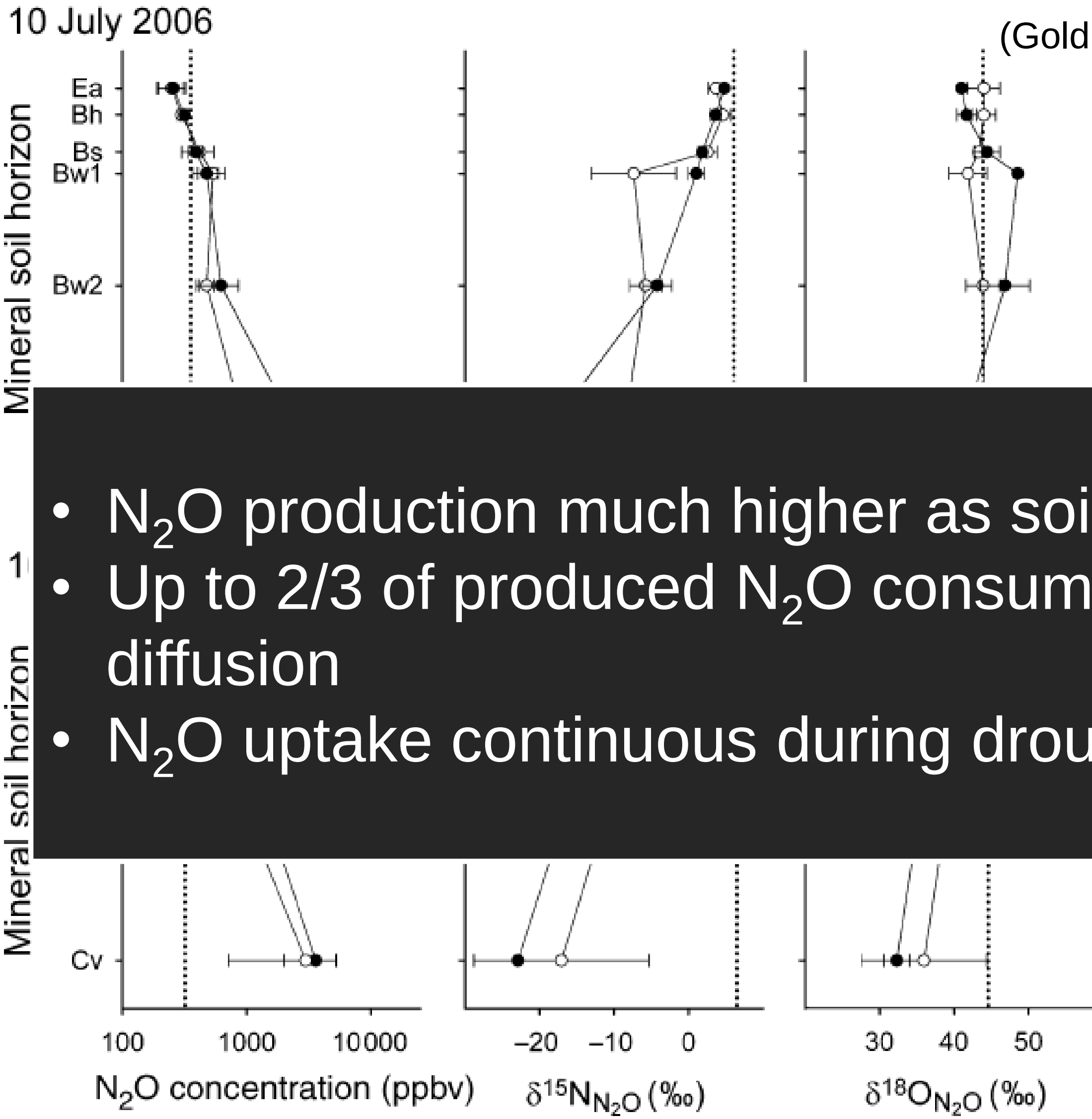
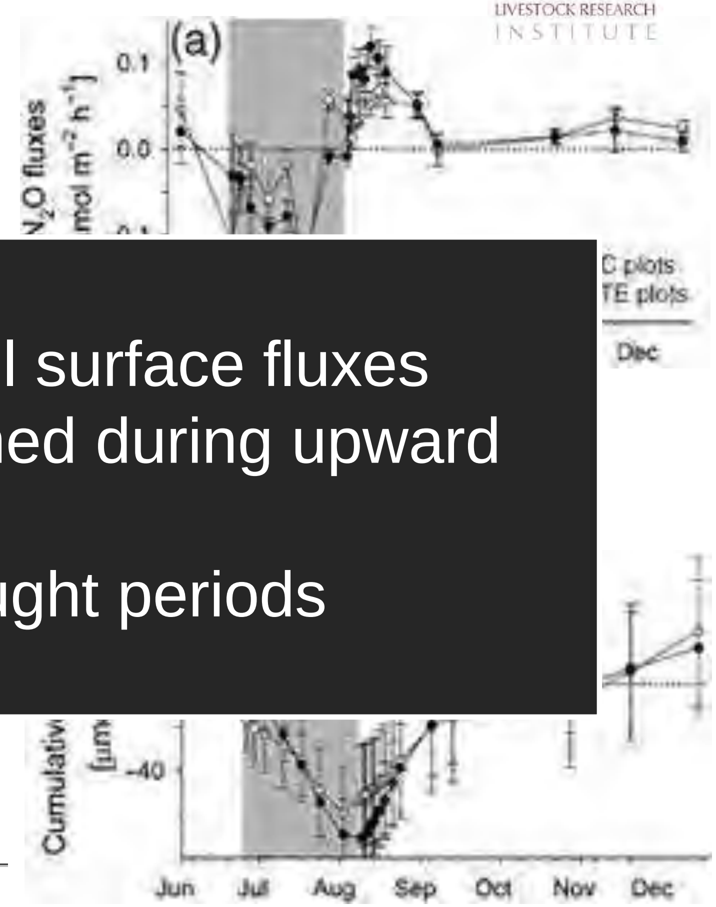
N_2O-isotope signals show significant N_2O consumption

(Goldberg & Gebauer 2009 GBC)

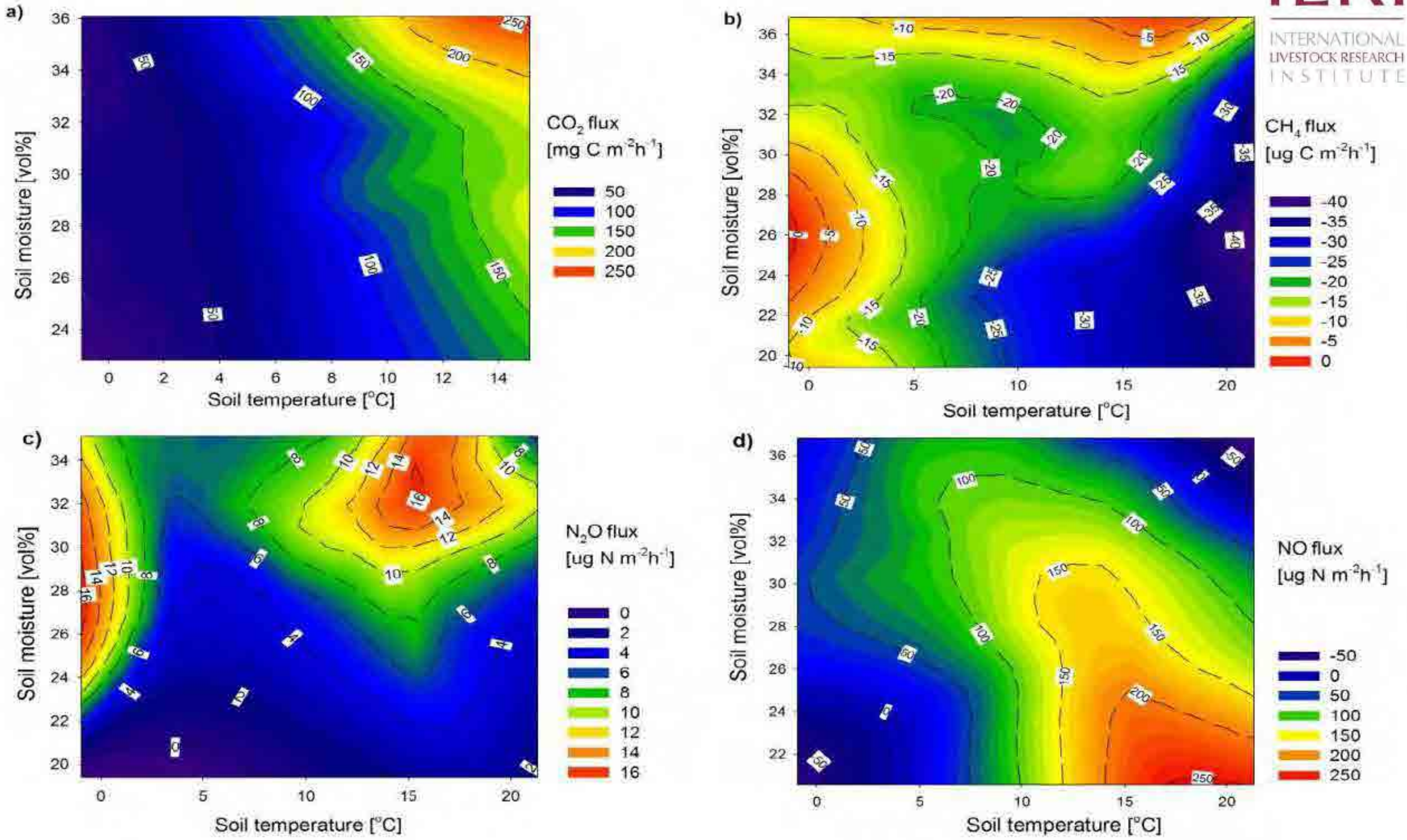




- N_2O production much higher as soil surface fluxes
- Up to 2/3 of produced N_2O consumed during upward diffusion
- N_2O uptake continuous during drought periods

Moisture-temperature control of soil trace gas fluxes

Höglwald Forest, Germany (Luo et al. Biogeosciences, 2012)



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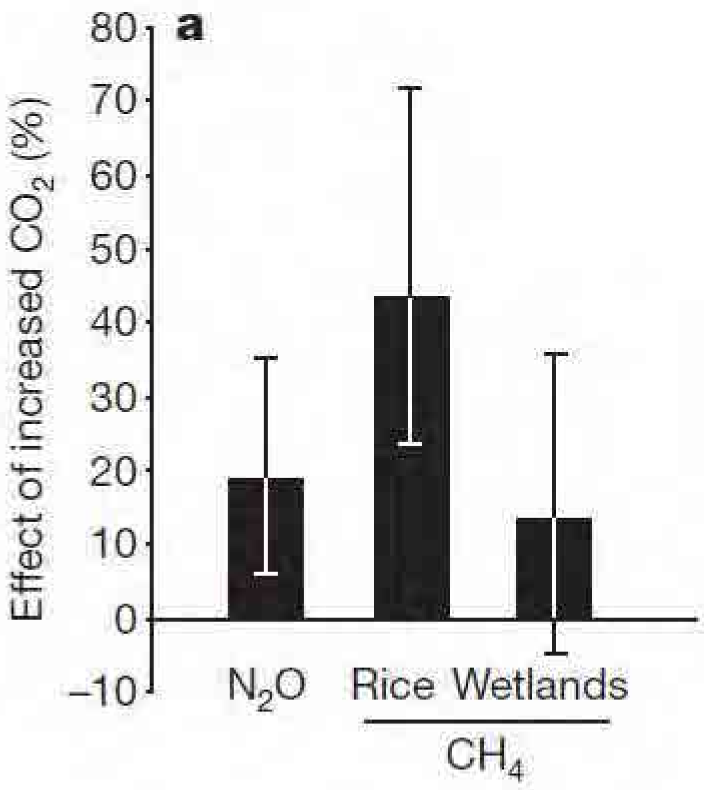
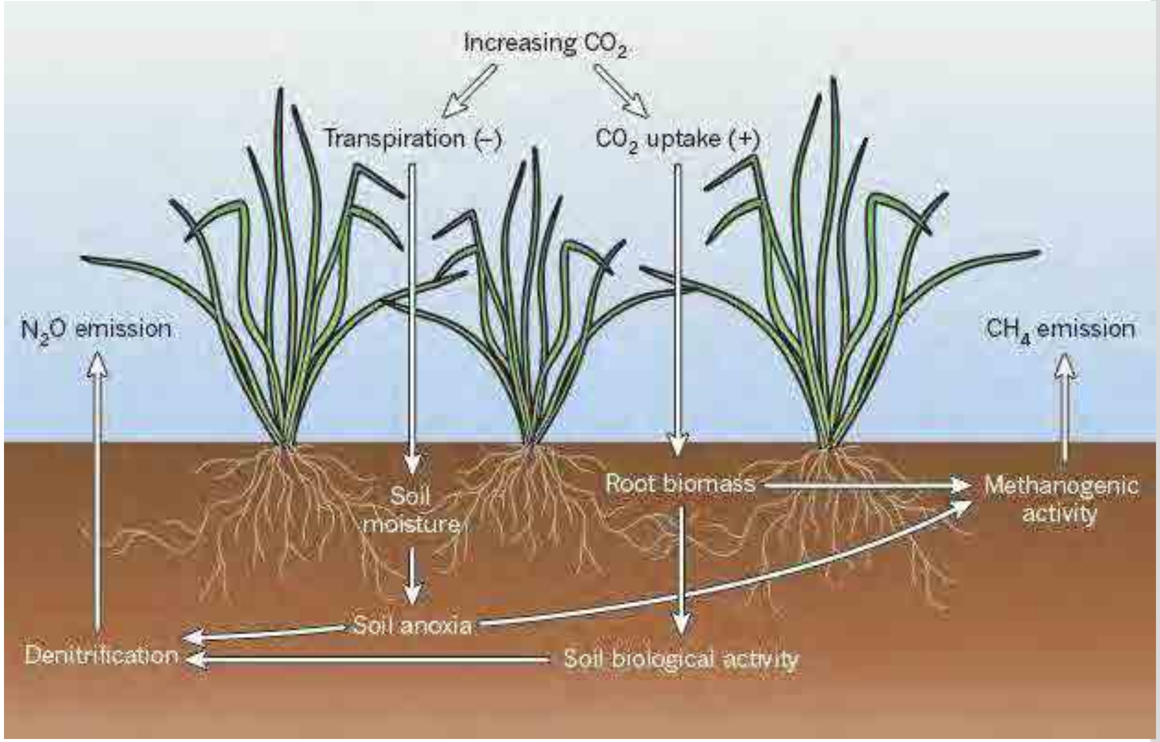
Increased atmospheric CO_2 and soil N_2O & CH_4 fluxes

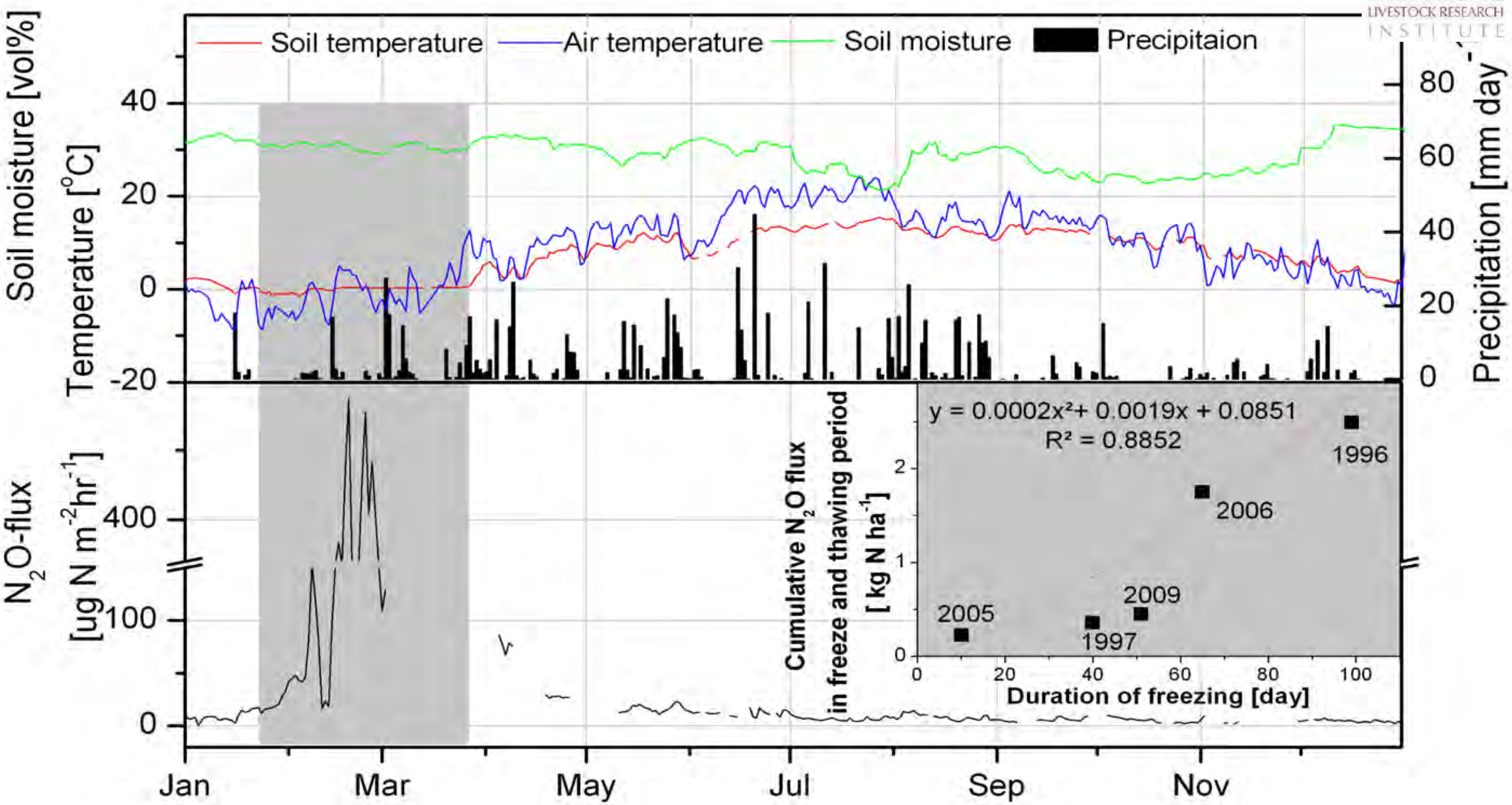
Meta-data study (Van Groeningen et al. 2011 Nature, Knohl & Veldkamp 2011 Nature)





Freeze-thaw N_2O fluxes

Höglwald Forest, Germany (Luo et al. Biogeosciences,2012)



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Enigma of denitrification at various scales

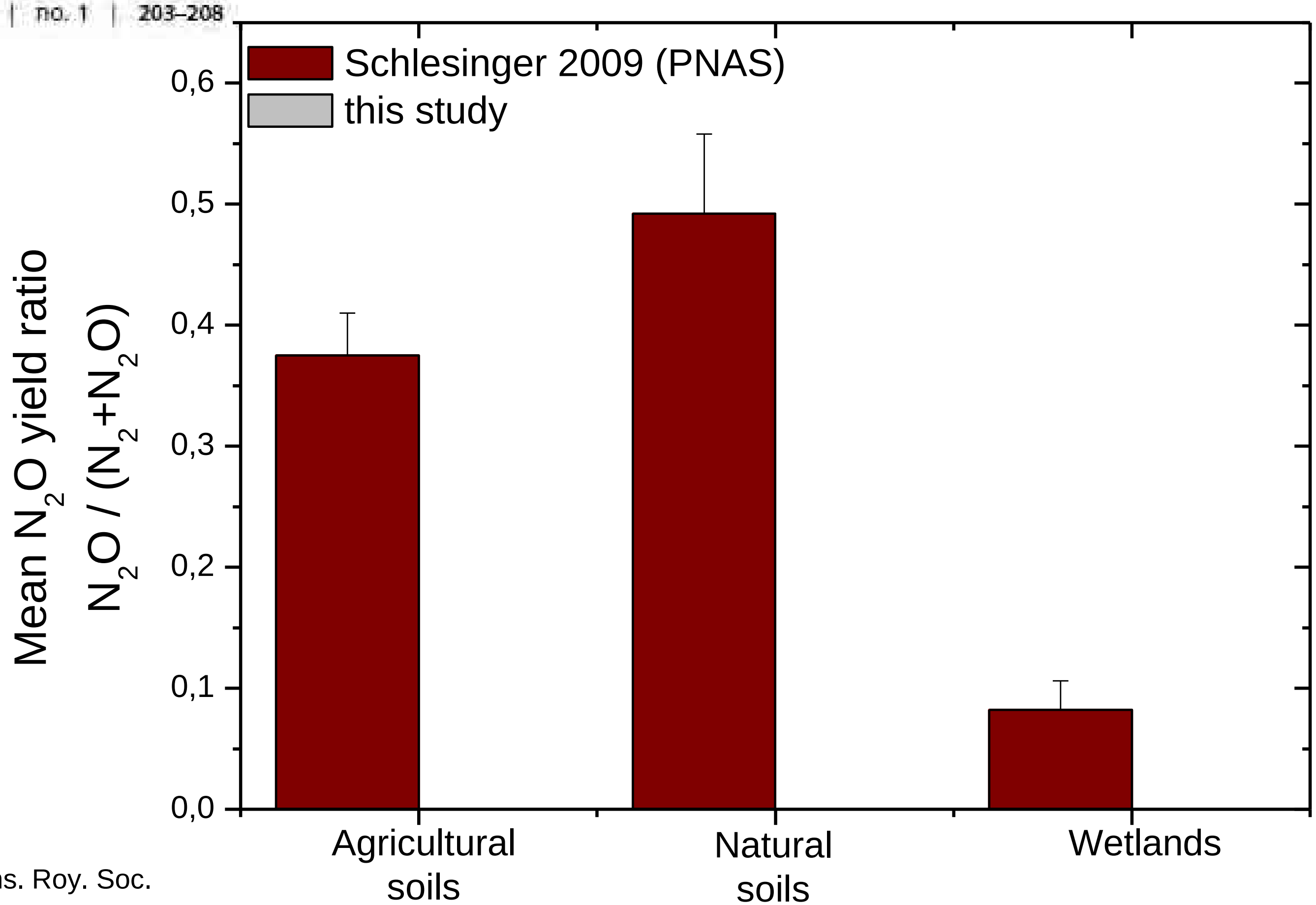
PNAS

On the fate of anthropogenic nitrogen

William H. Schlesinger[1]

Cary Institute of Ecosystem Studies, Box AB, Millbrook, NY 12545

PNAS | January 6, 2009 | vol. 106 | no. 1 | 203–208



Butterbach-Bahl et al., 2013, Phil. Trans. Roy. Soc.

Draw backs of the acetylene method

...osystem	reference	Remarks	gross nitrification kg N ha^{-1} yr^{-1}	net nitrification kg N ha^{-1} yr^{-1}	N_2 flux method	N_2O flux kg N ha^{-1}	N_2 loss kg N ha^{-1}	N_2:N_2O ratio	N_2:gross nitrification (%)	mean N_2O:(N_2O+N_2) this study ±SE	N_2O:(N_2O+N_2) Schlesinger et al. 2009 ±SE
...est, Germany ...Wald)	Wolf and Brumme 2002 Brumme et al. 1999	N-saturation	n.a.	n.a.	^{15}N gas flux	0.17	0.71	4.2	n.a.		
...st, Germany	Wolf and Brumme 2002 Brumme et al. 1999 Corre et al. 2003	N-saturation	211-744	n.a.	^{15}N gas flux	3	0.51	0.3	0.06-0.2		
...luegrass, USA	Horgan et al. 2002	Addition of 49 kg N ha^{-1} as K^{15}NO$_3^-$	n.a.	n.a.	^{15}N gas flux	0.1-2.9	1.6-10.4	2-11 (mean 5.5)	n.a.		
...est (Höglwald),	Butterbach-Bahl et al. 2002 Rosenkranz et al 2010 Wu et al. 2010 Kreutzer et al 2010 Matejek et al 2008	Cambisol, N-saturation; atmospheric N deposition of 30 kg N ha^{-1} yr^{-1}	403-487 (organic layer+mineral topsoil)	8	He/O$_2$	1.2 (0.09)	7 (0.7)	7.4	1.4-1.7		
...st (Höglwald),	Butterbach-Bahl et al 2002	Cambisol, N-saturation; atmospheric N deposition of 20 kg N ha^{-1} yr^{-1}	n.a.	n.a.	He/O$_2$	1.6-6.6	12.4 (3.1)	1.9	n.a.		
...st, Germany	Dannenmann et al. 2008 Dannenmann et al. 2006	Leptosol, atmospheric N deposition <10kg N ha^{-1} yr^{-1}, pH 6.2-7.2 ca. 8-11% SOC	69-105 (0-10cm topsoil)	15-20 (0-10cm topsoil)	He/O$_2$	0.05-0.22	1.8 - 6	27-112 mean 67	2.6-5.7		
...st, Germany	Dannenmann et al. 2006 Dannenmann et al. 2008	Leptosol, atmospheric N deposition <10kg N ha^{-1} yr^{-1}, pH 6.2-7.2; ca. 8-11% SOC, after reduction of basal area of trees by 70%	249 (0-10cm topsoil)	21-42 (0-10 cm topsoil)	He/O$_2$	0.85	30.7	36	12.3		
...inforest, Australia ...Ker)	Kiese et al. 2008 Kiese et al. unpublished (N_2) Kiese et al. 2003 N_2O	Tropical rainforest pH 4.1, Oxisol	0-5 cm 559	n.a.	He/O$_2$	0.96	2.0-4.7	2.0-4.7	0.3-0.8		
...plantation	Uri et al 2011	N fixation of 150 kg N ha-1 yr-1	n.a.	124	He/O2	0.5	73.8	47-261 mean 171	n.a.	0.207 ±0.079	0.492 ±0.066
...l soil (California)	Rolston et al (1978)	Yolo loam soil, ryegrass; 300 kg N ha^{-1} K^{15}NO$_3$ addition, different soil water content	n.a.	n.a.	^{15}N gas flux	0.1-1.8	1. 9-24	5-25	n.a.		
...soil California	Rolston et al (1978)	Yolo loam soil, Manured; 300 kg N ha^{-1} K^{15}NO$_3$ addition, different soil water content	n.a.	n.a.	^{15}N gas flux	3.8-9.9	26-198	8-20	n.a.		
...soil California	Rolston et al (1978)	Yolo loam soil, uncropped; 300 kg N ha^{-1} K^{15}NO$_3$ addition	n.a.	n.a.	^{15}N gas flux	0.2-2.1	0-5.7	1-7	n.a.		
...soil California	Rolston et al (1982)	straw addition; 300 kg N ha^{-1} KNO$_3$ addition	n.a.	n.a.	^{15}N gas flux	0.8-1.8	4-17.6	5-25	n.a.		
...l soil ...UK	Colbourn et al. 1984	Winter wheat; Fertilized 53 kg NH$_4$NO$_3$ ha^{-1}	n.a.	n.a.	^{15}N gas flux	2.3±0.4	28.5	12	n.a.		
...l soil (USA)	Mosier et al 1986	Corn; fertilization with 200 kg ^{15}NH$_4^+$-N ha^{-1} 120 days monitoring	n.a.	n.a.	^{15}N gas flux, ^{15}NH$_4^+$ labelling	3	<1.5	0.8	n.a.		
...l soil (USA)	Mosier et al. 1986	Fertilization with 200 kg ^{15}NH$_4^+$ N ha^{-1} 100 days monitoring	n.a.	n.a.	^{15}N gas flux, ^{15}NH$_4^+$ labelling	0.8	<0.7	6	n.a.		
...otton field	Scheer et al. 2009	fertilization with 250 kg mineral N ha^{-1} yr^{-1}	n.a.	n.a.	He/O2	0.9-6.5	24-175	5-55 mean 27	n.a.	0.150 ±0.061	0.375 ±0.066
	Lindau and Delaune 1991	33 days period investigated, 100 kg N ha^{-1} as K^{15}NO$_3^-$	n.a.	n.a.	^{15}N gas flux	2	16	3-250 Mean 73	n.a.		
...lain forest	Delaune et al. 1998	100-300 kg N ha^{-1} yr^{-1} fertilization plus experimental addition of 100 kg ^{15}NH$_4^+$ or ^{15}NO$_3^-$	87.6	n.a.	^{15}N gas flux	3.4-5.4 year^{-1}	97-298 year^{-1}	42	111-340		
...eshwater marsh ...iver	Yu et al 2006	Annual estimates of N_2 and N_2O provided, 38 kg ^{15}NO$_3^-$ N ha^{-1} addition	n.a.	n.a.	^{15}N gas flux	2 yr^{-1}	145 yr^{-1}	66	n.a.		
...tland Canada	Wray and Bayley 2007	floating and non-floating conditions	n.a.	n.a.	He/O$_2$	-0.3 to 0.2	240	196 (at positive N_2O flux)	n.a.		
...d wetland for ...r treatment,	Mander et al 2008	monthly measurements for 1.7 years	n.a.	n.a.	He/O$_2$	0.37-0.6	15-23	25-61	n.a.		
...monolith fen in	Roebroeck et al. 2010	hollow and tussocks considered, low atmospheric N deposition	n.a.	n.a.	He/O$_2$	-0.1	157	N_2O fluxes <0	n.a.	0.016 ±0.004	0.082 ±0.024

...ssion

...on in

N_2

2

NO nitrification

n

Bollmann & Conrad (1997) Soil Biol. Biochem 29,7: 1067-1077

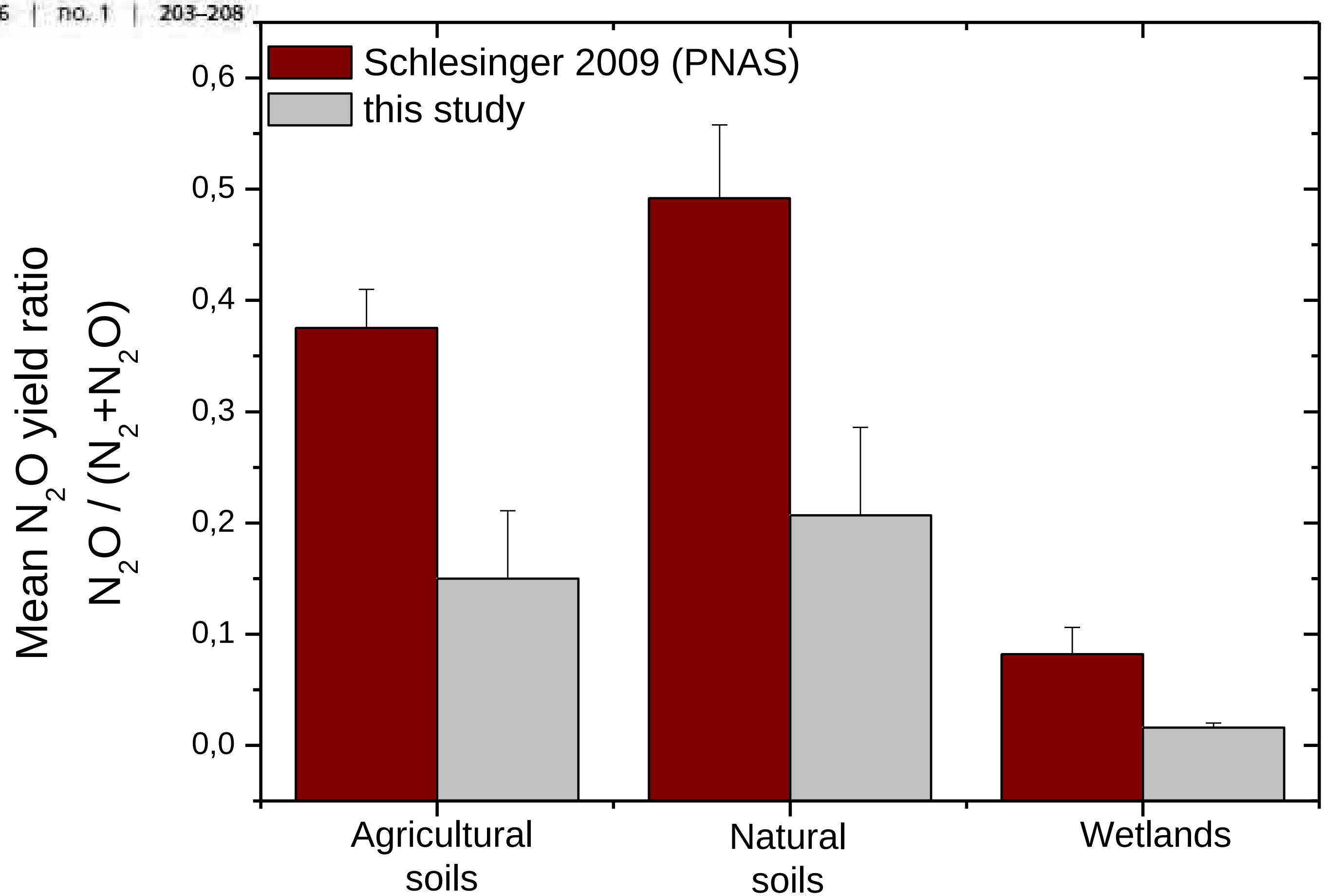
Enigma of denitrification at various scales

On the fate of anthropogenic nitrogen

William H. Schlesinger[1]

Cary Institute of Ecosystem Studies, Box AB, Millbrook, NY 12545

PNAS | January 6, 2009 | vol. 106 | no. 1 | 203–208



Karlsruhe Institute of Technology

Enigma of denitrification at various scales

ILRI
INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

PNAS

On the fate of anthropogenic nitrogen

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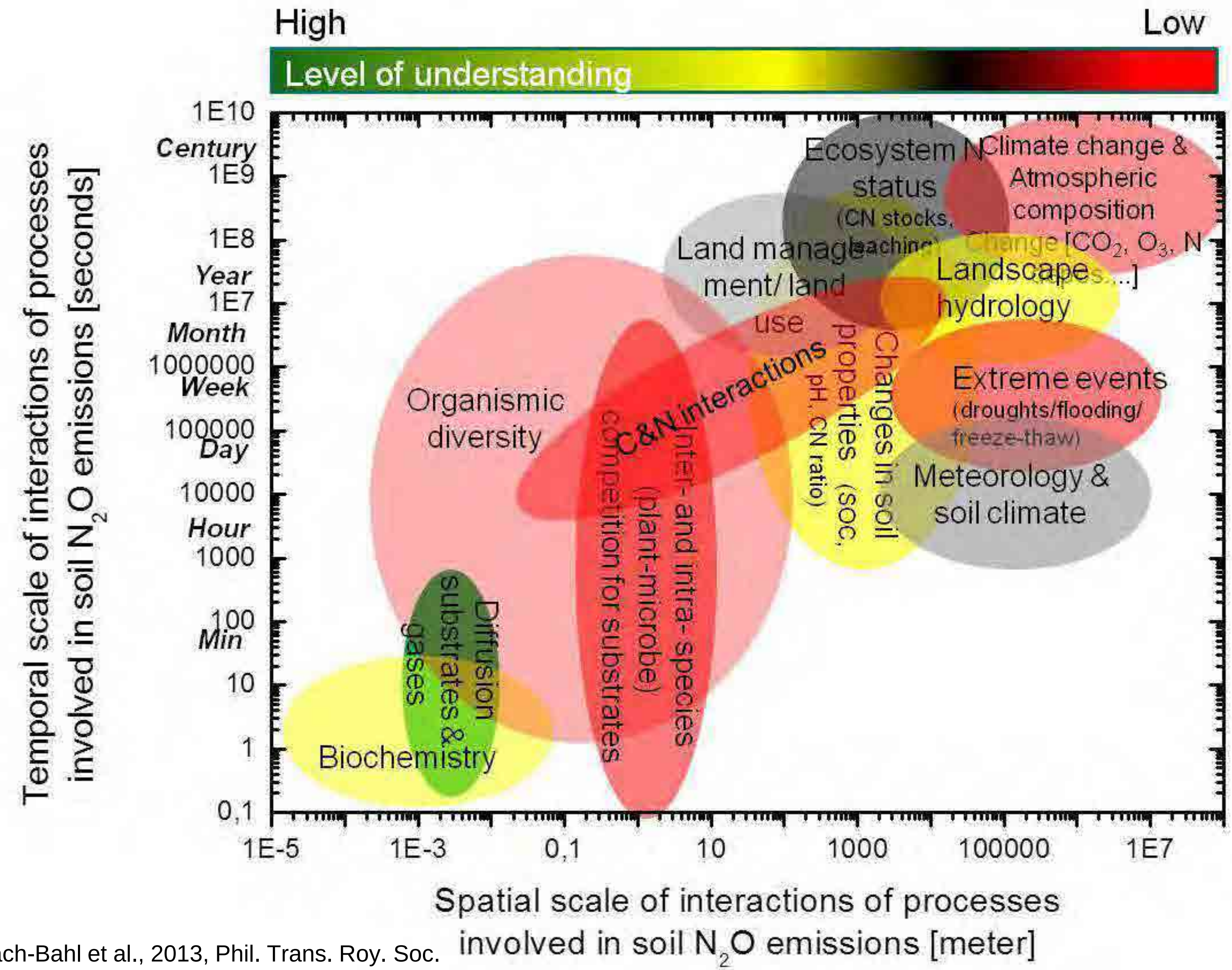
Table 3. Budgets for nitrogen on the global land surface (Tg)

	Pre-industrial	Human derived	Total
Inputs			
Biological nitrogen fixation	120	20†	140
Lightning	5	0	5
Industrial N-fixation	0	125‡	125
Fossil fuel combustion	0	25	25
Totals	125	170	295
Fates			
Biospheric increment	0	9	9
Riverflow	27	35	62
Groundwater	0	15	15
Denitrification	92*	17	109
Atmospheric transport to the ocean	6	48	54
Totals	125	124	249

46

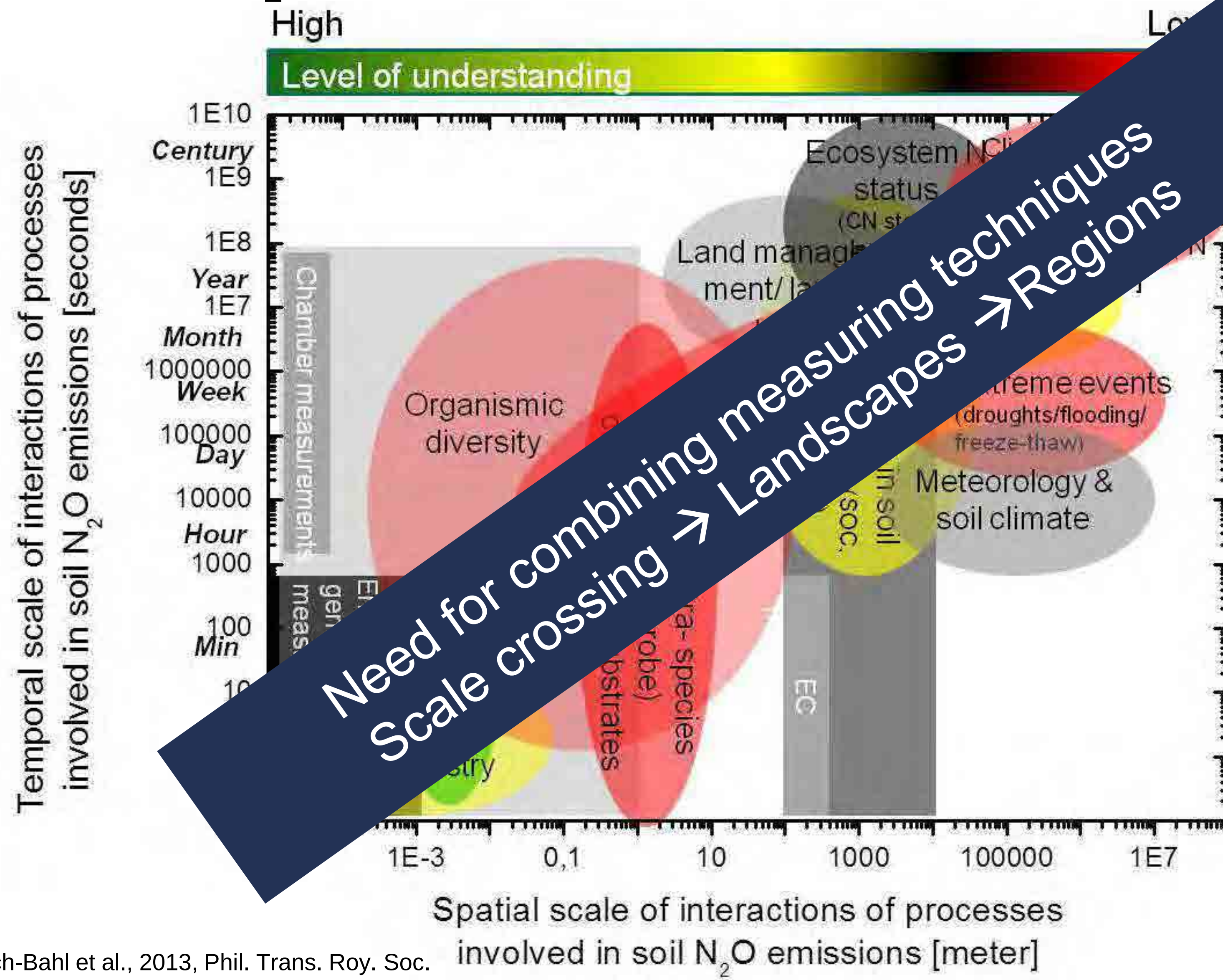
Butterbach-Bahl et al., 2013, Phil. Trans. Roy. Soc.

Interaction of N_2O processes – matter of scale



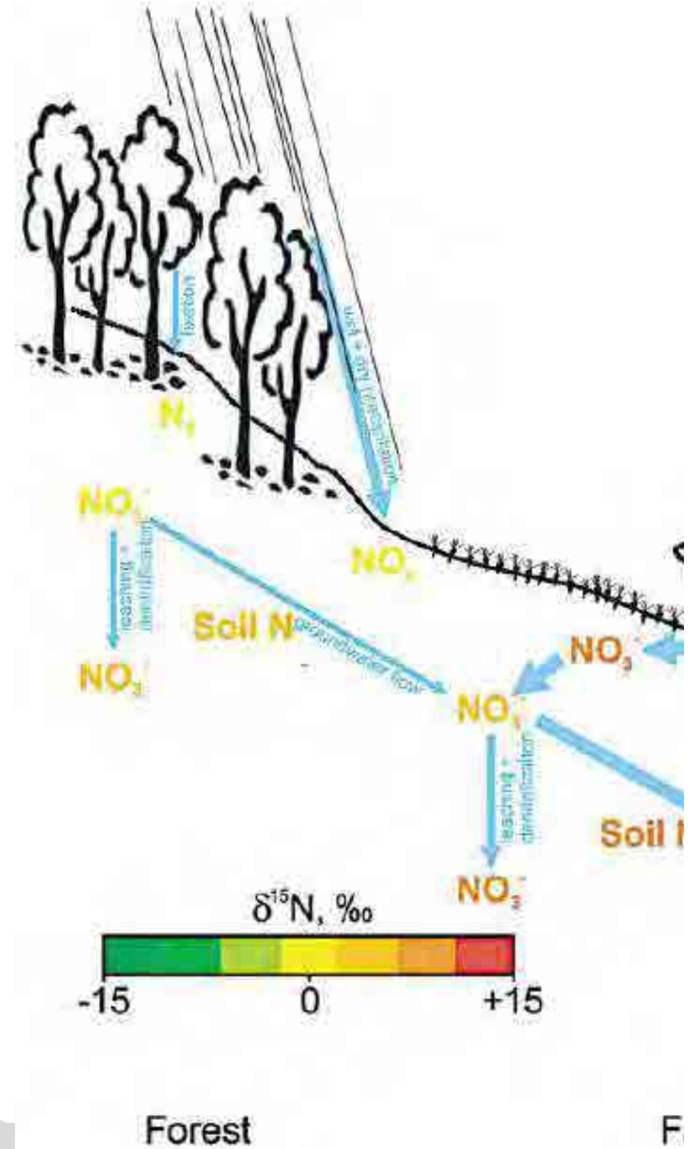
Butterbach-Bahl et al., 2013, Phil. Trans. Roy. Soc.

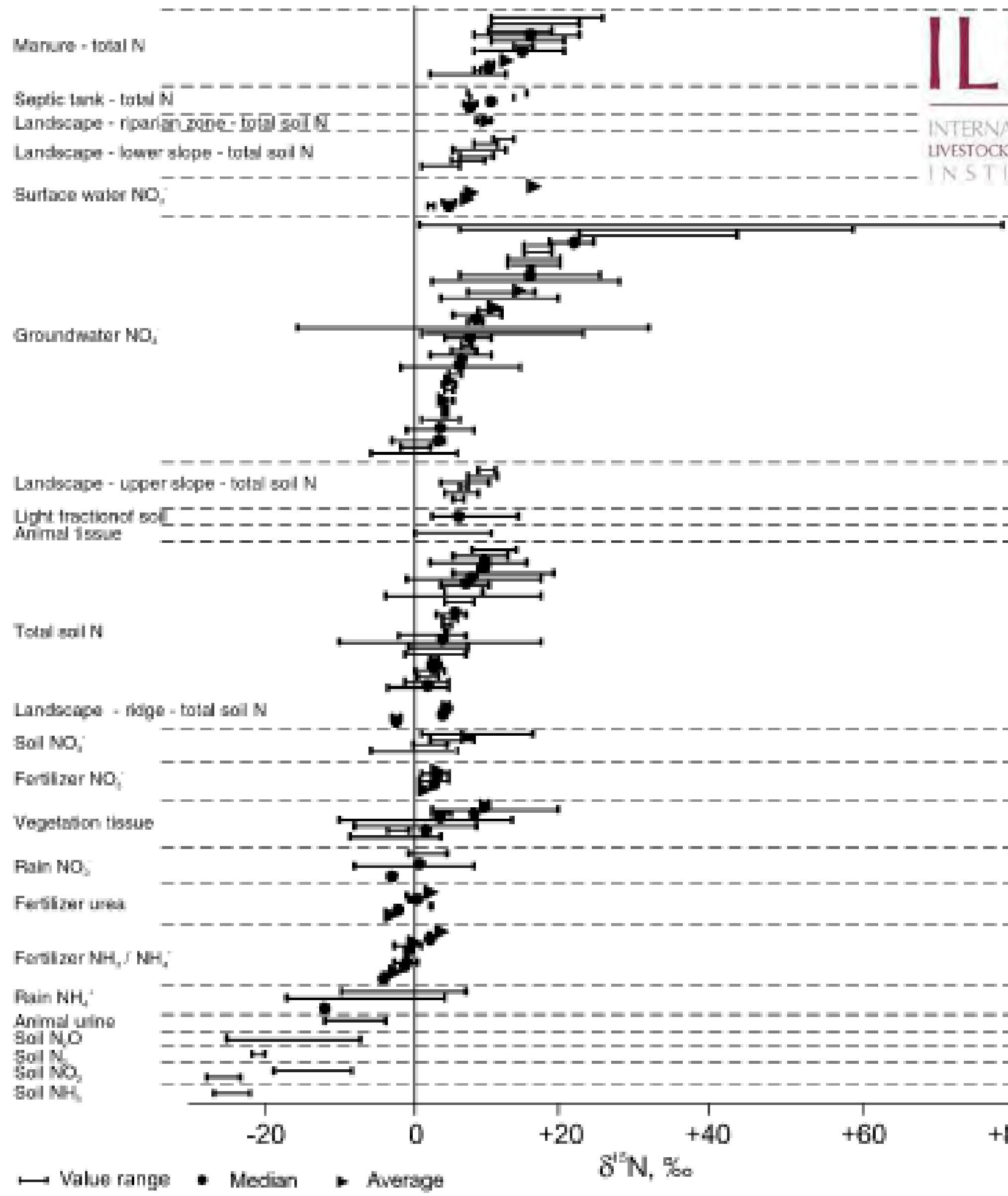
Interaction of N_2O processes – matter of scale



Butterbach-Bahl et al., 2013, Phil. Trans. Roy. Soc.

Tracing N (&N_2O?) at landscape scales (Bedard-Haughn et al., 2003, J. Hydrol.)





Tracing N (&N_2O?) at landscape scales

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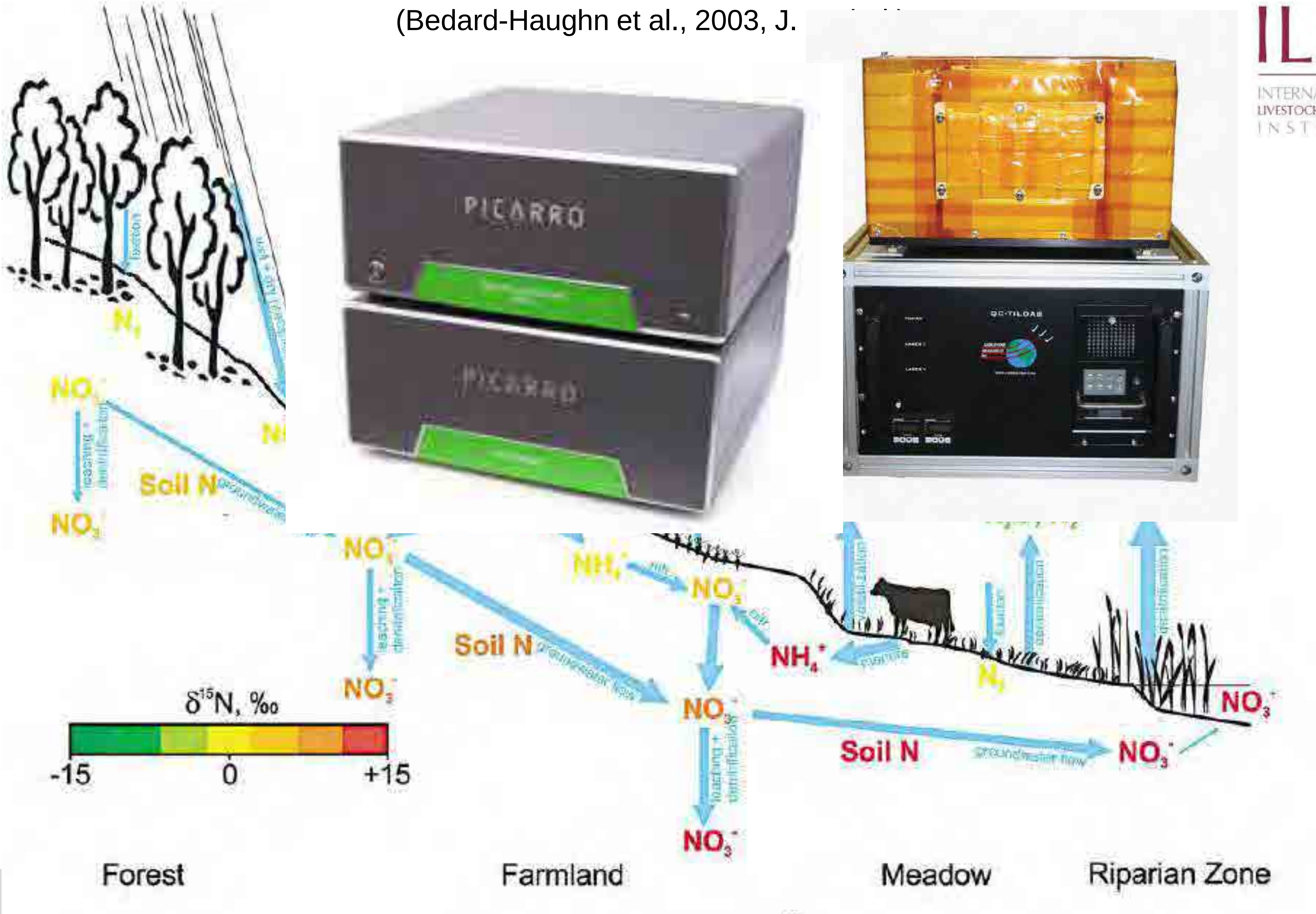
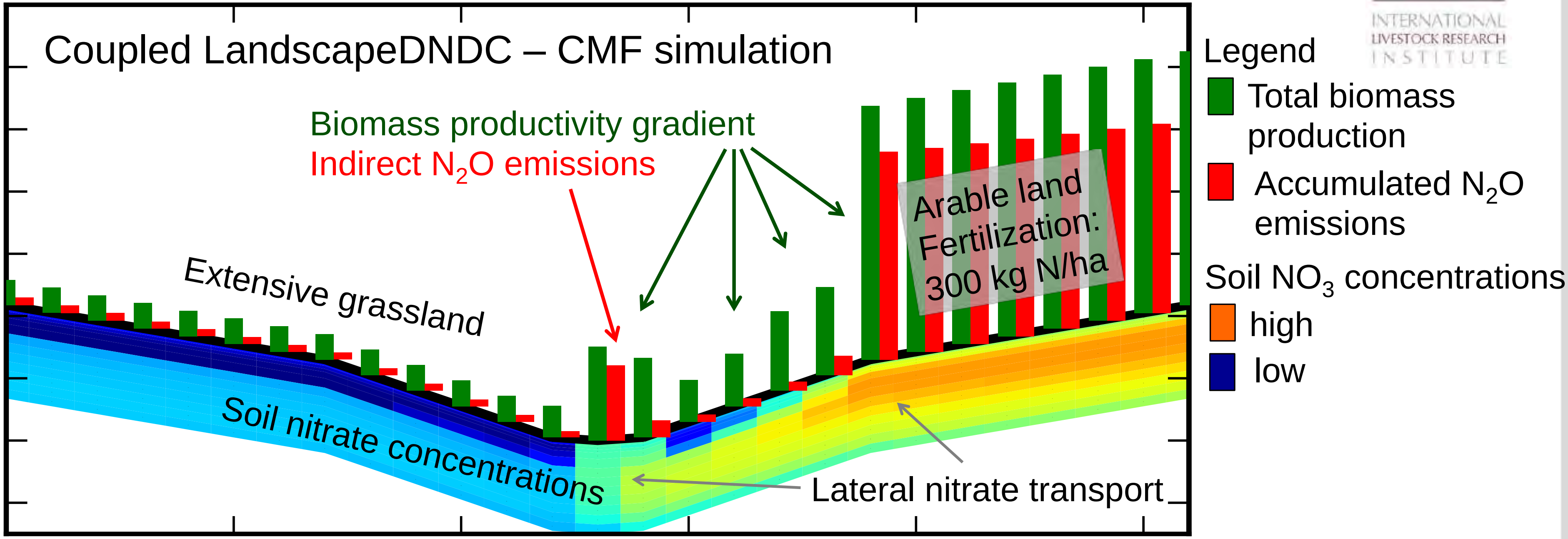
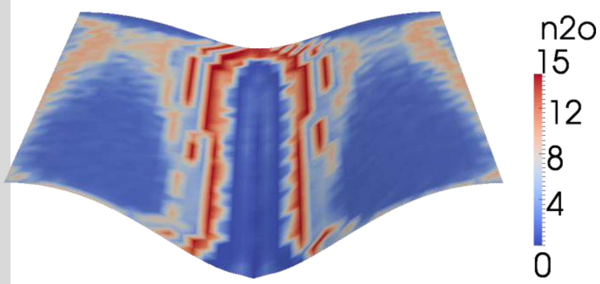
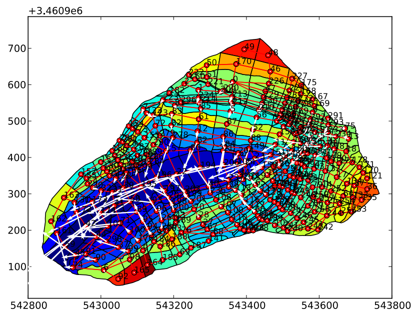


Coupling Biosphere - Hydrosphere Processes from the hillslope to the Landscape Scale

Haas et al, 2013, Landscape Ecology







Institute for Meteorology and Climate Research, Atmosphere-Biosphere Interactions and Global Change, Biogeochemical Processes

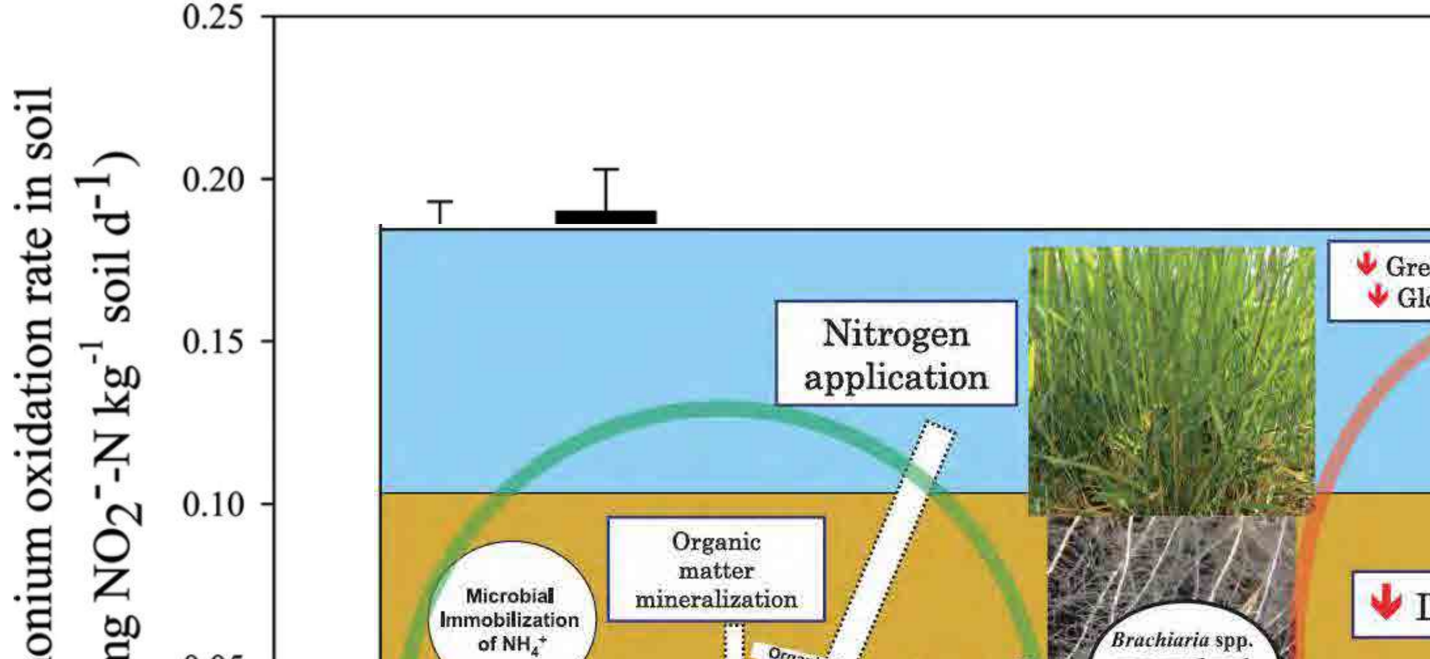
Conclusions

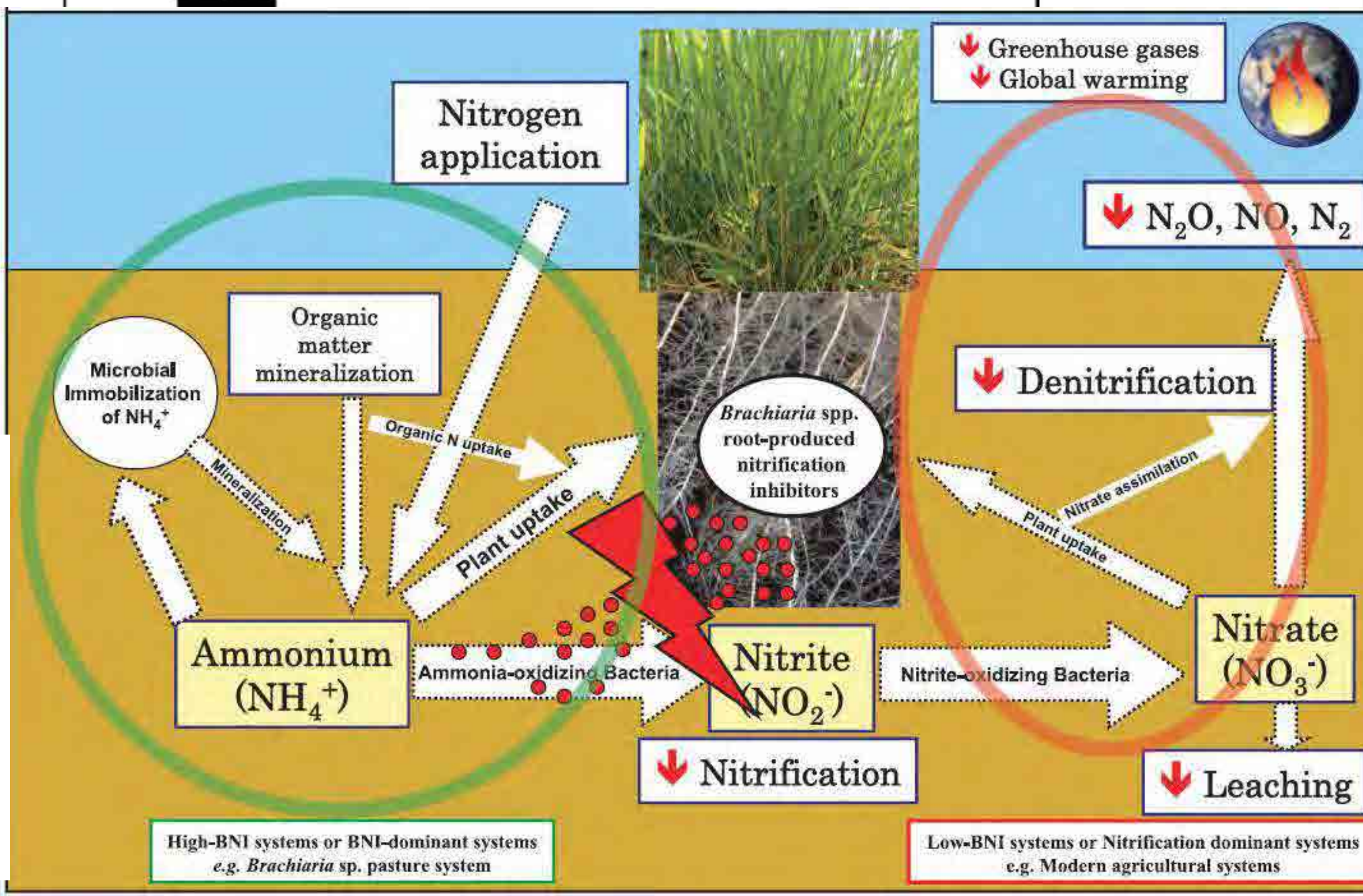
- Difficulties to identify source processes of soil N_2O fluxes
- Methodological problems with denitrification still unsolved
- Molecular biology tools may help to disentangle source and sink processes and importance of microbial diversity for flux regulation
- Scale issue hardly addressed by measurements
- Landscape scale modeling needed

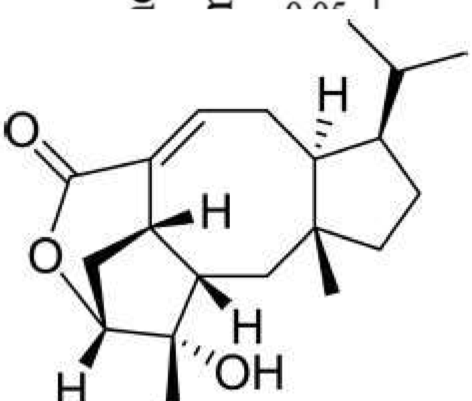
Institute for Meteorology and Climate Research,
Atmosphere-Biosphere Interactions and Global Change,
Biogeochemical Processes

Biological nitrification inhibition by plants

(Subbarao et al. 2009 Breeding Sci. & Subbarao et al. 2009 PNAS)



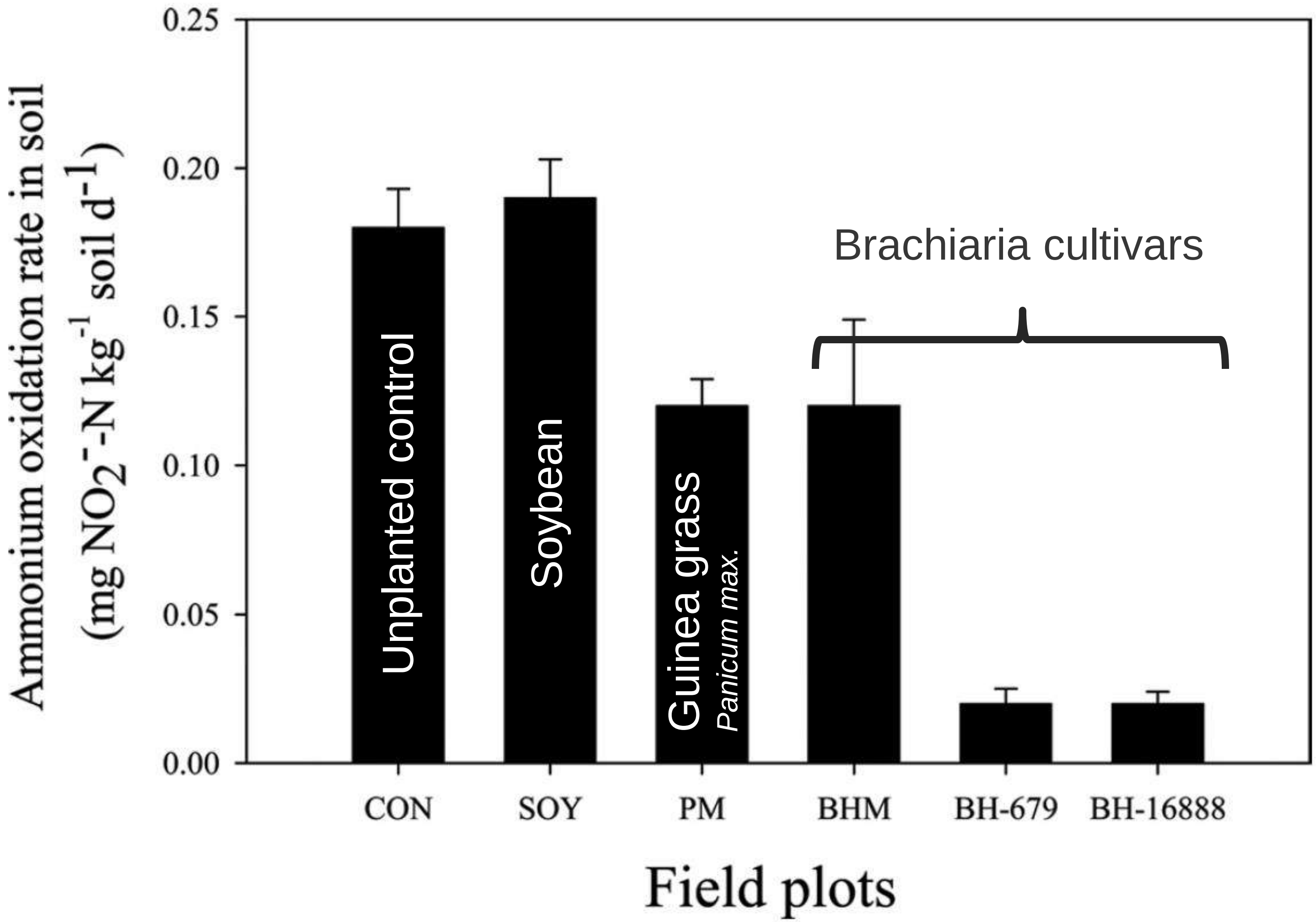




Brachialactone

Biological nitrification inhibition by plants

(Subbarao et al. 2009 Breeding Sci. & Subbarao et al. 2009 PNAS)



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Introductory lecture

State of the art of nitrous oxide emission models

Pete Smith

University of Aberdeen &
Scottish Food Security Alliance-Crops, UK

17-19 March 2014
PARIS

Workshop "Experimental databases and model of N2O emissions by croplands:
do we have what is needed to explore mitigation options?"

Many models simulate GHG emissions

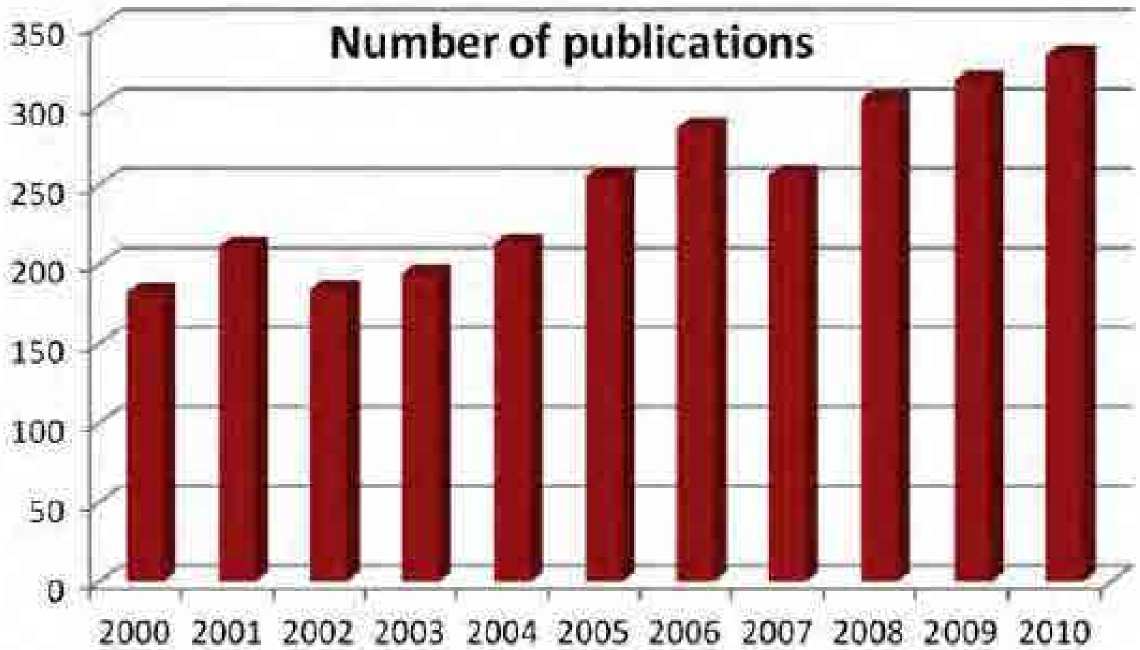
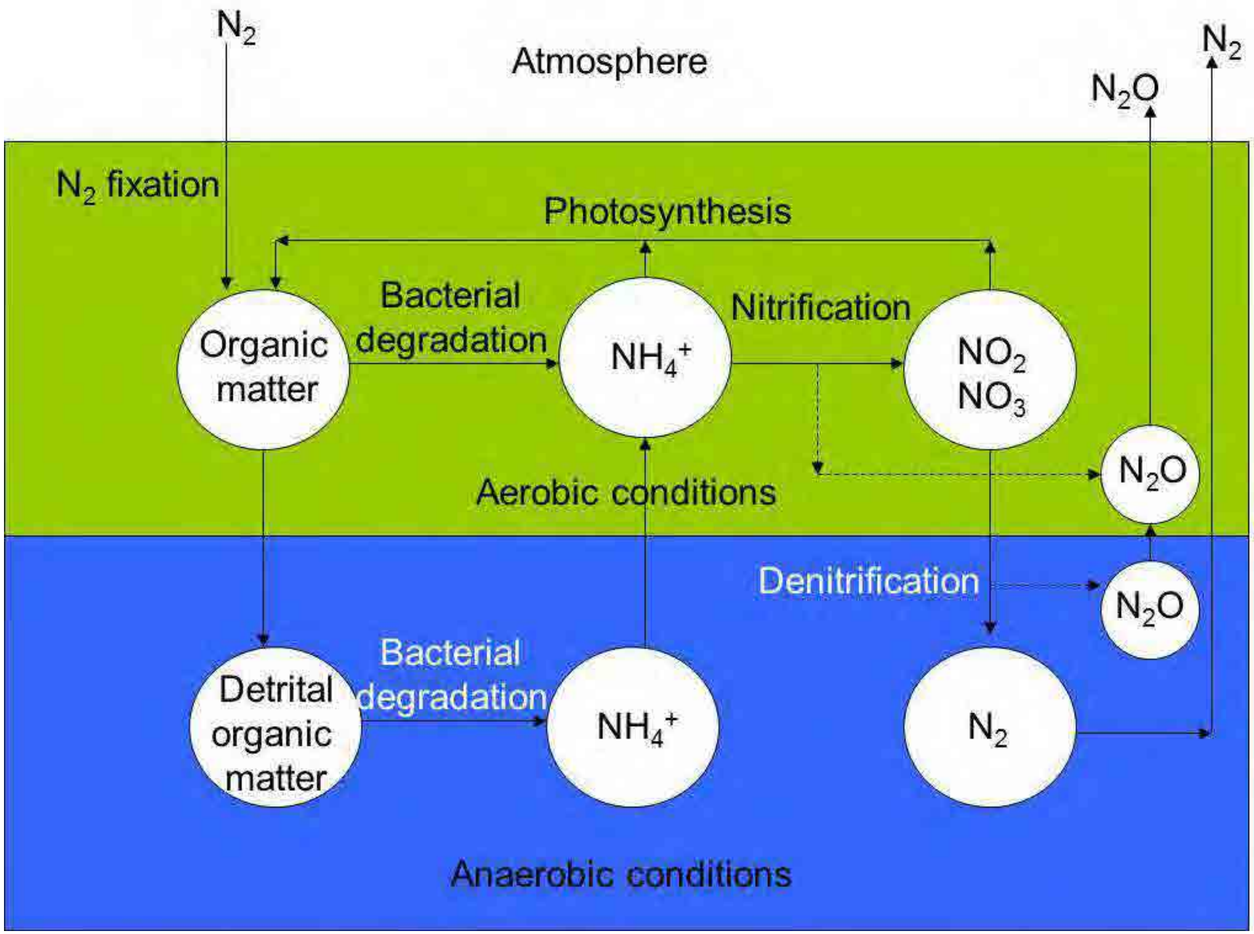


Fig. 1. Number of articles containing words "soil" "modelling" and one or more greenhouse gases (CO_2, N_2O, CH_4) in title or in the abstract, which were published in the previous decade according to the SCOPUS database (http://www.scopus.com). Search query: TITLE-ABS-KEY (**soil** AND (**model***) AND (**co2** OR **n2o** OR **ch4** OR **methane** OR (**nitrous oxide**))).

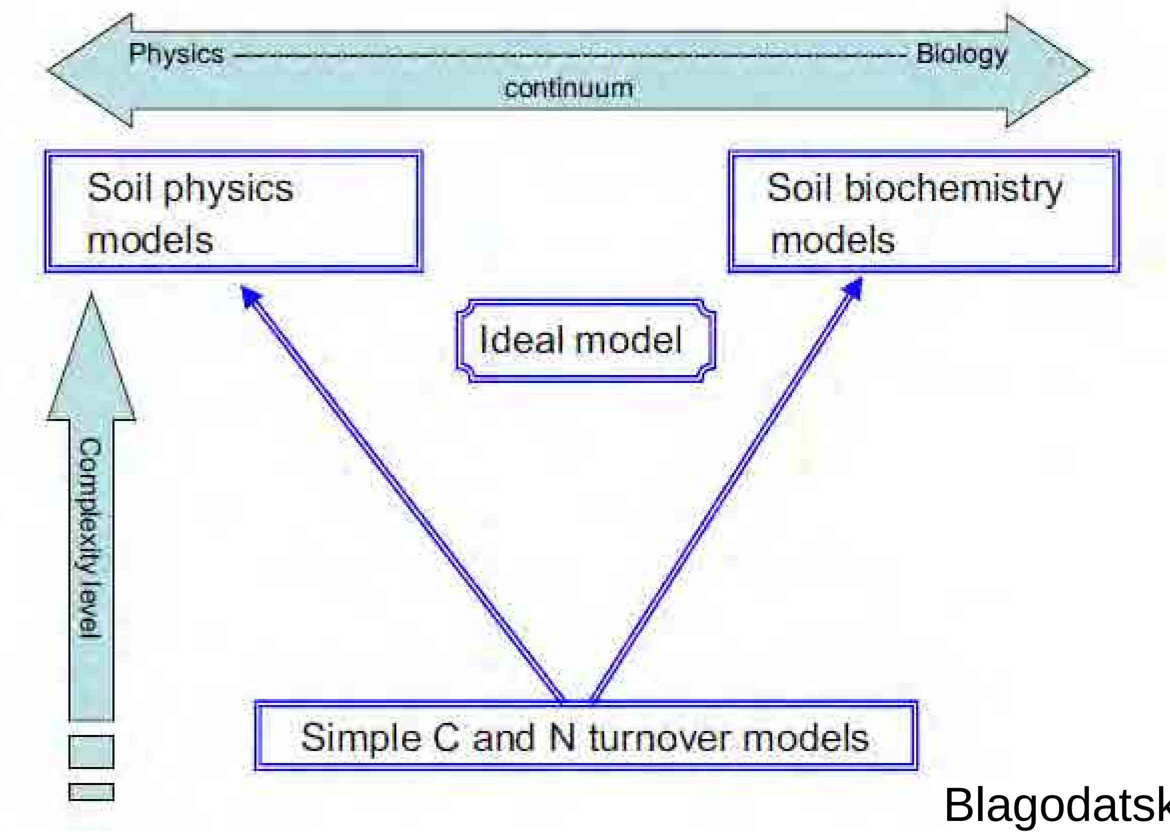
Blagodatsky & Smith (2012)

All N_2O emissions models are trying to do the same thing



After Wollast (1981)

Different types of model for simulating GHG emissions



Blagodatsky & Smith (2012)

Relative gas diffusivity differs

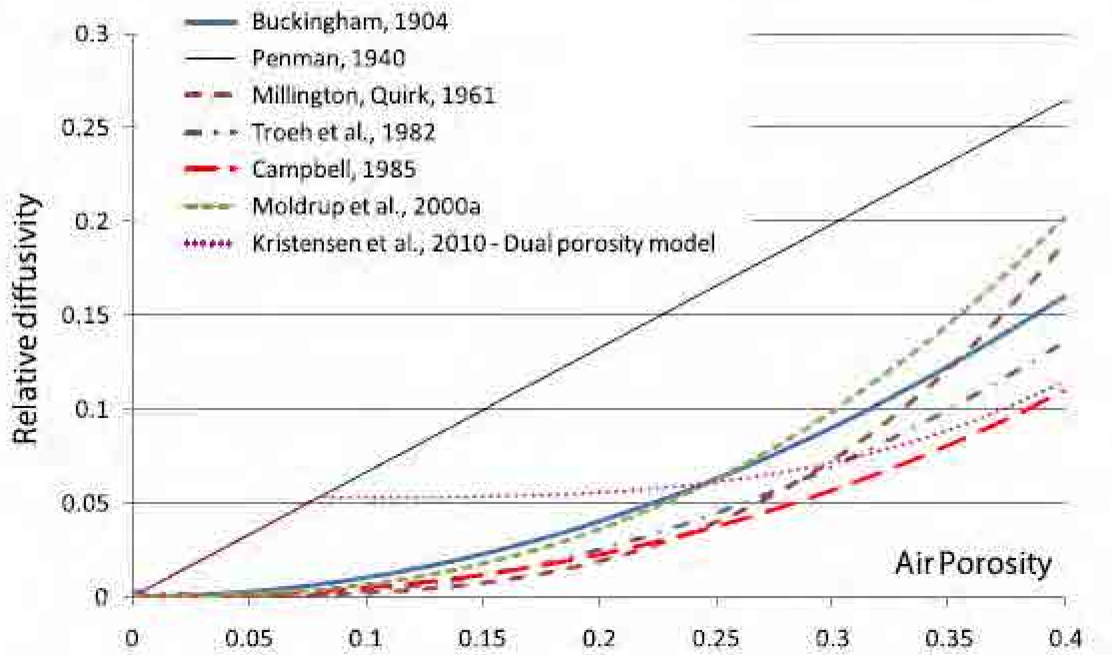
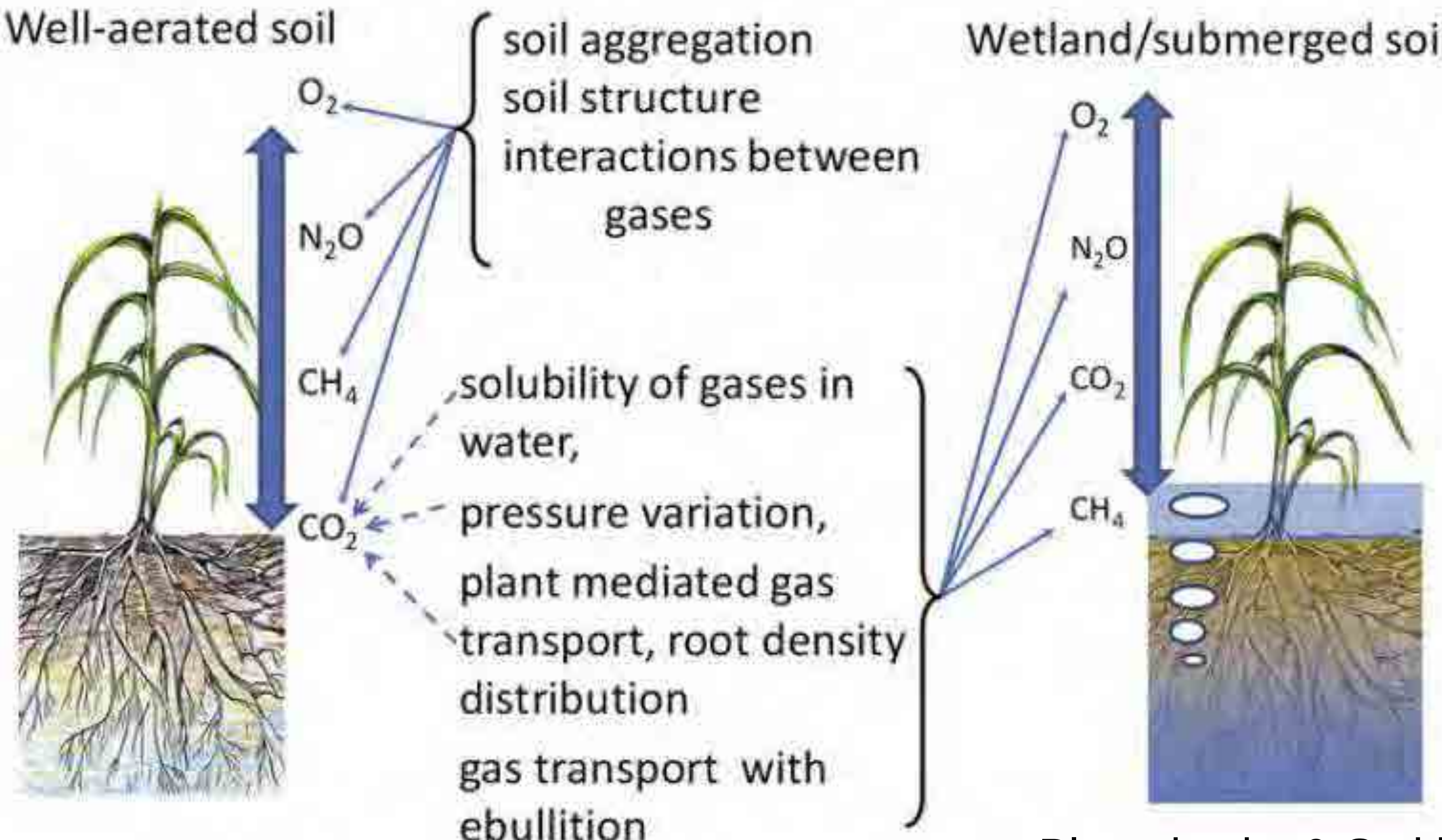


Fig. 3. Relative gas diffusivity D_p/D_0 as a function of air-filled porosity. The following dependencies are plotted: ε^2, (Buckingham, 1904); 0.66ε, (Penman, 1940); Eq. (3), (Millington and Quirk, 1961); Eq. (2), (Troeh et al., 1982); $0.9\varepsilon^{2.3}$ (Campbell, 1985); Eq. (4), (Moldrup et al., 2000a); Eq. (8), (Kristensen et al., 2010).

Blagodatsky & Smith (2012)

Necessary model features or driving variables



Blagodatsky & Smith (2012)

Lots of models out there…

Table 2
Models combining transport and biological processes leading to the emission of greenhouse gases. Number of asterisks (1–3) shows the level of detail in description of the physical and biological processes.

Model, reference	Simulated gases	Soil physics description	Soil biology (C and N turnover) description
Ouyang and Boersma, 1992a, b	O_2, CO_2	*** water, heat and gas transport, gaseous solubility in water and adsorption on solid phase	** root respiration, heterotrophic microbial growth (double Mono kinetics) and maintenance
ECOSYS, Grant et al., 1993a, b, c and other works	O_2, CO_2, N_2O, CH_4	*** transport within and transfer between aqueous and gaseous phases, vertical gaseous diffusion and convection	*** multiple group microbial growth (Mono kinetics), autotrophic nitrification, denitrification, methane production and oxidation
Arah and Stephen, 1998	O_2, CH_4	*** vertical gaseous diffusion in air and water and plant-mediated gas transport	** dual substrate Michaelis–Menten kinetics for CH_4 oxidation and CH_4 production with oxygen inhibition
PATCIS, Fang and Moncrieff, 1999; Hui and Luo, 2004	CO_2	*** inter- and intra-aggregate gaseous diffusion, gaseous convection, gaseous solubility and dispersion with water	* first-order two-pools decomposition with temperature, moisture and oxygen scaling factors
DNDC-family, e.g. Li, 2000; Li et al., 2000; de Bruijn et al., 2009	O_2, CO_2, NO, N_2O, N_2, CH_4	** water transport, vertical gaseous diffusion, anaerobic balloon concept	** multi-pool decomposition model with explicit description of denitrification
Walter and Heimann, 2000	CH_4	** gaseous transport as diffusion, ebullition and plant-mediated gas transport	** substrate dependent CH_4 production and Michaelis–Menten kinetics for CH_4 oxidation separated by water table
DAYCENT, Del Grosso et al., 2000; Parton et al., 2001;	CO_2, NO, N_2O, CH_4	* soil diffusivity affects final ratio of NO/N_2O and CH_4, no explicit description of gas transport	** first-order multi-pool decomposition model, no explicit modelling of microbial growth
PASIM, Schmid et al., 2001; Vuichard et al., 2007	CO_2, N_2O	* resistance model for N_2O diffusion in root-layer, N_2O transfer between gaseous and liquid phases and between anaerobic production zone and soil pool	** nitrification and denitrification process description, no explicit microbial growth
Segers and Leffelaar, 2001a, b	O_2, CH_4, CO_2, N_2	*** gaseous transport as diffusion, ebullition and plant-mediated gas transport	*** full kinetic description of CH_4 production and oxidation and other electron acceptor reduction/oxidation
COUP, Jansson and Moon, 2001; Norman et al., 2008	O_2, CO_2, NO, N_2O, N_2	** water, heat and gas transport (Fickian diffusion), anaerobic balloon concept	** multi-pool decomposition model with explicit description of microbial biomass dynamics and denitrification
Langeveld and Leffelaar, 2002	O_2, CO_2, N_2O	*** vertical gaseous diffusion, local anaerobiocity with randomly/regularly distributed pore model	** growth of denitrifiers and strict aerobs, double Mono kinetics
EXPERT-N, Kaharabata et al., 2003; Klier et al., 2011	N_2O	** gaseous diffusion/dispersion in air and liquid phase	*/** multiple options for multi-pool decomposition models, no explicit microbial growth description
Kettunen, 2003	O_2, CH_4	* vertical gaseous diffusion and plant-mediated gas transport	** Explicit dynamics of methanotrophs and methanogenes with double Mono kinetics (O_2 and CH_4)
De Visscher and Van Cleemput, 2003	O_2, CH_4, CO_2, N_2	*** multiple gas transport by dusty gas model	*** growth of methanotrophs and CH_4 oxidation with dual substrate Mono kinetics
Jassal et al., 2004	CO_2	*** water and heat transport gaseous diffusion, convection, gaseous solubility and dispersion with water	* first-order two-pools decomposition with temperature, moisture and oxygen scaling factors
PASTIS + CANTIS, Cannavo et al., 2006;	O_2, CO_2, N_2O, N_2	*** water, heat and gas transport by dusty gas model	** first-order, or one and half order kinetics, 6 SOM pools and 2 biomass pools
Xu et al., 2007	O_2, CH_4	** gaseous transport with diffusion, ebullition and plant-mediated gas transport	*** kinetic description of CH_4 production and oxidation and explicit description of alternative electron acceptors reduction: O_2, NO_3^-, Mn(IV), Fe(III), SO_4^{2-}
Herbst et al., 2008	CO_2	*** SOILCO2 model: water, heat and gas transport	* RothC model, four pools with first-order decay rates
TOUGHREACT-N Maggi et al., 2008; Gu et al., 2009	O_2, CO_2, N_2O, NO, NH_3	*** vertical water flow (Darcy-Richards equation), Fickian diffusion in gas and liquid phases	*** microbial growth (Mono kinetics) and substrate transformations according second order (substrate * biomass) kinetics, 4 microbial groups
Tang et al., 2010	O_2, CH_4, CO_2, N_2	*** gaseous transport with diffusion, plant-mediated transport and pressure-based ebullition	*** two substances model (O_2 and CH_4) for methane production (competition with aerobic C consumption) and oxidation
ANIMO, Stolk et al., 2011a, b	CO_2, N_2O, CH_4	** effective diffusion in water and air, mobile–immobile concept for N_2O emission	* first-order multiple pools decomposition, no explicit microbial growth

21 models in this table of models including soil biology and soil physics

Blagodatsky & Smith (2012)

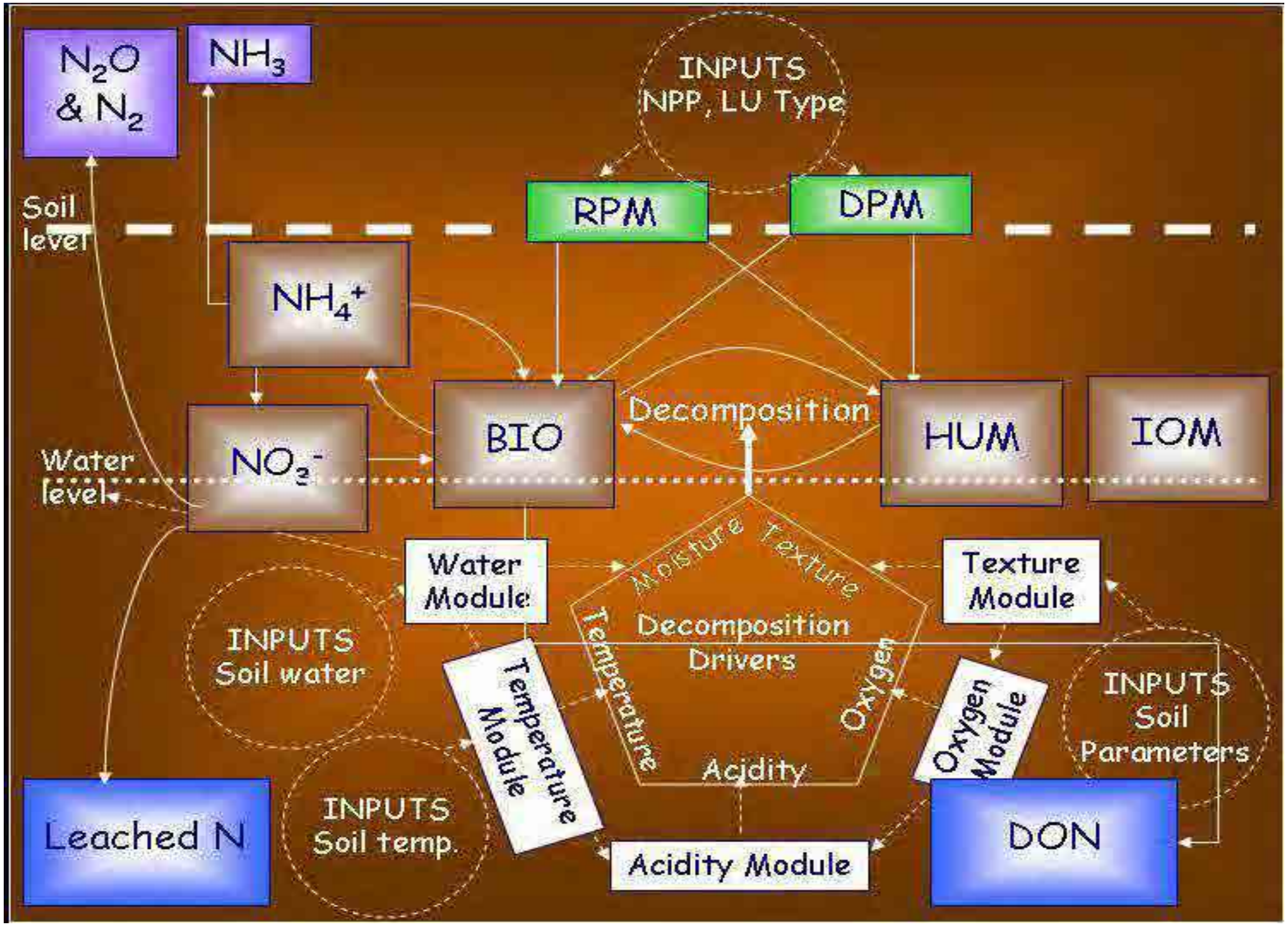
Models differ in complexity

- Some models are very detailed and mechanistic – short time-step and require lots of input data
- But scratch below the surface of any model and you find empirical relationships!
- Some models are simpler – longer time-step – require less input data – more empirical relationships
- Differ in ways e.g. temperature/energy transfer, diffusion, anaerobicity, O_2 availability, REDOX are dealt with

Examples from 3 commonly used biogeochemical models

- ECOSSE
- DailyDayCent
- DNDC

N routines in ECOSSE



ECOSSE

- Soil temperature = air temperature
- Daily to monthly time-step version
- Anaerobic processes determined by water table depth / soil moisture (tipping bucket)
- O_2 availability implicit (water table)
- Diffusion rate fixed by soil type
- pH considered – but REDOX potential not explicit

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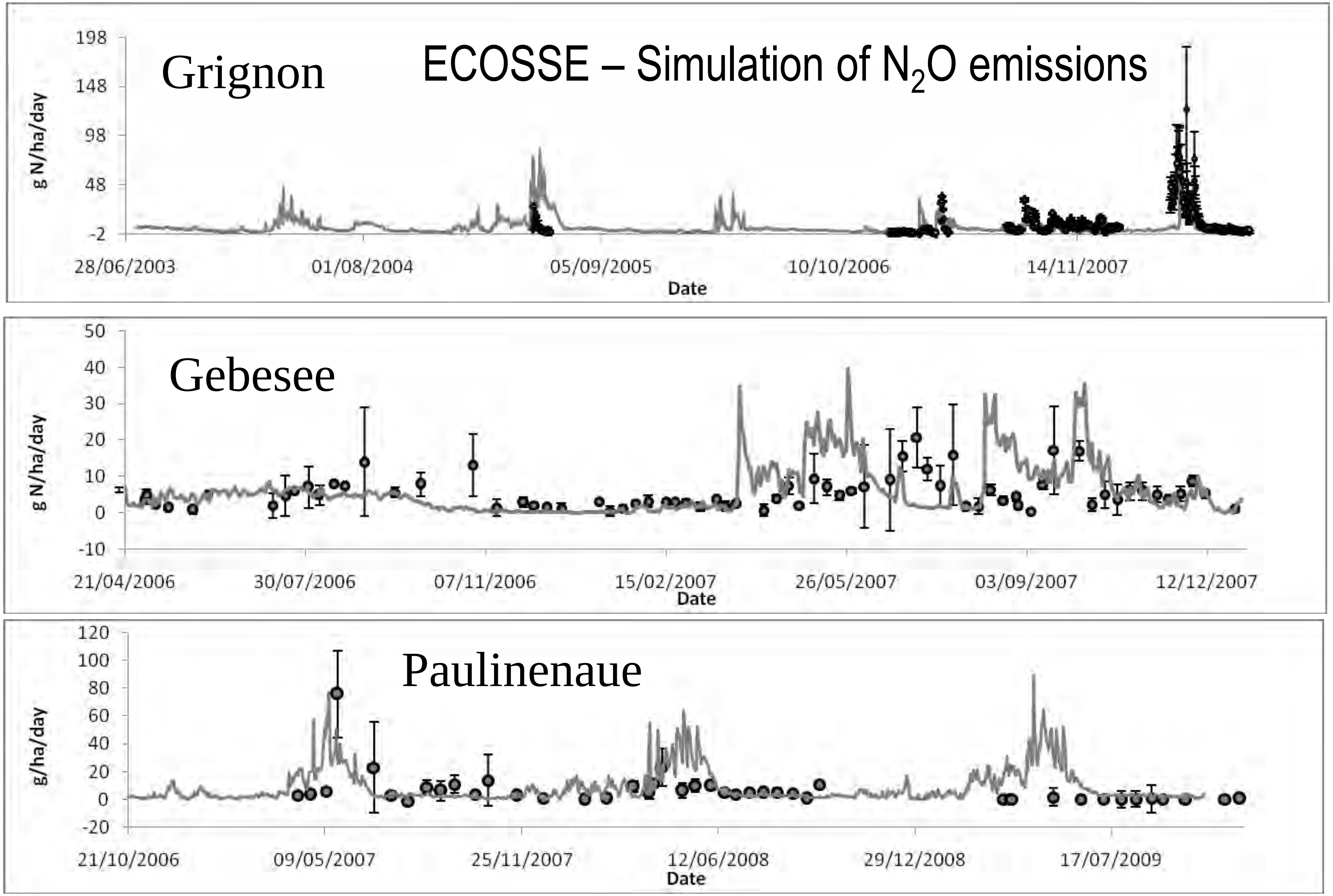
ECOSSE – Simulation of N_2O emissions



Bell *et al.* (2011)

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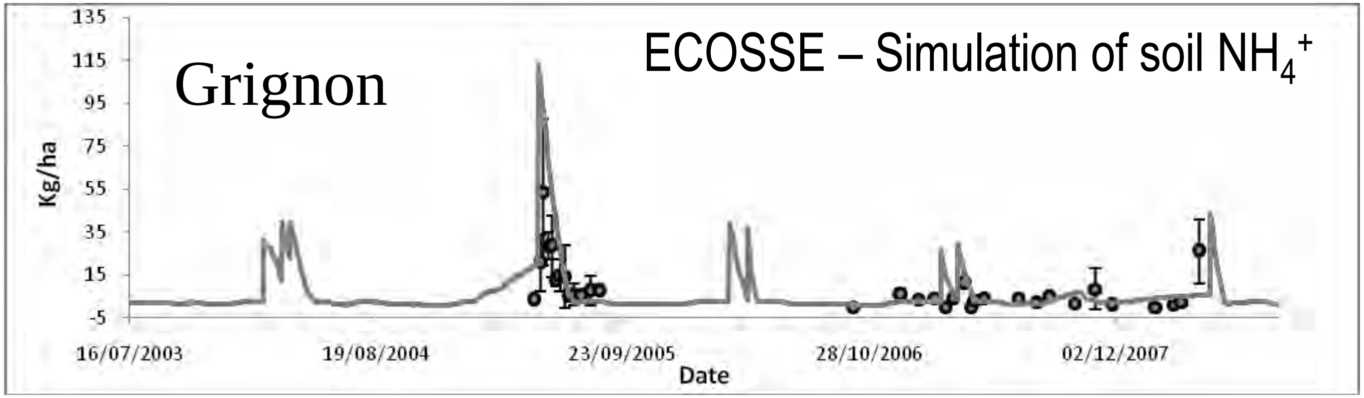
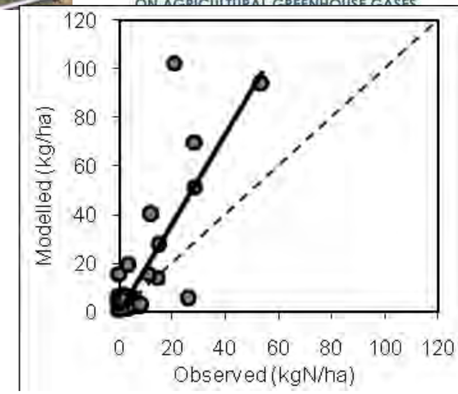
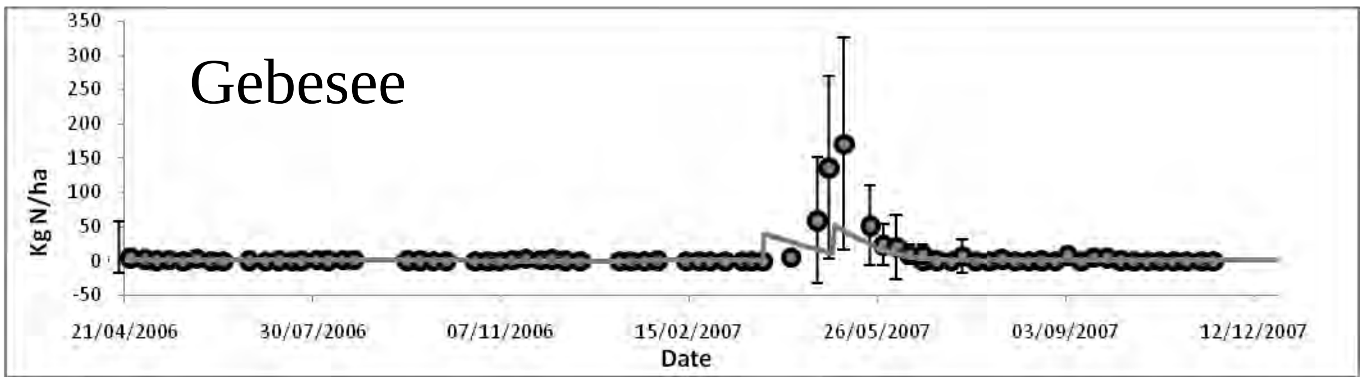
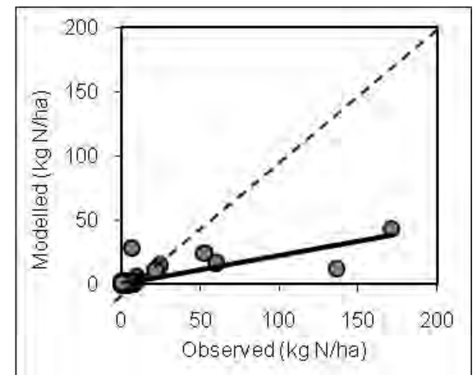
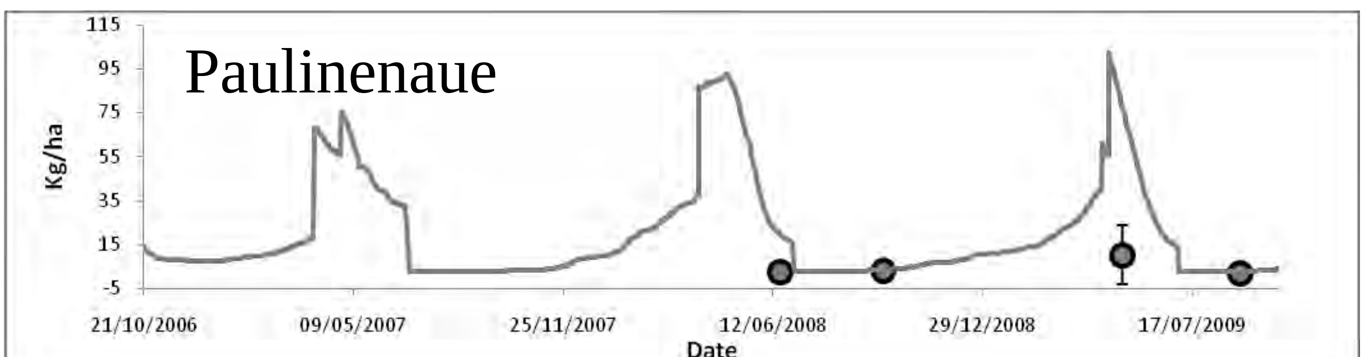
ECOSSE – Simulation of soil NH_4^+

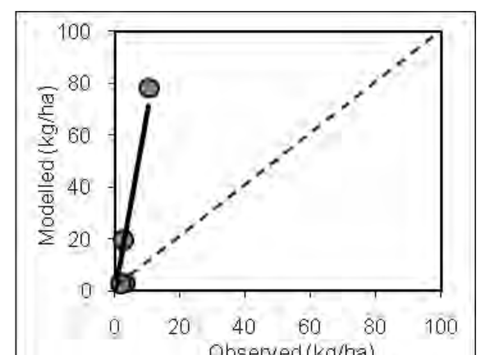












Bell *et al.* (2011)

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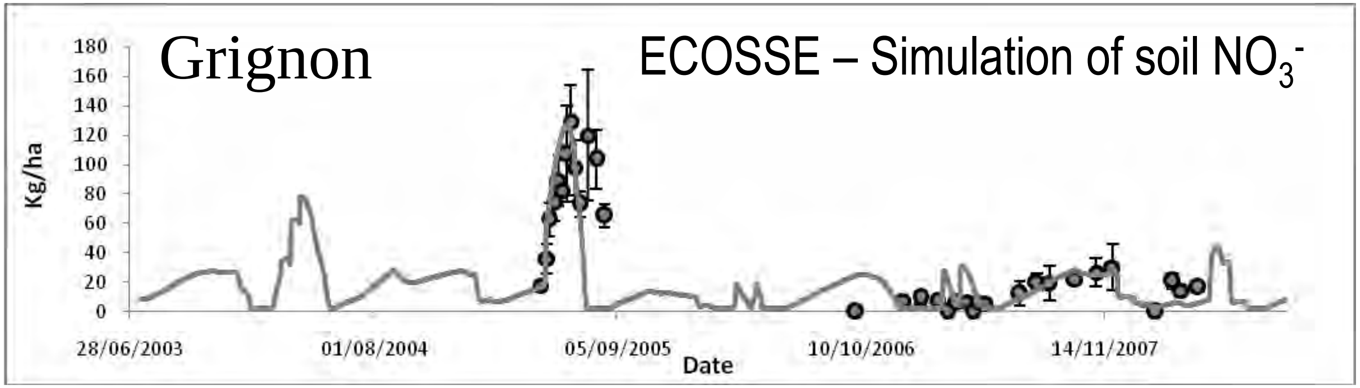
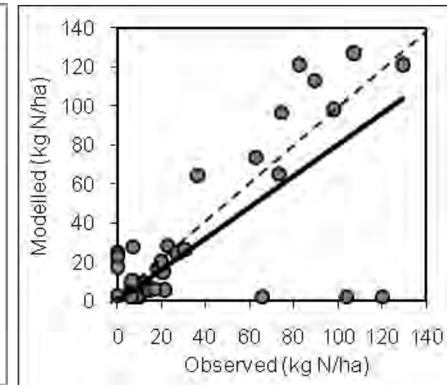
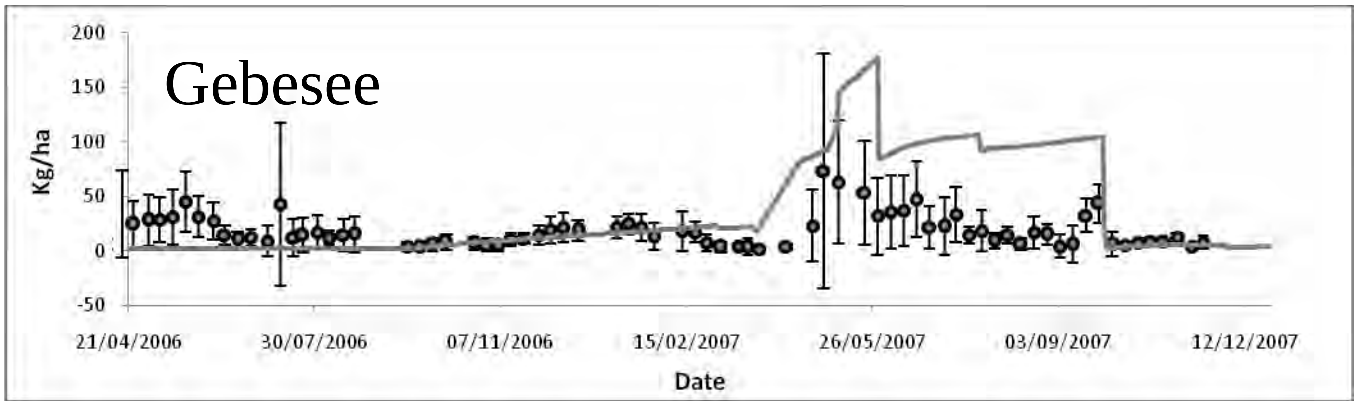
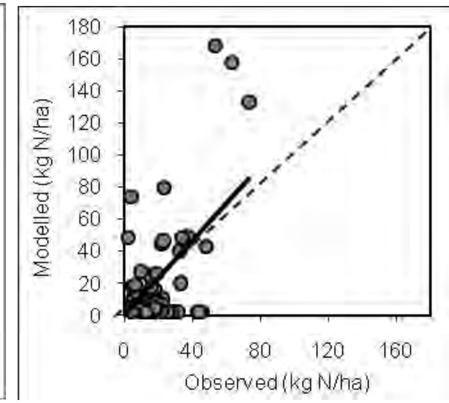
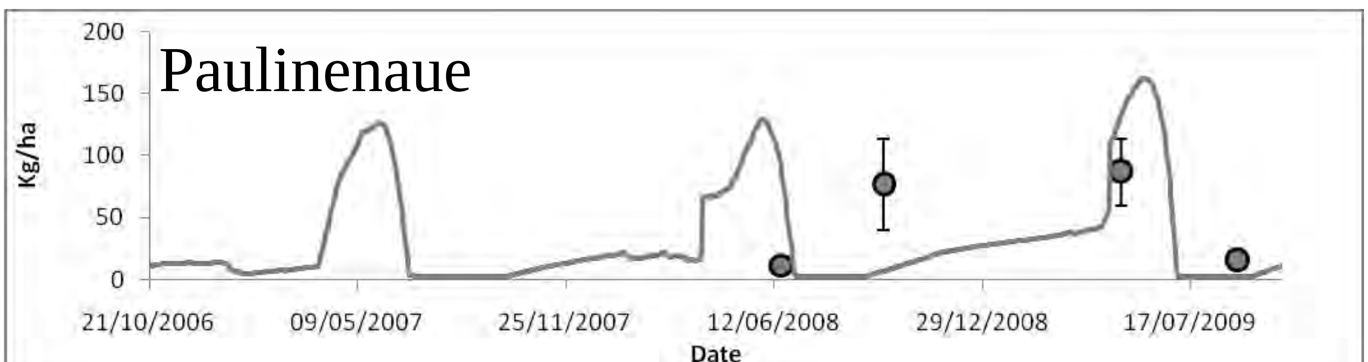
ECOSSE – Simulation of soil NO_3^-

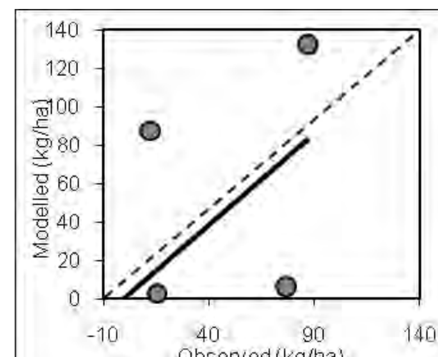












Bell *et al.* (2011)

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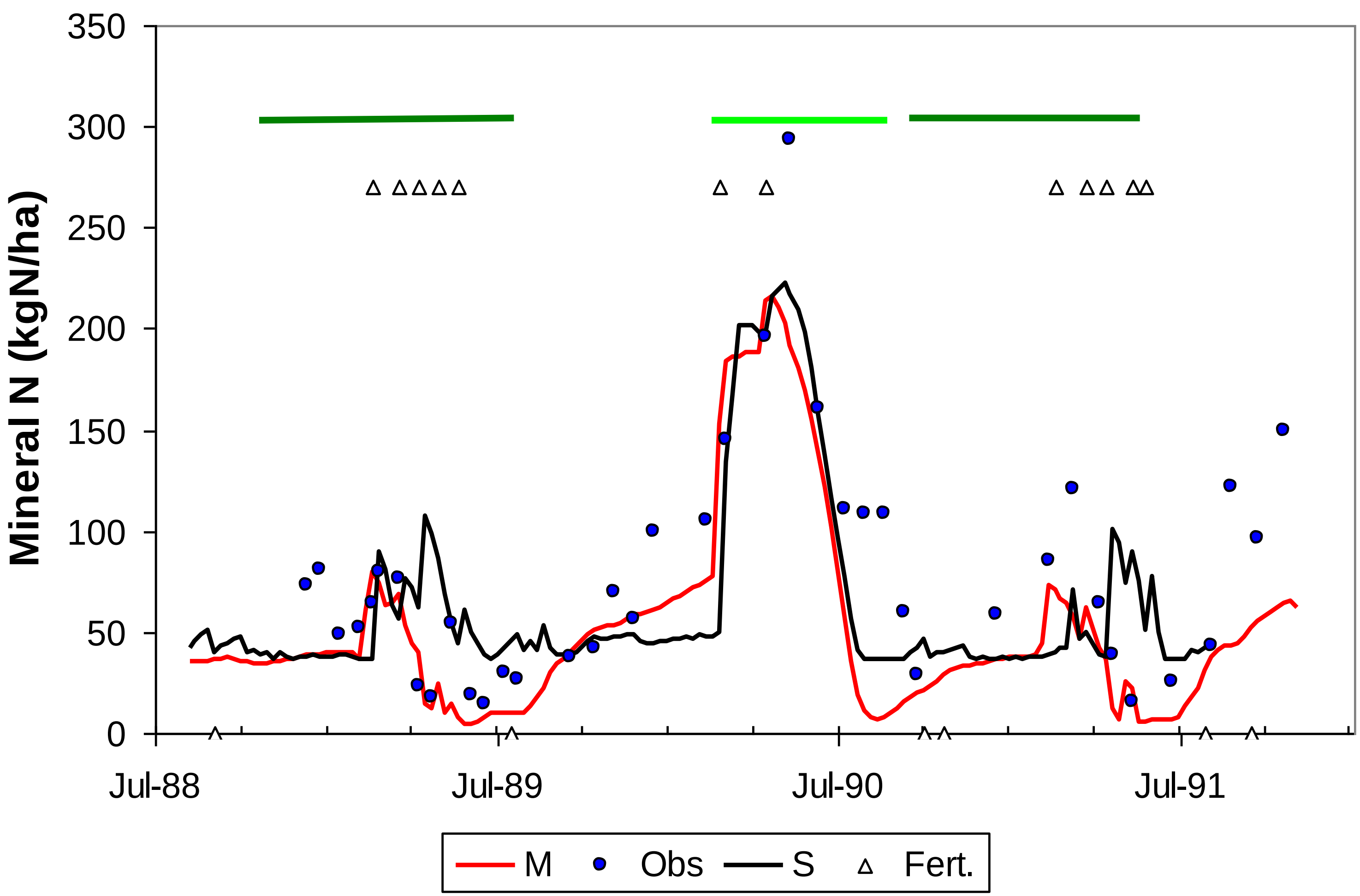
Simulated and Observed N_{min} in the Profile (0-90 cm) of the Loam site (Krummbach) - Treatment Without Manure



J.U. Smith et al. (2003)

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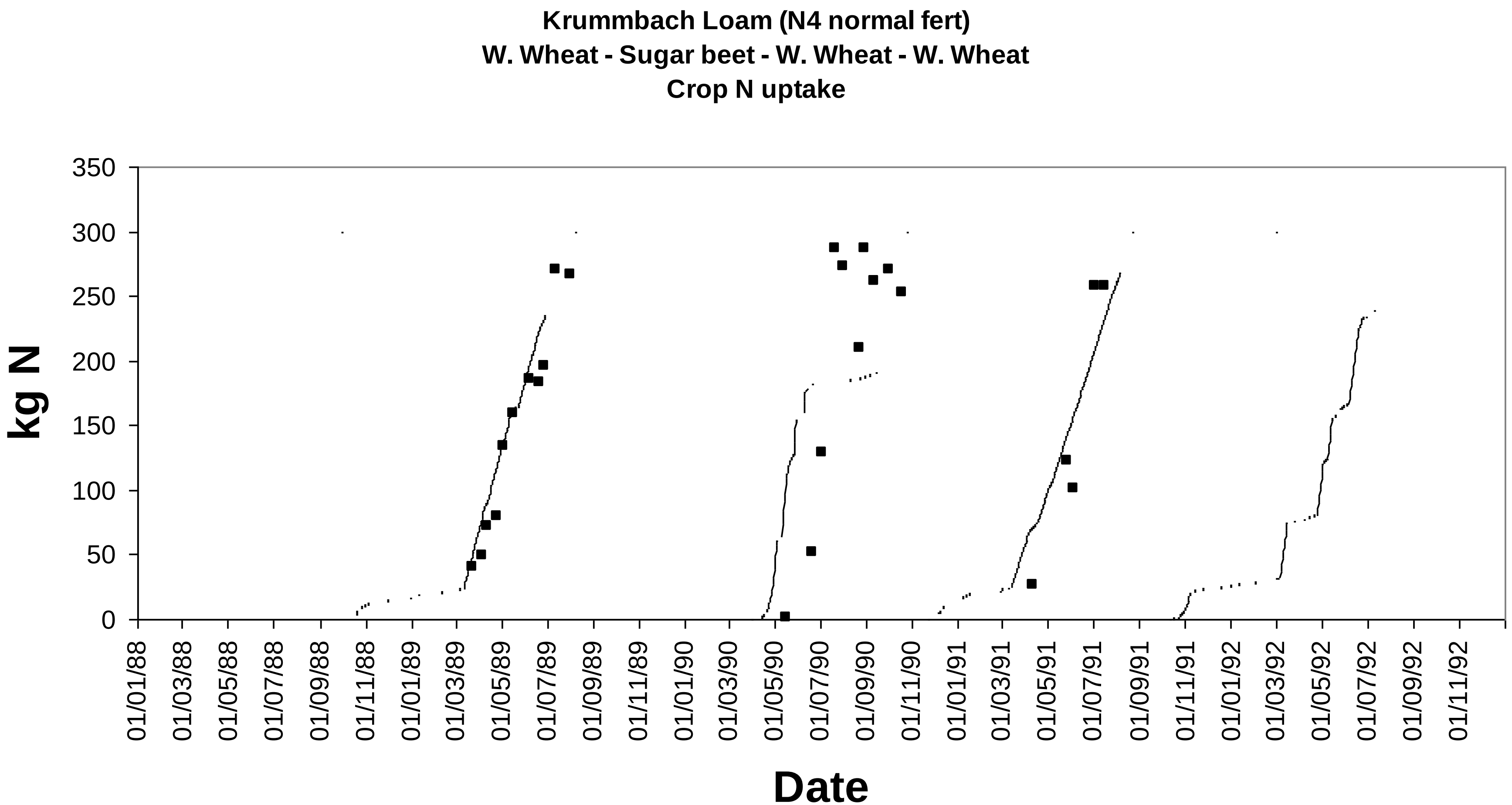
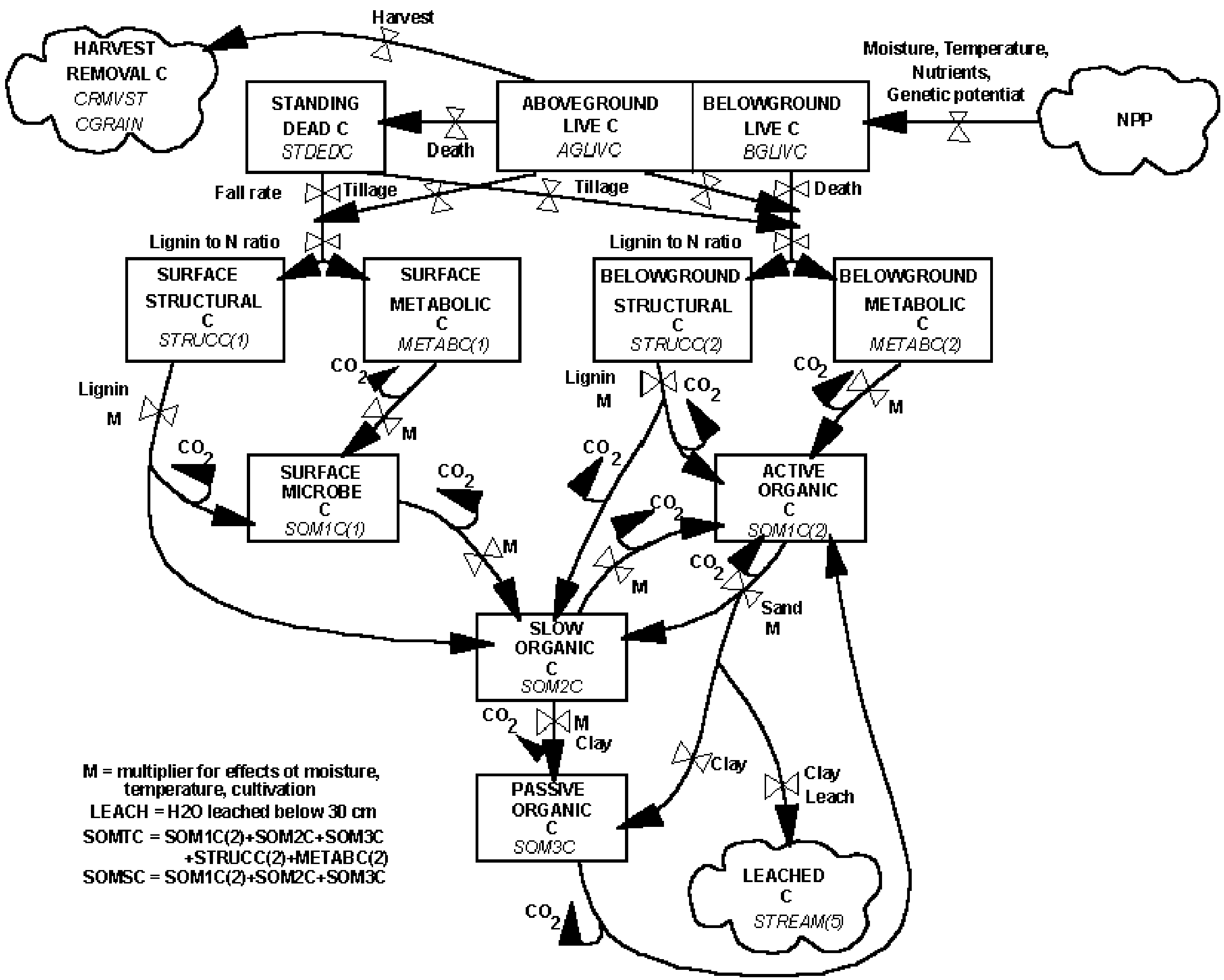
Multiple season / multiple crop. As with all models, it doesn't always get it right!! See Sugar beat N uptake

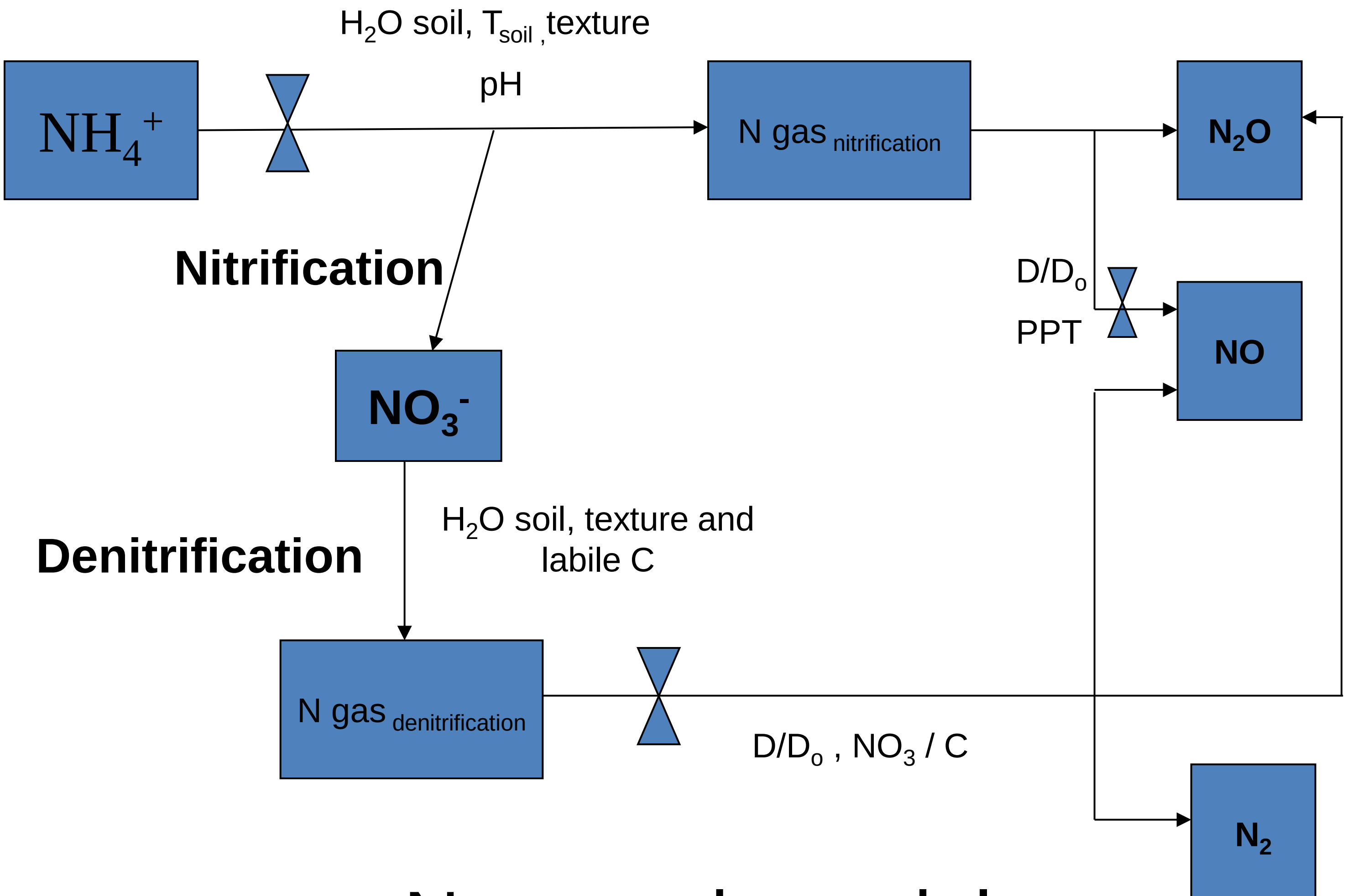


Smith *et al.* (2001)

DailyDayCent



DailyDayCent



N gas sub-model

DailyDayCent

- Soil temperature derived from air temperature
- Daily time-step version
- Anaerobic processes determined by soil moisture
- O_2 availability implicit?
- Diffusion rate simulated
- pH considered – but REDOX potential not explicit

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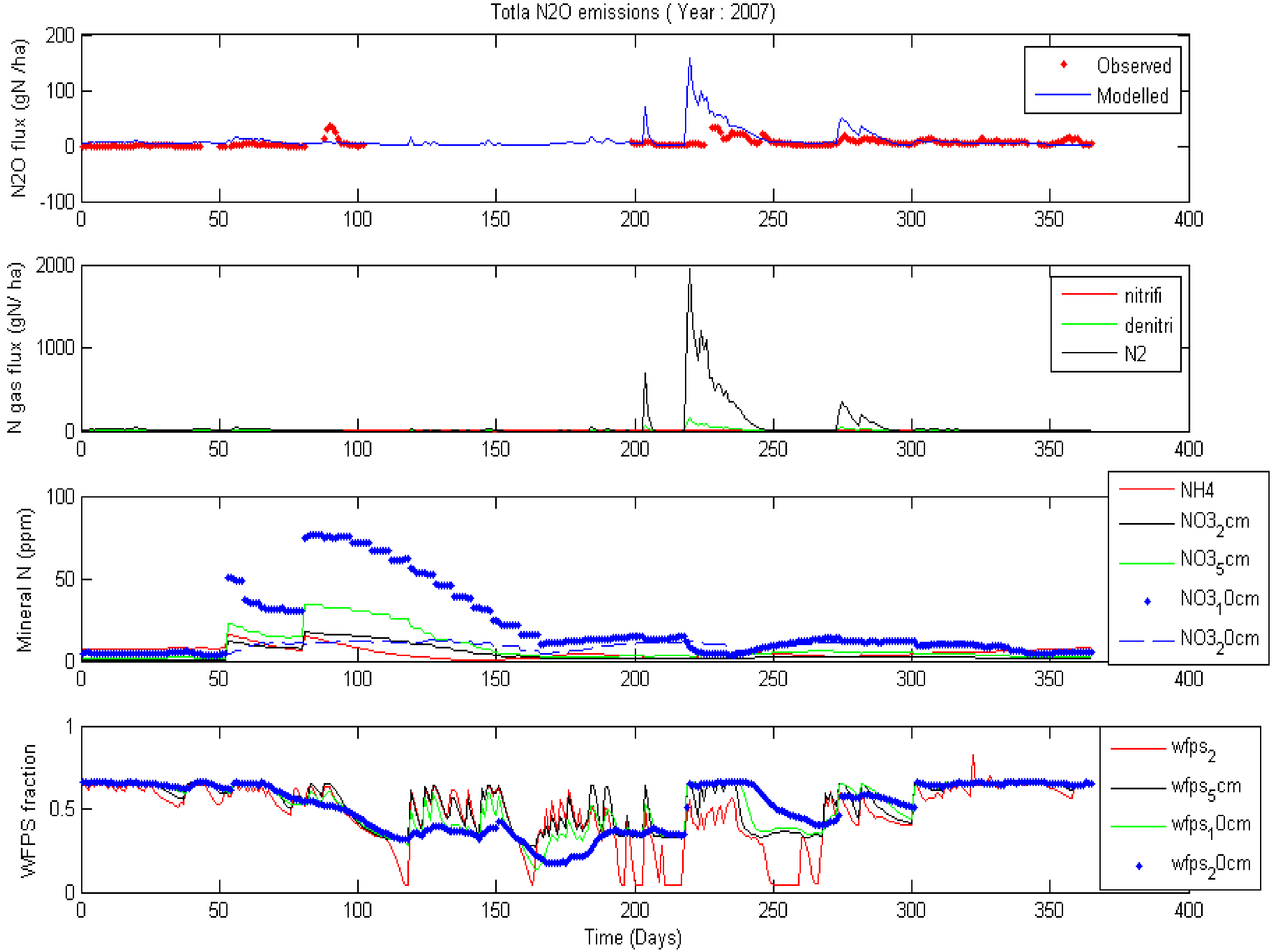
DailyDayCent



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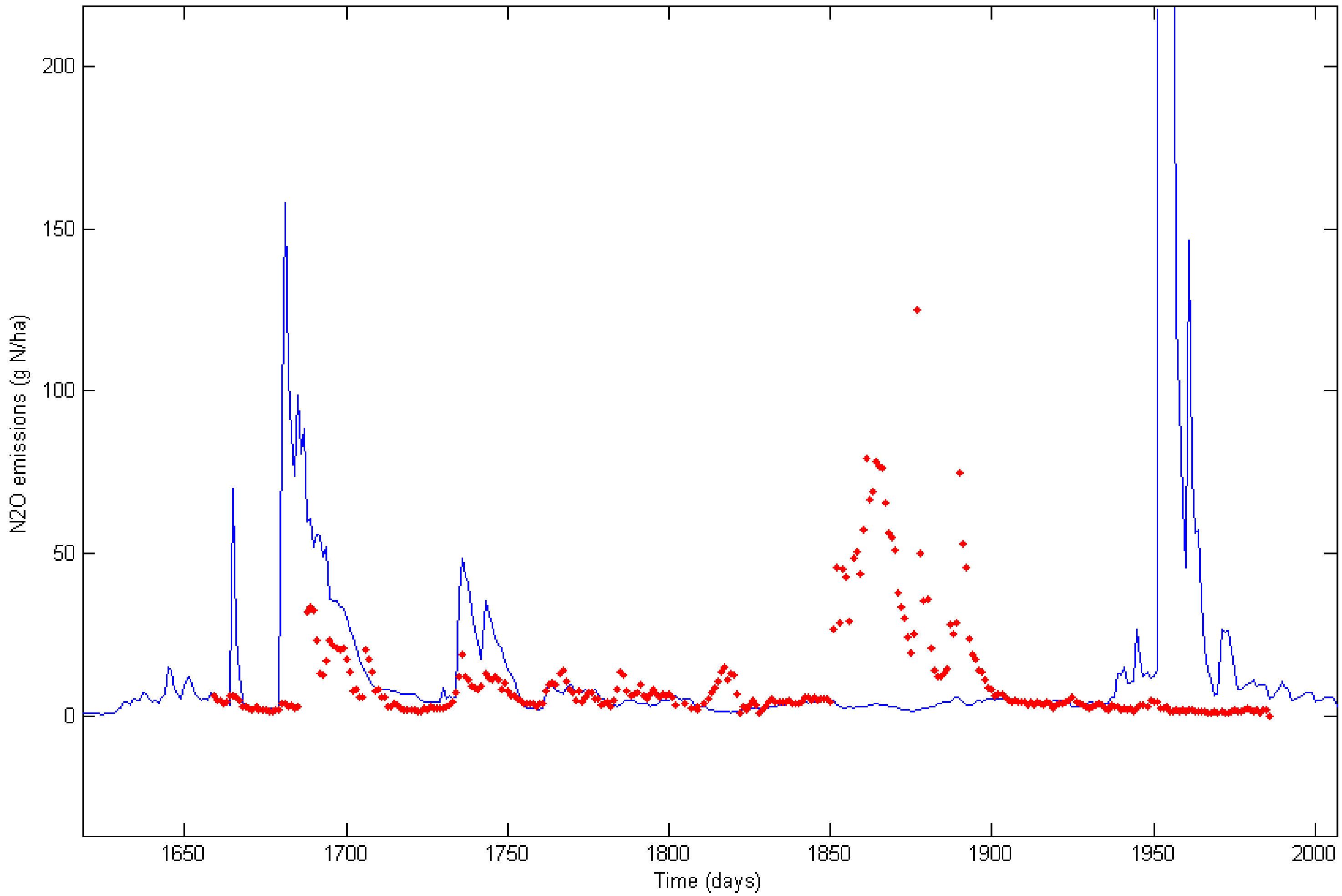
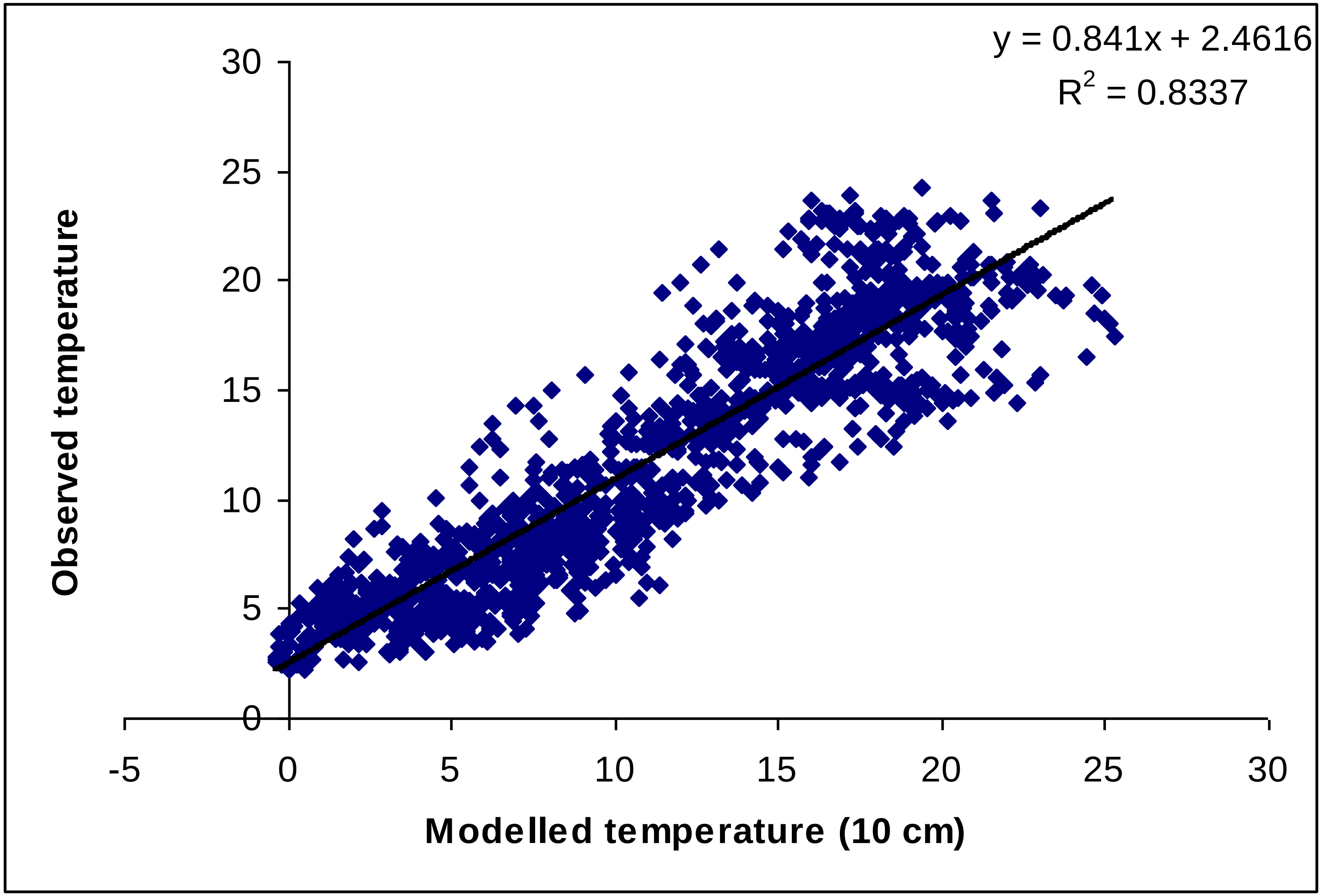
ON AGRICULTURAL GREENHOUSE GASES

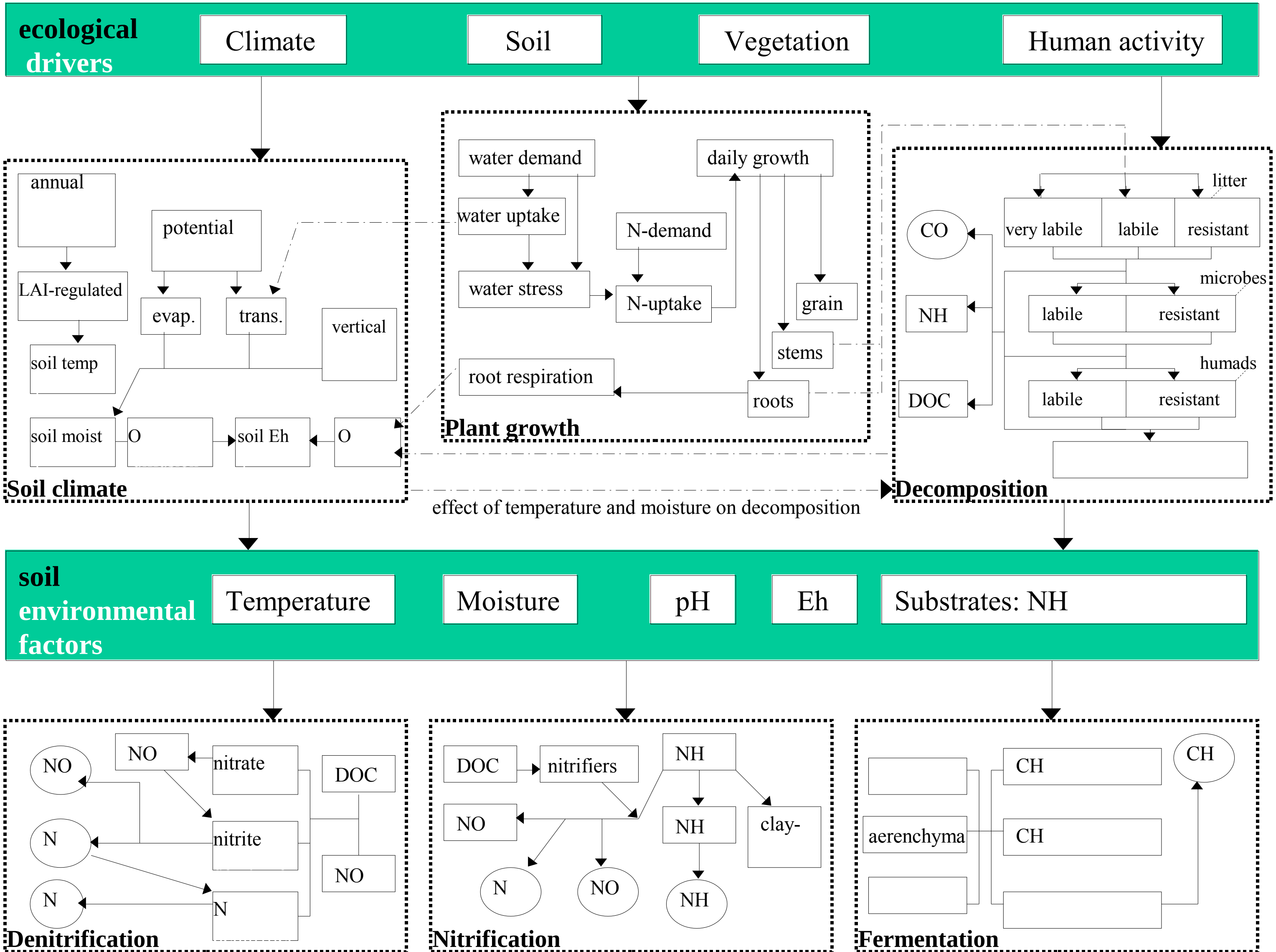
DailyDayCent



DailyDayCent



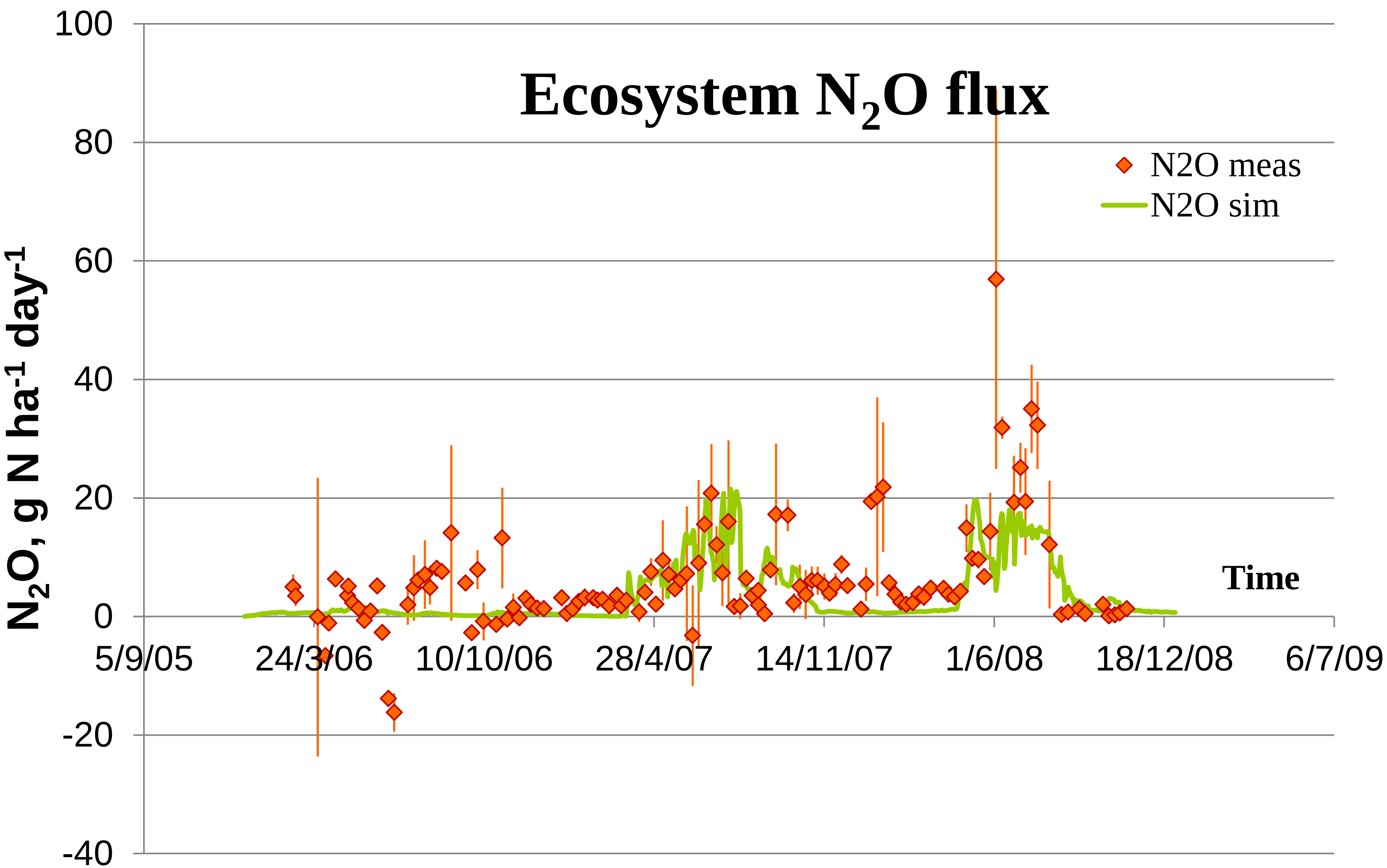
The DNDC Model



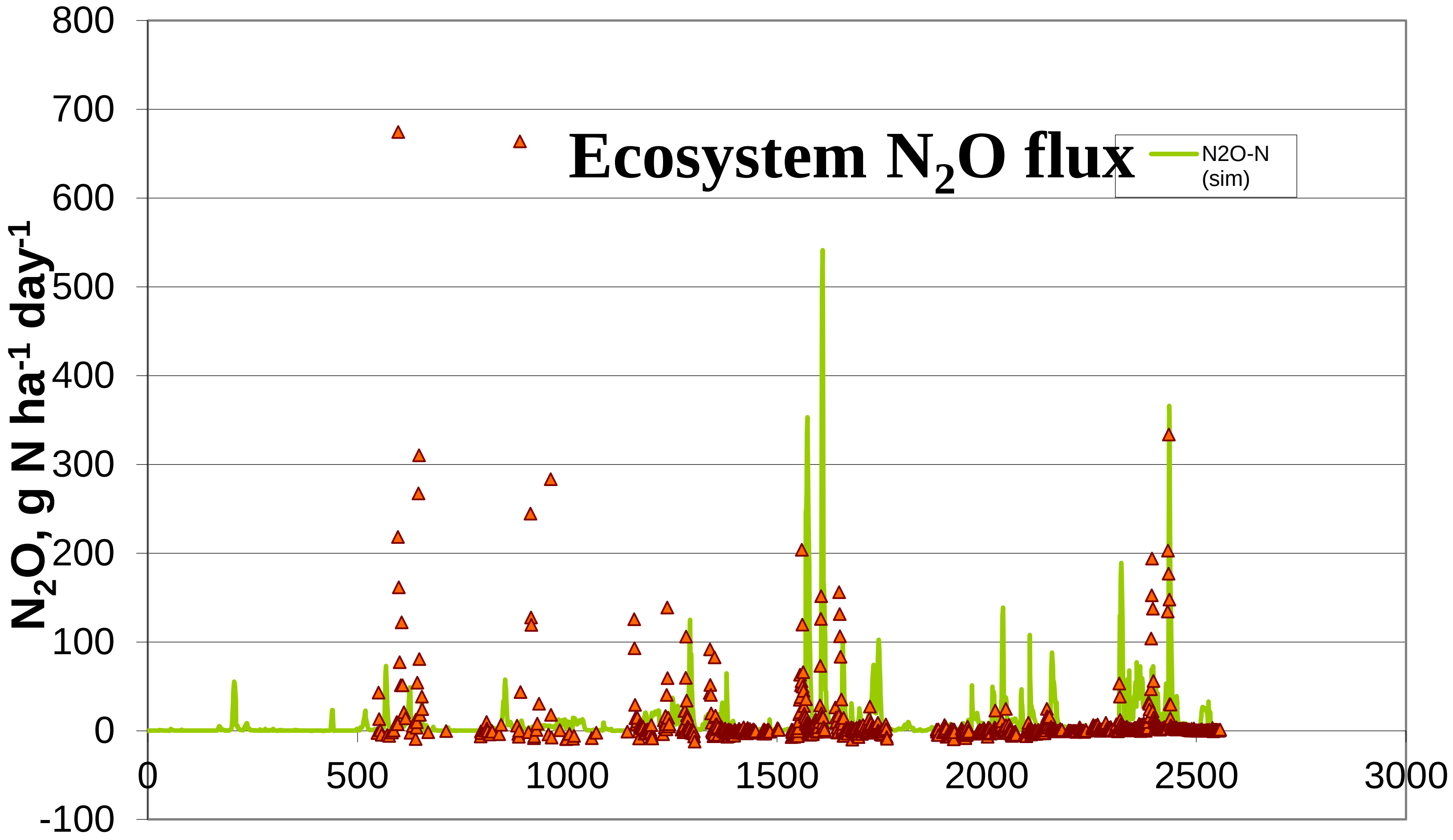
DNDC

- Soil temperature and energy transfer modelled
- Daily time-step version – some processes at sub-daily time-step (diurnal curve)
- Anaerobic processes modelled explicitly using "anaerobic balloon"
- O_2 availability explicitly modelled
- Diffusion rate simulated explicitly
- REDOX potential explicit (simulated by "anaerobic balloon")

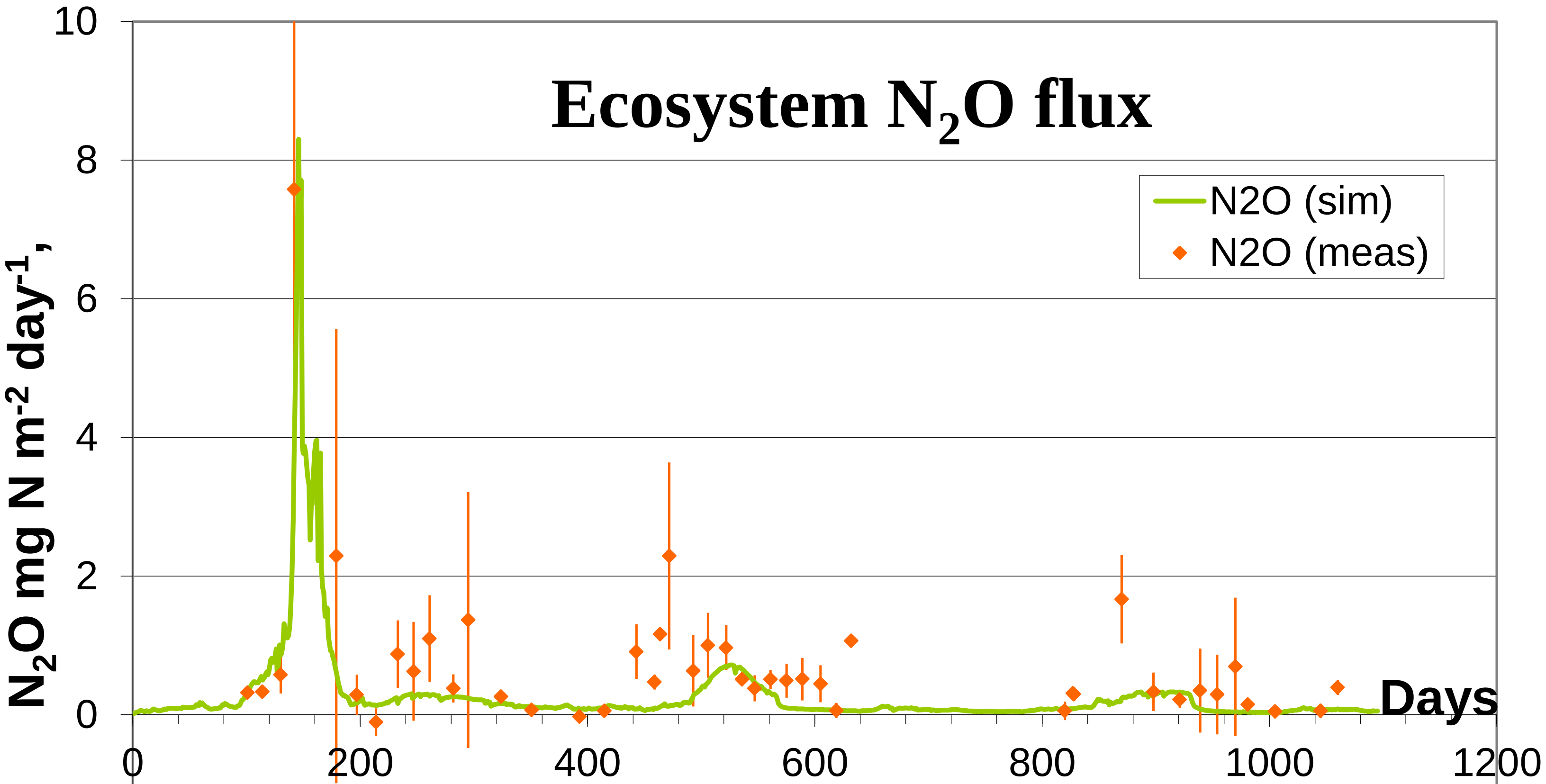
Model vs data: Mobile-DNDC, Gebesee, arable 2006-08



Model vs data: Mobile-DNDC, Oensingen, grassland 2001-07



Model vs data: Mobile-DNDC, Paulinenaue, arable 2007-09



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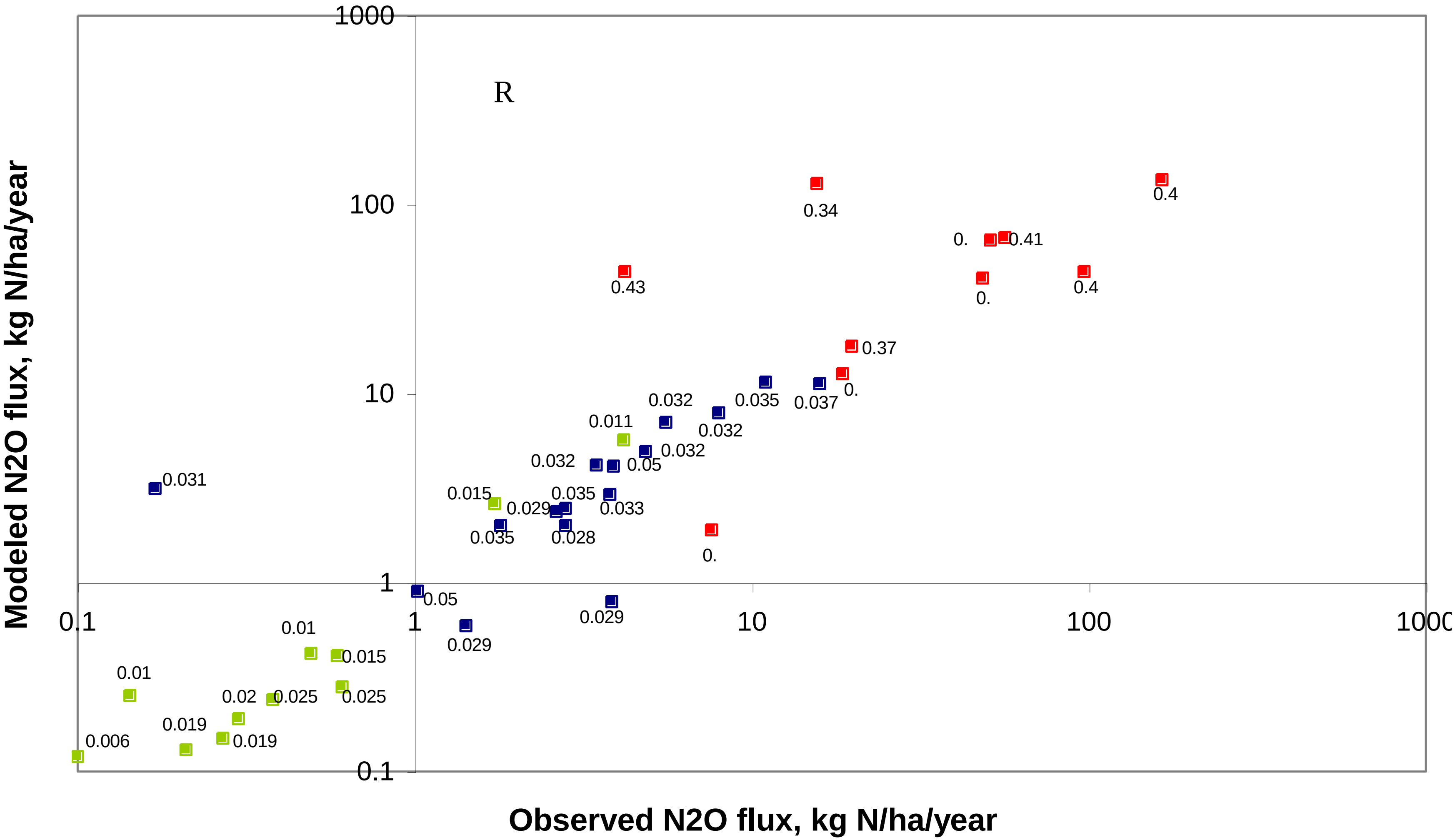
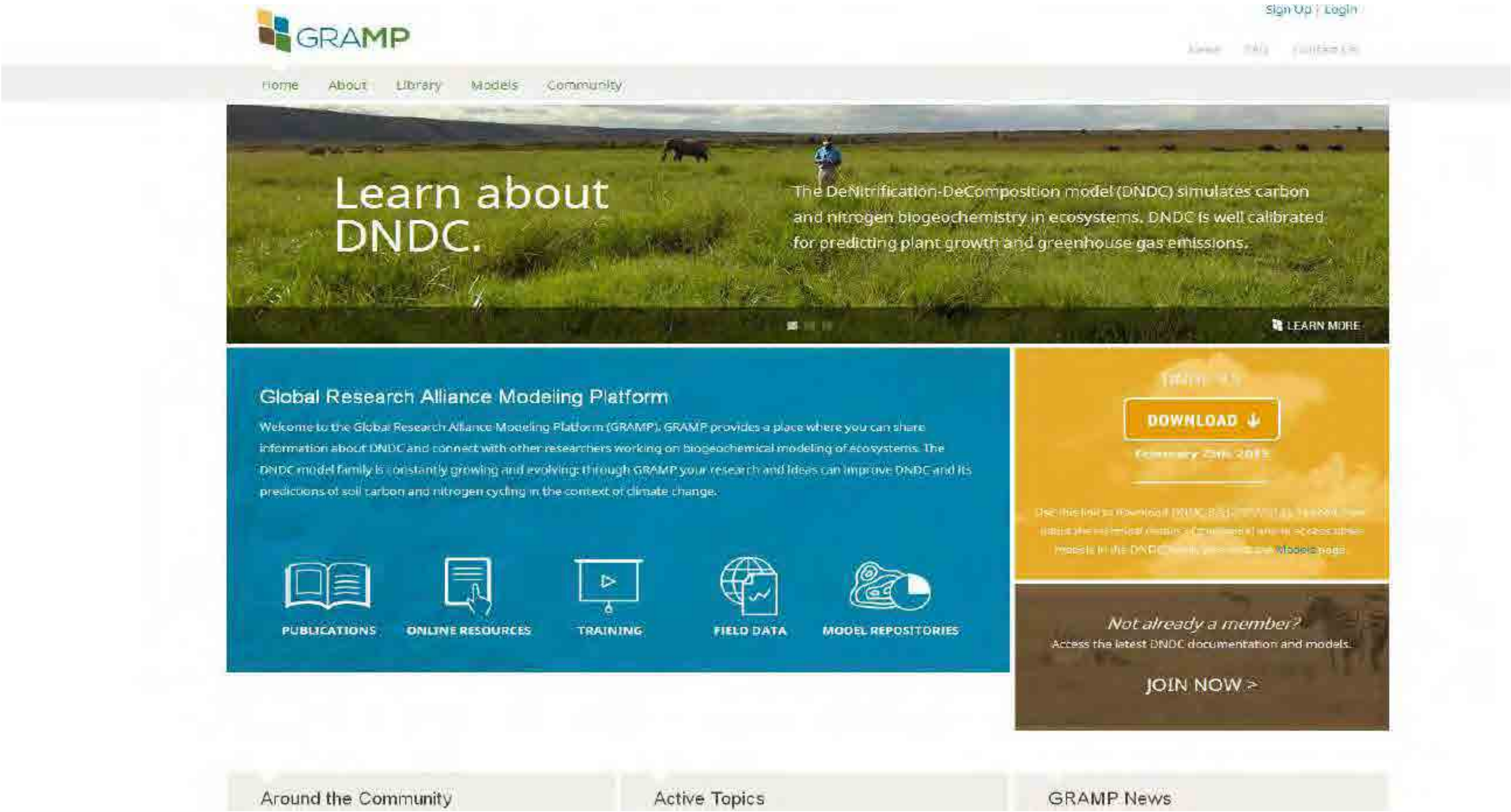
Observed and DNDC-Modeled N2O Fluxes from Agricultural Soils in the U.S., Canada, the U.K., Germany, New Zealand, China, Japan, and Costa Rica



Conclusions

- Models differ greatly in complexity and process detail
- There is no right or wrong way to model N_2O – “horses for courses”
- Simple models require fewer inputs, but compromise on process-description
- Complex models are not necessarily more accurate – particularly if they cannot be parameterised
- We still have a lot to learn about modelling N_2O emissions
- Getting it wrong ultimately improves our understanding – we should not fear model failure

GRA Modelling Platform (GRAMP)



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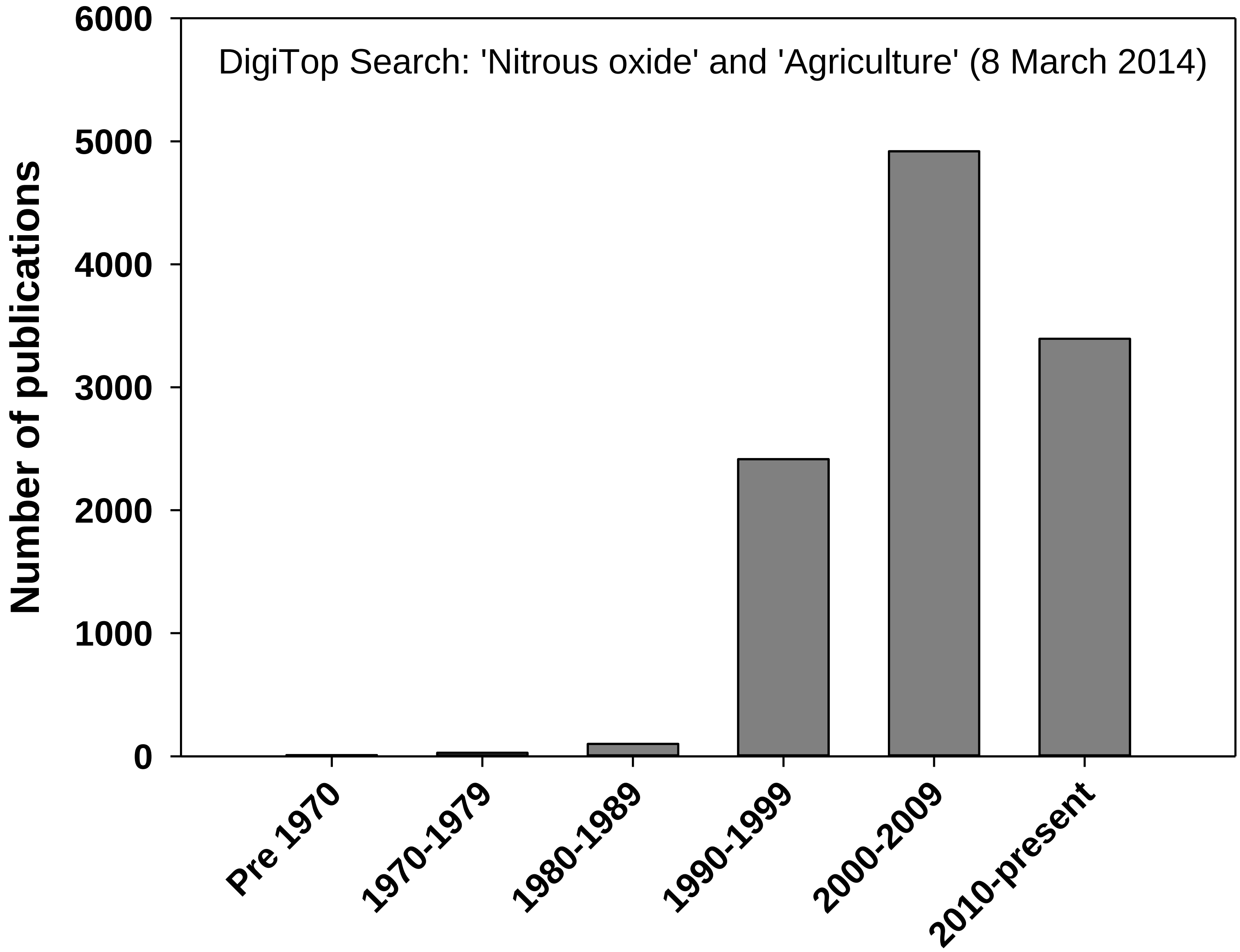
Introductory lecture

N2O Flux from Measurement to Databases: Navigating the Maze

Mark Liebig and Pierre Cellier

USDA Agricultural Research Service, Mandan, ND - USA

INRA Unité Mixte de Recherche Environnement et Grandes Cultures, 78850 Thiverval-Grignon - France



USDA United States Department of Agriculture Agricultural Research Service

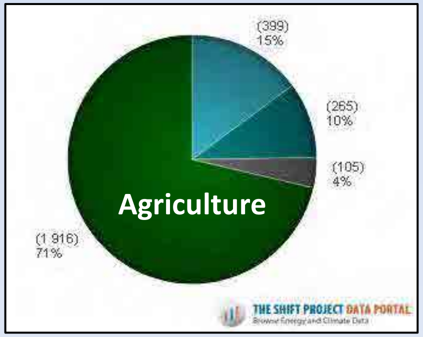
INRA SCIENCE & IMPACT

N_2O emissions and Agriculture

- **A convergence of contributing factors…**
  - Environmental impacts of N loss (Davidson et al. 2012)

  - Global N use for agricultural production increasing (Conant et al., 2013)

  - Across sectors, agriculture accounts for the majority of N_2O emissions (IPCC, 2007)



What is required to provide high quality N_2O flux data?

Measurement Table: Greenhouse Gas Flux

Please enter methods for all your measurements on the Methods page.

Required! Enter the number 1 if preceding data is from an actual field measurement, or enter the number 0 if data is interpolated.

Experimental Unit and Treatment Information					Greenhouse Gas Flux Data		
	mm/dd/yyyy					*g N/ha/day*	
Exp_UnitID	**Date**	**Time**	**TreatmentID**	**Crop**	**Chamber_Placement**	**N_2O**	**N_2O_Interp_Obs**
FCW	10/21/2003		FCW	Rangeland	Rangeland	11.85	1
FCW	10/28/2003		FCW	Rangeland	Rangeland	4.20	1
FCW	11/18/2003		FCW	Rangeland	Rangeland	3.85	1
FCW	12/2/2003		FCW	Rangeland	Rangeland	8.22	1
FCW	12/16/2003		FCW	Rangeland	Rangeland	8.05	1
FCW	12/30/2003		FCW	Rangeland	Rangeland	24.73	1
FCW	1/13/2004		FCW	Rangeland	Rangeland	30.09	1
FCW	1/28/2004		FCW	Rangeland	Rangeland	2.94	1
FCW	2/10/2004		FCW	Rangeland	Rangeland	18.38	1
FCW	2/20/2004		FCW	Rangeland	Rangeland	8.40	1
FCW	2/27/2004		FCW	Rangeland	Rangeland	3.71	1
FCW	3/9/2004		FCW	Rangeland	Rangeland	4.79	1
FCW	3/22/2004		FCW	Rangeland	Rangeland	24.11	1
FCW	3/30/2004		FCW	Rangeland	Rangeland	10.84	1
FCW	4/5/2004		FCW	Rangeland	Rangeland	10.85	1
FCW	4/13/2004		FCW	Rangeland	Rangeland	5.29	1
FCW	4/16/2004		FCW	Rangeland	Rangeland	8.18	1
FCW	4/20/2004		FCW	Rangeland	Rangeland	12.02	1
FCW	4/22/2004		FCW	Rangeland	Rangeland	8.38	1
FCW	4/27/2004		FCW	Rangeland	Rangeland	4.22	1
FCW	5/4/2004		FCW	Rangeland	Rangeland	8.22	1
FCW	5/10/2004		FCW	Rangeland	Rangeland	7.19	1
FCW	5/14/2004		FCW	Rangeland	Rangeland	6.52	1
FCW	5/18/2004		FCW	Rangeland	Rangeland	3.85	1

Within constraints of money, time, and expertise, we follow…

- A tortuous path…
- with multiple decision points…
- many with significant tradeoffs.
  - Spatial representation
  - Temporal coverage
  - Treatment numbers
  - Treatments type
  - Magnitude of N_2O flux

Measurement Techniques

- **Chamber Methods**
  - Small scale (1 m^2)
  - Manual and automated
  - Most common technique (Denmead, 2008)

- **Micrometeorological Methods**
  - Large scale (1000+ m^2)
  - Highly automated
  - Emerging use (Nicolini et al., 2013)

Chamber Methods: Manual

Benefits	Drawbacks
Simple in concept and operation	Chamber/Frame interference with crop/environment
Low material costs, no power	High labor cost, manual sampling
Portable, thereby allowing assessment of many treatments	Low temporal sampling frequency
High sensitivity	Increase in gas concentration within headspace may affect emission rate
Do not require large experimental areas	Small assessment area + High spatial variability = ↑CVs

(Clough et al., 2012; Rochette et al., 2012; Denmead, 2008)

Chamber Methods: Automated

Benefits	Drawbacks
Still simple in concept…	…but not so simple in operation
Immediate analysis, Lower labor cost	Moderately high material costs, power required
High temporal sampling frequency	‘Less’ portable, limiting number of treatments
High sensitivity	Animal ‘interference’ a potential problem
Do not require large experimental areas	Small assessment area + High spatial variability = ↑CVs

(Grace et al, 2012; Denmead, 2008)

Micrometeorological Methods

- **Flux gradient**
  - Fluxes a product of an eddy diffusivity and the vertical concentration of gas (two measurement heights).

- **Eddy covariance**
  - Direct measurements of the vertical transport of gas; fluxes estimated by the covariance of concentration and wind speed.

(Nicolini et al., 2013; Skinner and Wagner-Riddle, 2012)

Micrometeorological Methods

Benefits	Drawbacks
Large spatial footprint	Limited treatments
Continuous measurement, High temporal resolution	Data gaps common
Fast response, high precision analyzers (FTIR, TDLAS, QCLAS)	High material costs, Specialized labor requirements
Rigorous, Computationally intensive	Many corrections/assumptions necessary

(Skinner and Wagner-Riddle, 2012)

Data Analysis Considerations

Chamber Methods

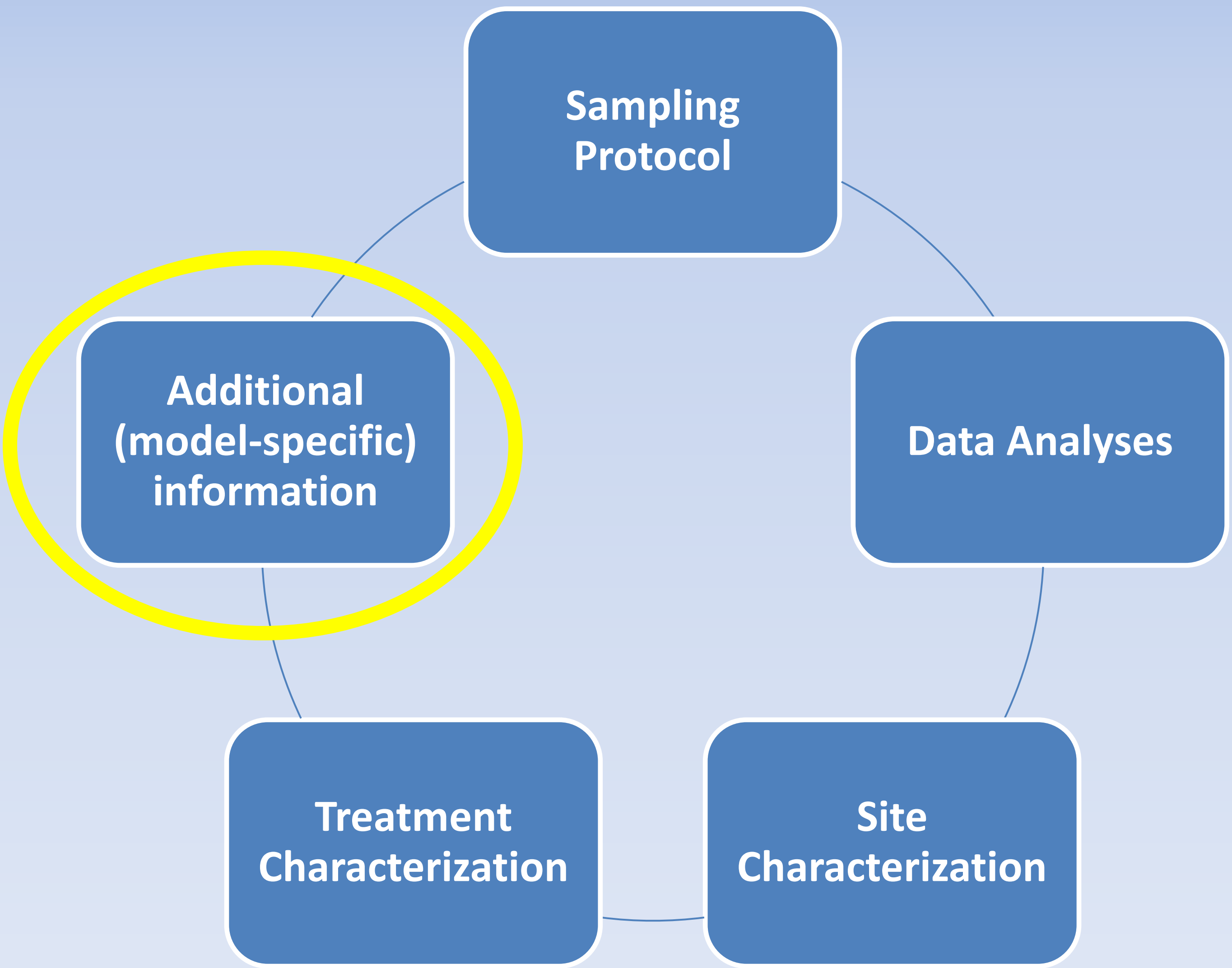
- **Presently, there is no ideal choice for calculation of 'best' flux across applications**
  (Venterea et al., 2012; Venterea, 2013)
  – Linear regression; Quadratic regression
  – Non-steady state diffusive flux estimator method; Hutchinson-Mosier (HM) method; Modified HM method; Chamber bias correction method
- **Tradeoff between bias and variance**
  (Parkin and Venterea, 2010)
  – Magnitude of flux
  – Data curvi-linearity
  – Analytical precision

"There is no simple answer"

Approach	Advantages	Disadvantages	Recommendations
Linear regression (LR)	Least sensitive to meas. error; Simple	No basis in diffusion theory	≥3 sampling points, and convex-upward data
Quadratic regression (QR)	Less bias than LR for convex-downward data	No basis in diffusion theory	≥4 sampling points
Hutchinson and Mosier (HM)	Based on quasi-steady state diffusion theory; Least-biased for convex-downward data	Restricted to 3 equally-spaced time points; More sensitive to meas. error than LR & QR	Not recommended
Non-steady state diffusive flux estimator (NDFE)	Based on non-steady state, one-dimensional diffusion theory	Highly sensitive to violation of underlying assumptions	≥4 sampling points
Modified HM method (HMR)	Based on diffusion theory, considers lateral gas transport; Available as software package	More sensitive to random measurement error than LR & QR (at lower flux values)	≥4 sampling points
Chamber bias correction method (CBC)	Delivers single flux value; Less sensitive to violation of assumptions than NDFE; Can be combined with LR or QR.	Requires additional soil data; Requires multiple calculations	≥3 sampling points with LR; ≥4 sampling points with QR

(Venterea et al., 2012)

Data Reporting



(Alfaro et al., 2012)

Data Reporting

General Requirements for Process-based Models

- Detailed description of site/management history
- Thorough baseline characterization of soil properties
- Daily time-step of relevant weather variables
- Soil moisture content and available N for each sampling date
- Biomass production; Components of yield

GRA - Soil C-N cross-cutting group,
AgMIP - Grasslands and Livestock group
&
Associated projects on modeling agricultural GHG emissions
-

Site registration Spreadsheet for Model Intercomparison & Benchmarking

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AgMIP The Agricultural Model Intercomparison and Improvement Project

Soil initial conditions

Please describe for each layer

Optionnal data are pasted in blue

Soil type

Reference name (WRB, FAO) : NGPRL Historical Grazing Trial, Mandan, ND USA

or

Short description : 2003 soil sampling

Maximum soil depth (mm) (eg 1000) : 3000-5000

Rooting depth (mm) : 1800

Description of the layers

	Moderately grazed pasture						Heavily grazed pasture						Crested wheatgrass pasture					
Layer depth (mm) (bottom limit)	*50*	*100*	*200*	*300*	600	1000	*50*	*100*	*200*	*300*	600	1000	*50*	*100*	*200*	*300*	600	1000
Sand (%)	30.8	27.5	27.0	27.8	30.0	35.0	29.5	26.8	26.5	27.3	30.0	32.3	32.3	28.0	29.3	29.3	33.8	37.0
Silt (%)	54.5	52.8	53.8	51.0	46.3	47.3	56.0	53.3	56.5	52.0	46.5	45.0	50.5	51.0	51.8	50.5	42.0	31.5
Clay (%)	14.8	19.8	19.3	21.3	23.8	17.8	14.5	20.0	17.0	20.8	23.5	22.8	17.3	21.0	19.0	20.3	24.3	31.5
Bulk soil density (t soil m^{-3})	0.87	1.20	1.09	1.18	1.26	1.40	0.92	1.14	1.12	1.17	1.32	1.43	1.02	1.34	1.23	1.28	1.28	1.44
Saturated water content (m^3 m^{-3})	0.67	0.55	0.59	0.55	0.52	0.47	0.65	0.57	0.58	0.56	0.50	0.46	0.62	0.49	0.54	0.52	0.52	0.46
Field capacity (m^3 m^{-3})	0.42	0.39	0.40	0.39	0.38	0.33	0.42	0.40	0.40	0.39	0.37	0.34	0.40	0.37	0.38	0.37	0.37	0.35
Permanent wilting point (m^3 m^{-3})	0.19	0.21	0.21	0.22	0.23	0.20	0.19	0.22	0.20	0.22	0.23	0.22	0.20	0.22	0.21	0.21	0.23	0.26
Saturated hydraulic conductivity (mm/d)	864	864	864	86.4	86.4	86.4	864	864	864	86.4	86.4	86.4	864	864	864	86.4	86.4	86.4
Total organic C (kgC m^{-2})	2.28	1.67	2.42	1.84	3.66	4.86	2.84	1.91	2.64	1.94	3.71	4.59	2.86	1.67	2.60	2.09	4.41	4.82
Total organic N (kgN m^{-2})	0.18	0.14	0.21	0.17	0.38	0.30	0.21	0.16	0.23	0.18	0.36	0.32	0.23	0.15	0.24	0.20	0.40	0.31
Coarse organic matter fraction (%)	13.8	5.6	4.0	4.7			12.4	6.6	4.4	4.3			39.1	9.7	6.3	6.5		
pH H2O (1:1 soil-water ratio)	6.44	6.46	6.63	6.81	7.06	7.70	6.62	6.65	6.70	6.79	6.98	7.69	5.10	5.80	6.39	6.70	7.15	7.73
Cation Exchange Capacity (cmol.kg^{-1})	17.3	16.7	18.2	18.8	21.3	31.6	18.2	18.0	19.3	19.3	22.7	32.9	10.4	16.8	18.6	19.9	24.3	34.0
Extractable aluminium (ppm)																		
Extractable calcium (ppm)	2273	2220	2387	2372	2651	4194	2411	2388	2465	2342	2624	4258	1277	2236	2459	2538	3092	4098

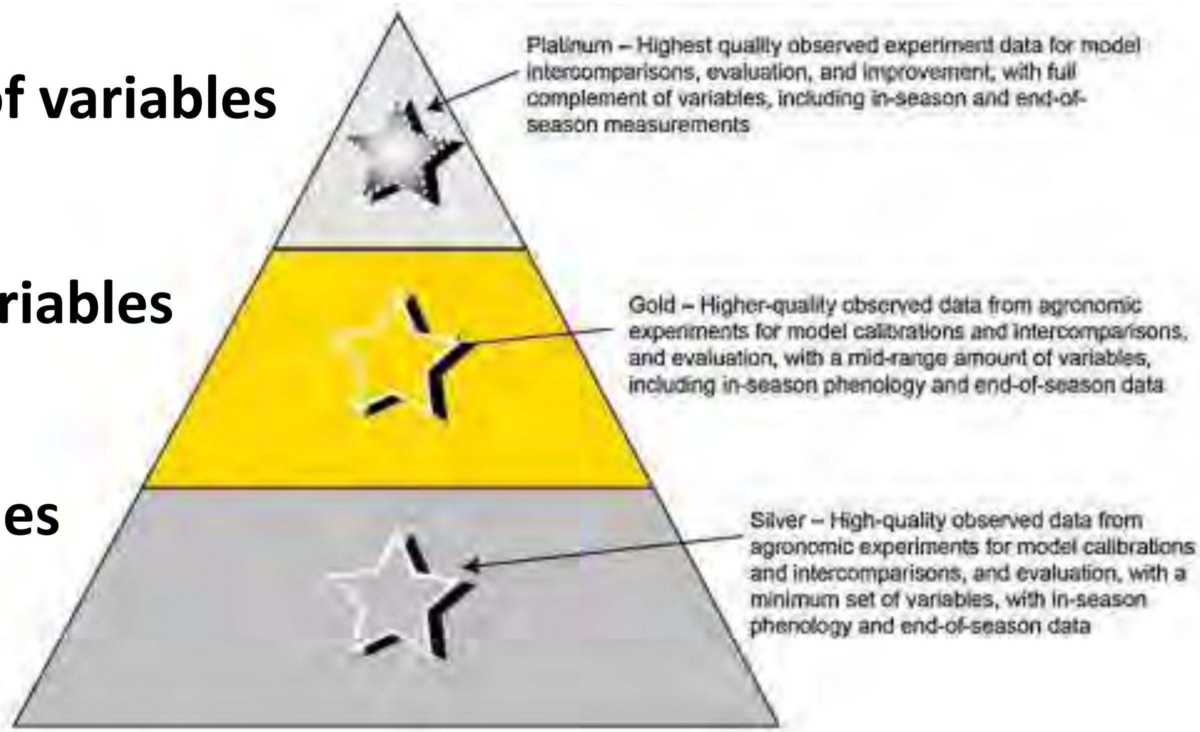
A range of experimental sites

AgMIP Sentinel Site Classification System

Full complement of variables

Most, but not all variables

Minimum set of variables



(Rosenzweig et al., 2013)

N_2O Flux Networks and Databases

Establishing higher-level connections among experimental sites

- Complexity of the topic
- Long-term nature of research
- Benefits of standardization
- Systematic archival of data/samples
- Facilitates testing of theories by multiple researchers
- Transition to ‘open access’ data

(Brouder and Volenec, 2013; Baker and Follett, 2012)

(after Baker and Follett, 2012) **Network**	**Primary location**	**Primary focus**	**Currently active?**	**Data Available?**
N_2O Network	Australia	N_2O	Y	Y
Fluxnet Canada	Canada	GHG & SOC	N	Y
Green Crop Network	Canada	GHG & SOC	N	N
N2O-France	France	N_2O	Y	Y
Agric. UK GHG Platform	UK	GHG	Y	Pending
GRACEnet	USA	GHG & SOC	Y	Y
Tragnet	USA	GHG	N	Y
GHG Europe	Europe	GHG	N	Y
NitroEurope	Europe	N_r	N	Y
CarboEurope	Europe	GHG & SOC	N	Y
CarboAfrica	Africa	GHG & SOC	N	Y
IPCC EFDB	Global	GHG	N	Y
Global Research Alliance	Global	GHG & SOC	Y	TBD

Improving the Knowledge and Management of N_2O Emissions by Field Crops (UMT GES-N2O)

- Established in 2008
- National research effort to improve the knowledge/management of N_2O emissions by field crops.
- Two partners in Grignon
  - INRA (Two research units: Agronomy, Environment and Arable Crops),
  - CETIOM (French applied research institute for oilseed crops)
- More partners by the way of research projects
- Measurement, database, simulation tool efforts.
- Implementation of a tier-2 method

The N_2O-France network

Datasets:

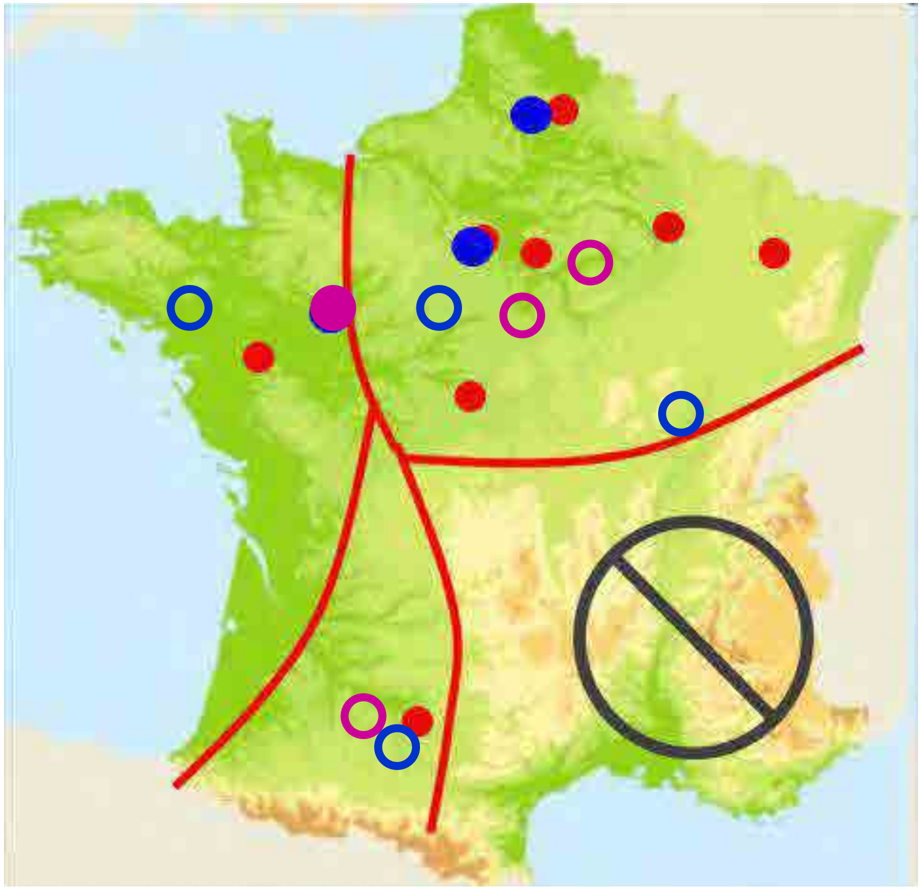
- NO GAS project
- Inra projects
- other institutes

Full circle : updated datasets

Open circle: pending datasets

A range of conditions:
- Climate
- Soils
- Practices:
  - Fertilisation (min/org)
  - Soil tillage
  - Legume crops

Different treatments for each site



Presently > 250 data

(one data = 1 site/1full year/1 treatment)

Greenhouse Gas Reduction through Agricultural Carbon Enhancement Network (GRACEnet)

- Established 2002
- USDA Agricultural Research Service
- Three-pronged objective:
  - Determine management effects on SOC and GHG fluxes
  - Provide land managers with strategies to help mitigate GHG emissions, improve soil quality, and adapt to climate change
  - Provide policy- and decision-makers timely and relevant information
- Resource for numerous synthesis publications; Contributed to Livestock GRACEnet; Centralized data portal.

USDA United States Department of Agriculture
Agricultural Research Service

GRACEnet Data Portal

Standardized Excel spreadsheet used for data entry template

Spreadsheets converted to Access data tables

Data tables compiled to create one location database

Each location database uploaded to central database to produce data query and download application

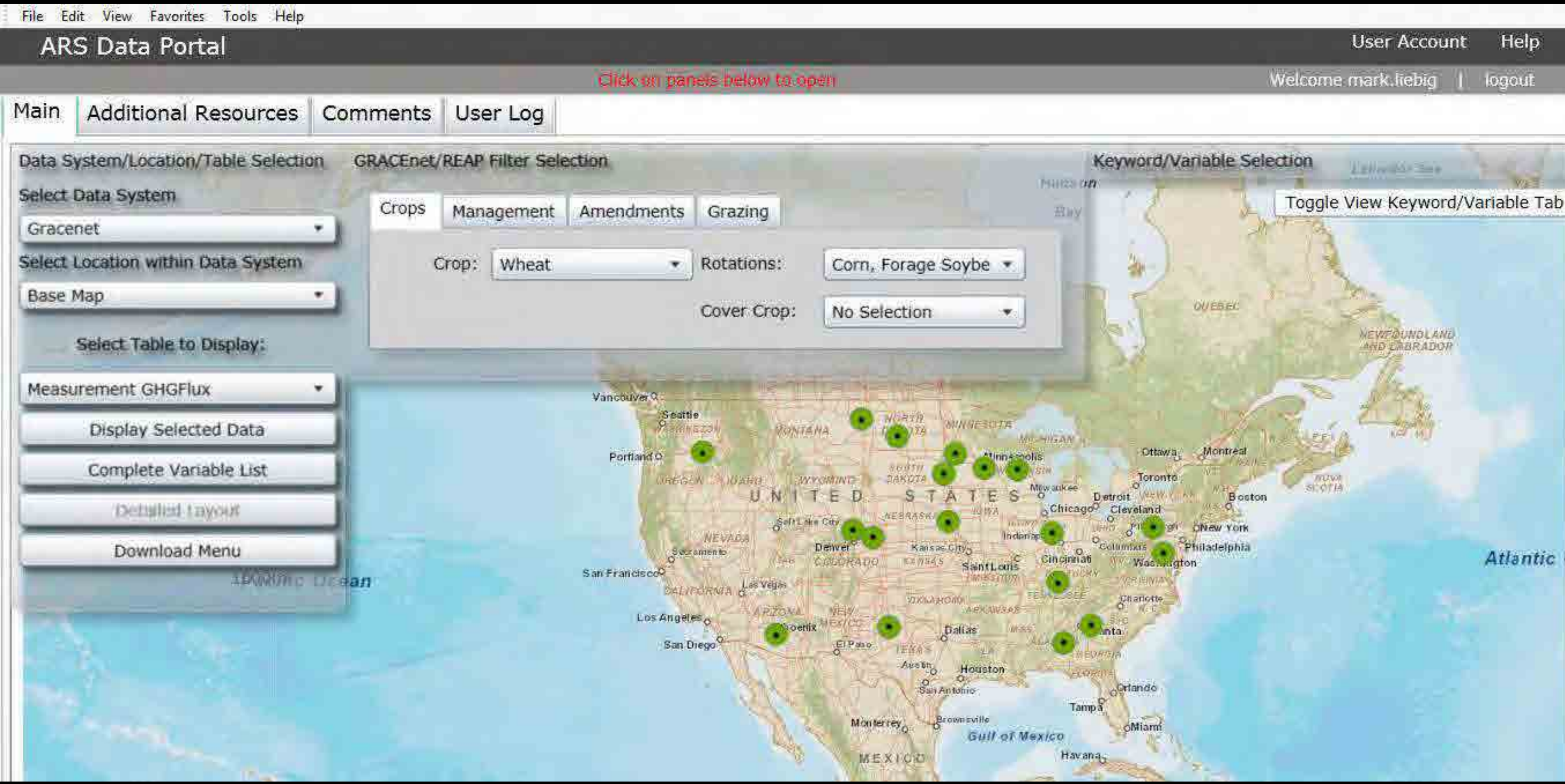

Published July 15, 2013

Journal of Environmental Quality SHORT COMMUNICATIONS

Introducing the GRACEnet/REAP Data Contribution, Discovery, and Retrieval System

S. J. Del Grosso,* J. W. White, G. Wilson, B. Vandenberg, D. L. Karlen, R. F. Follett, J. M. F. Johnson, A. J. Franzluebbers, D. W. Archer, H. T. Gollany, M. A. Liebig, J. Ascough, M. Reyes-Fox, L. Pellack, J. Starr, N. Barbour, R. W. Polumsky, M. Gutwein, and D. James

(Del Grosso et al., 2013)

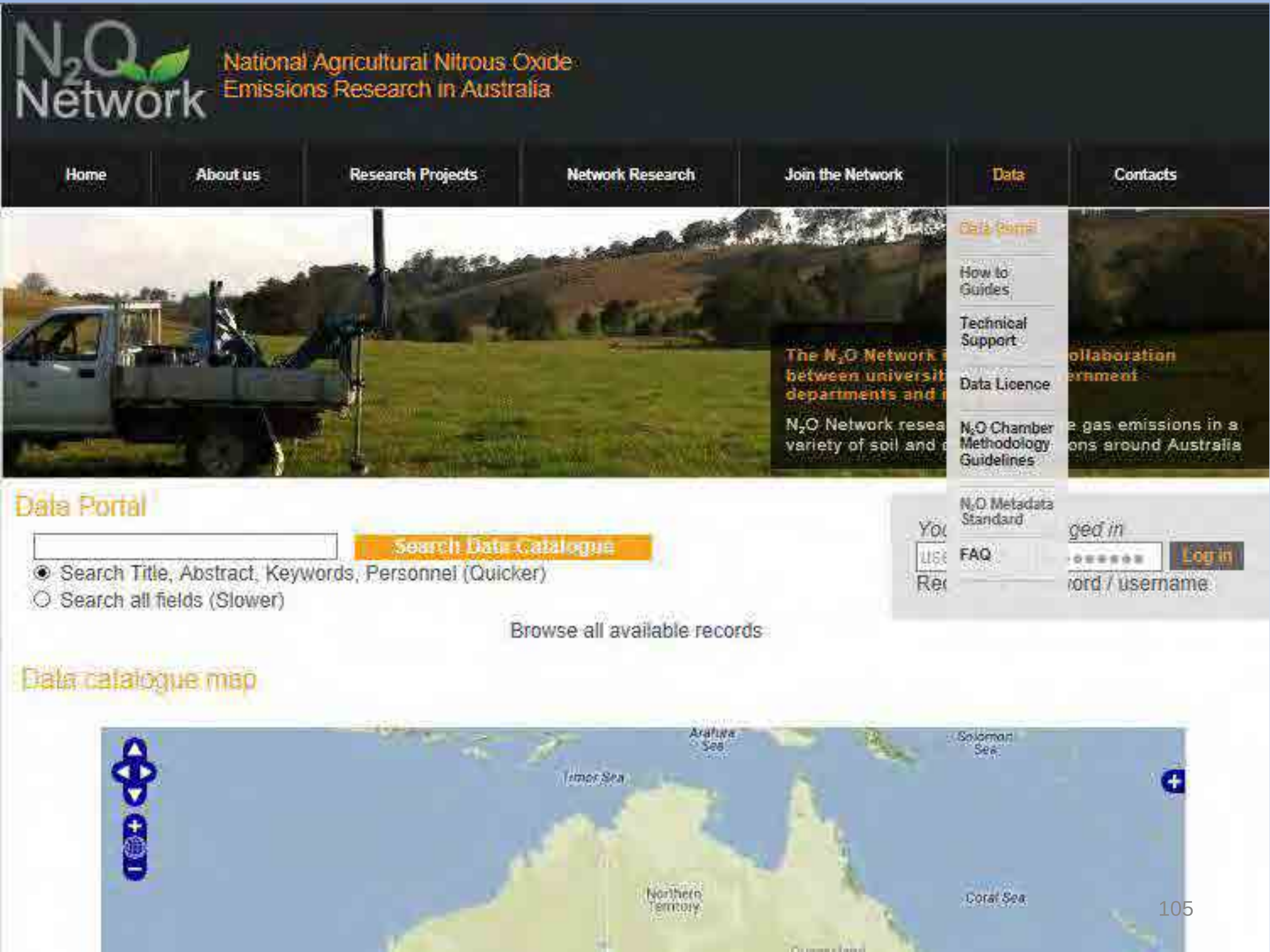


http://nrrc.ars.usda.gov/arsdataportal

National Agricultural Nitrous Oxide Emissions Research in Australia (N_2O Network)

- Established 2005
- Collaboration among university, government, and industry (Queensland University of Technology, Australian Government Department of Agriculture, Grains Research & Development Corporation)
- National research network to develop and deliver effective and practical strategies for reducing N_2O emissions while maintaining productivity.
- Resources/tools for growers, policy makers, and researchers.

http://www.n2o.net.au/


N2O Network
National Agricultural Nitrous Oxide
Emissions Research in Australia
Home
About us
Research Projects
Network Research
Join the Network
Data
Contacts
Data Portal
How to Guides
Technical Support
Data Licence
N2O Chamber Methodology Guidelines
N2O Metadata Standard
FAQ
Data Portal
Search Data Catalogue
Search Title, Abstract, Keywords, Personnel (Quicker)
Search all fields (Slower)
Browse all available records
Log in
Data catalogue map
Arafura Sea
Timor Sea
Solomon Sea
Northern Territory
Coral Sea

Closing Thoughts

Each measurement technique has its niche…

- **Manual chambers** – Small scale; Simple; Suitable where labor is abundant and resources limit use of more temporally intensive techniques

- **Automated chambers** – Small scale; Temporally intensive; Moderately specialized labor requirements

- **Micromet** – Large scale; Temporally intensive; Highly specialized labor requirements; Ideal for long-term monitoring

The critical issue of auxiliary data…

- Auxiliary implies a supporting role, yet these data are a requirement for model improvement.
- What criteria should we have for categorizing experimental sites? (e.g., What's Silver, Gold, and Platinum?)
- Can models use similar criteria groupings, or must these criteria be model-specific?

Networks and databases are like children…

"Conceiving new offspring is more exciting than tending to those already present. And yet, the latter activity generally produces more lasting rewards."

John Baker

- And so it's an issue of stable, long-term support.
- How can the GRA facilitate such support?
  - Global agroecosystem network (similar to *NEON* in scope, but for agricultural systems), <u>or</u>
  - Data network only; Open access; *Knowledge Network of Biocomplexity* as an example.

Thank you for your attention

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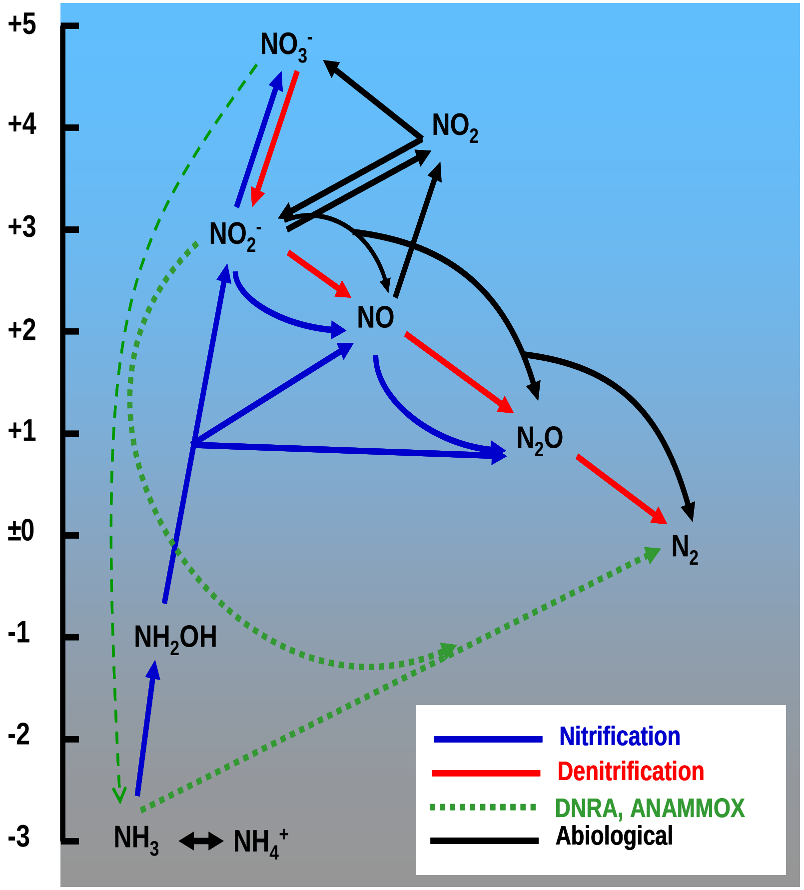
Objectives and expected deliverables of the workshop

Sylvain Pellerin, Pierre Cellier

INRA, France

- N transformation processes in soils which produce N_2O (Nitrification, denitrification) are controlled by many chemical, physical and biological variables
    - $[NO_3^-]$, $[NH_3]$, pH
    - T°, WFPS
    - Bacterial communities (ammonia oxidizing bacteria, denitrifiers,…)
- These variables, and their distribution in space and time, depend on soil and climatic conditions, and are also strongly impacted by several management agricultural practices
    - N fertilisation doses, forms and placement
    - Tillage
    - Residue management
    - Crop succession,
    - …



Butterbach-Bahl, 2014

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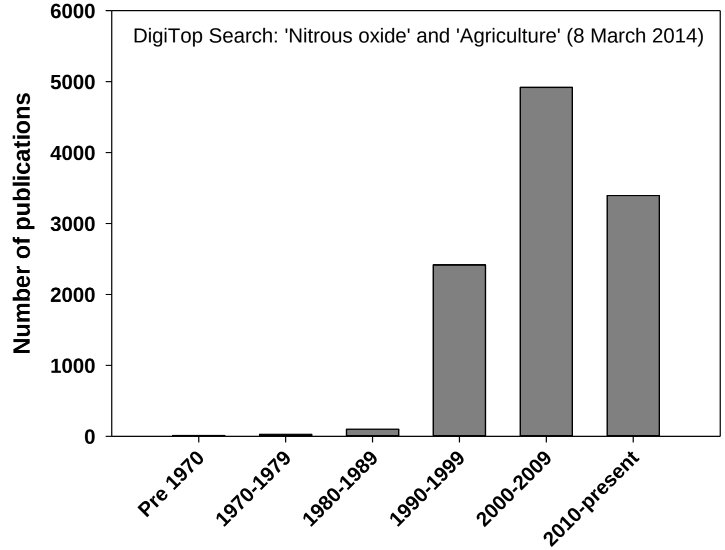
- Efforts for measuring N_2O emissions in field trials have started only recently (much later than for NO_3^- losses in water).

- Shortcomings remain about measurement techniques, especially when comparing several management practices (needs for trade-offs between number of treatments and sampling density)

- Common databases are at their early stages



Liebig and Cellier, 2014

- Because of processes acting at different time-scales and spatial scales, and because of complex interactions, the effect of agricultural practices on N_2O emissions is not always easily interpretable, and often hardly predictable

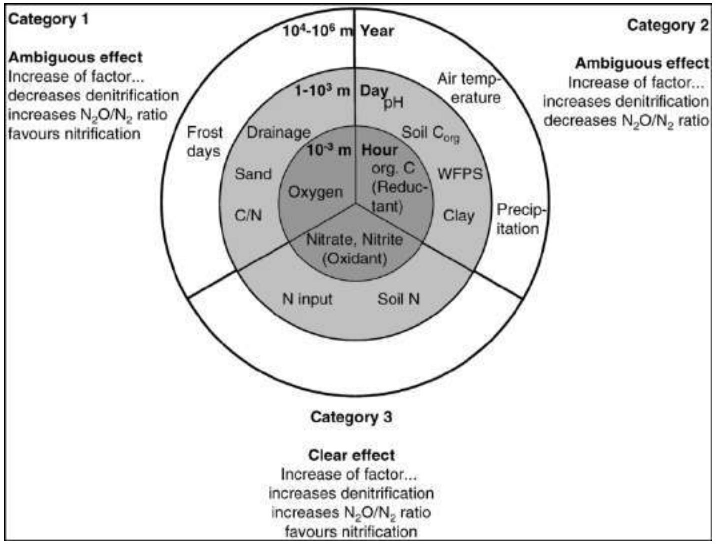
- Simulation models are needed:

  - to decipher the relative effects of soil properties, climate, agricultural management practices for a wide range of circumstances;

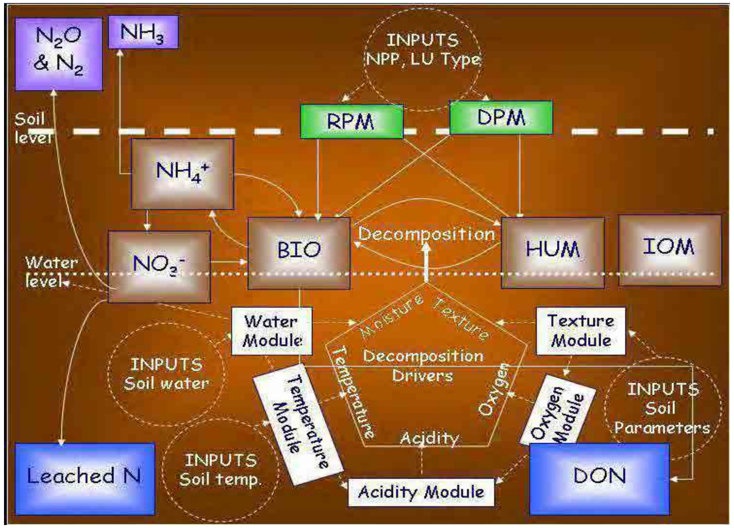
  - to interpret and compare data from different experiments;

  - for inventory purposes

- But to what extent process-based models account for the effect of agricultural management practices remains a question



Freibauer and Kaltschmitt, 2003



Smith, 2014

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Conversely, management practices offer levers for mitigating N_2O emissions

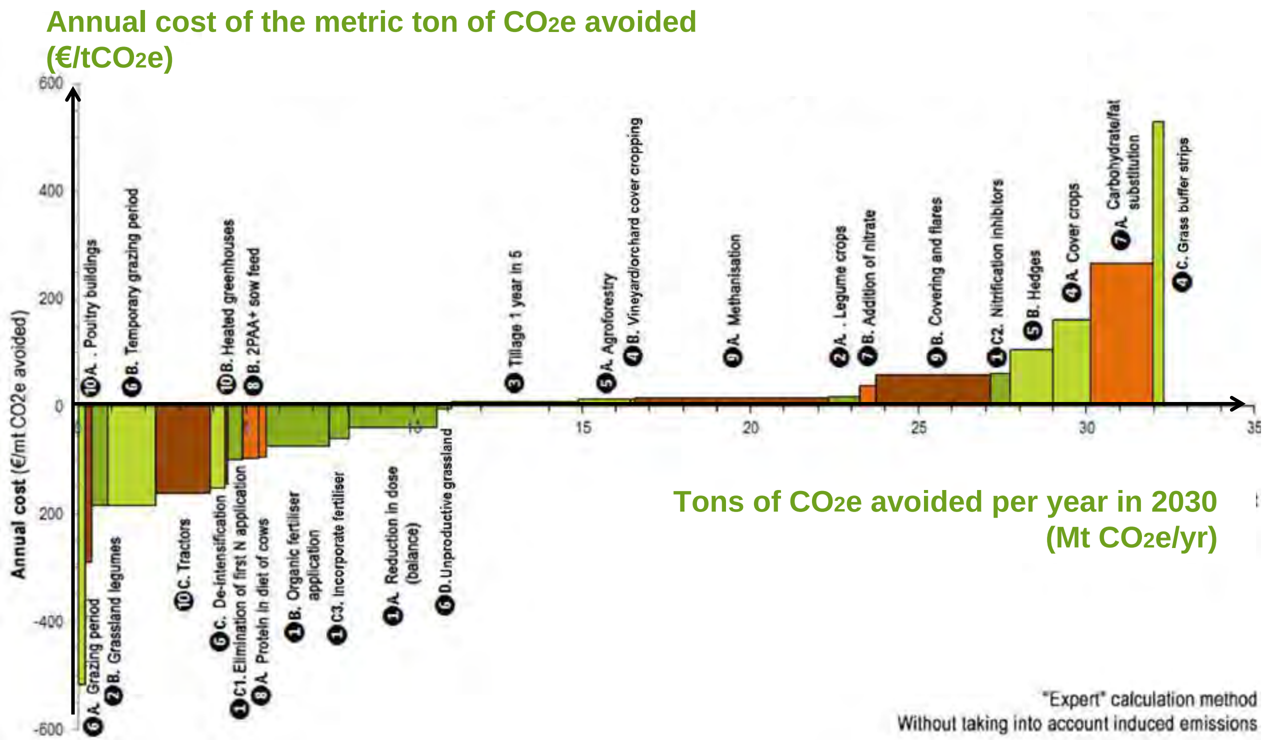
Example of a recently published advanced study in France:

« How can french agriculture contribute to reducing greenhouse gas emissions? Abatement potential and cost of ten technical measures »

26 proposed technical measures, each of them characterized by

- the annual GHG emission abatement potential (in Mtons of CO_2e avoided per year)

- the cost to the farmer of the metric ton of CO_2e avoided (in € per t of CO_2e avoided)

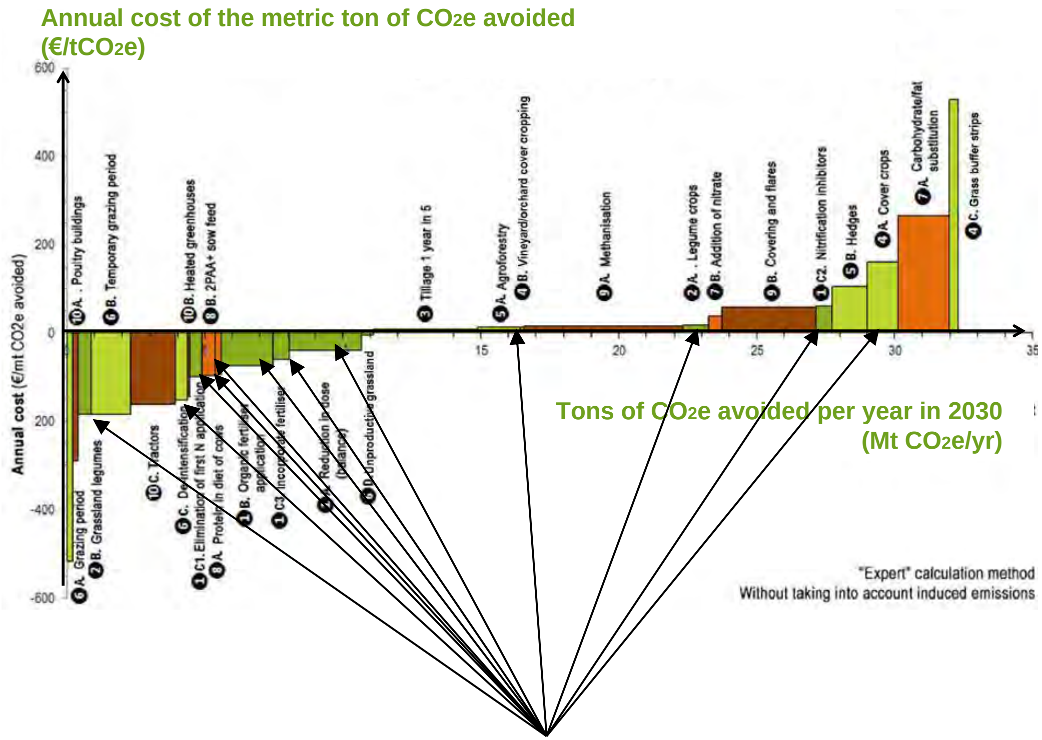


Pellerin et al., 2013

CROPLANDS GROUP

GLOBAL RESEARCH ALLIANCE ON AGRICULTURAL GREENHOUSE GASES

- Adjust fertiliser application rates to more realistic yield targets
- Make better use of organic fertiliser
- Adjust application dates to crop requirements
- Add a nitrification inhibitor
- Incorporate fertiliser
- Introduce more grain legumes in arable crop rotations
- Increase legumes in temporary grassland
- Introduce more cover crops and vineyard/orchard cover cropping
- Make the most intensive permanent and temporary grassland less intensive by more effectively adjusting nitrogen fertiliser application
- Reduce the nitrogen content in the diet of dairy cows
- Reduce the nitrogen content in the diet of pigs

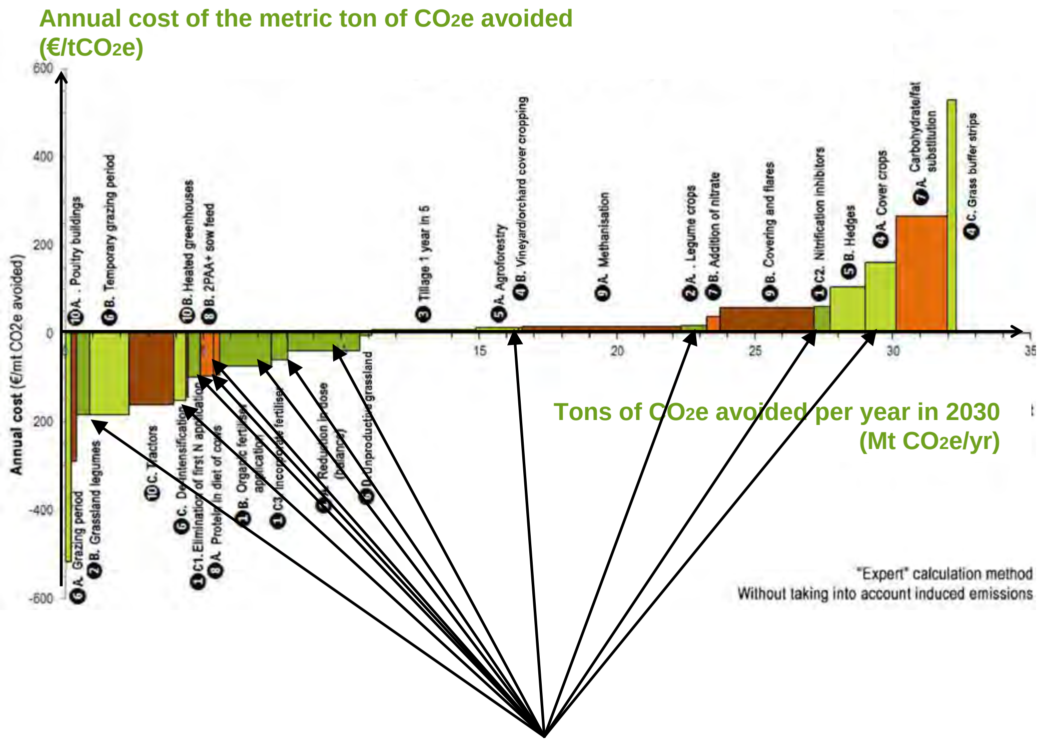


Measures targeting a reduction of N_2O emissions

• 30% of the cumulated abatement potential is related to N management and associated N_2O emissions (N fertilisation, legumes, N content in animal diets,…).

• The main part of the potential abatement targeting N_2O emissions has a negative cost (win-win measures)

• However, the assessment of the potential abatement of most measures was characterized by a very high uncertainty (especially because of uncertainty on N_2O emissions), also for measures not targeting N_2O emissions (ex reduced tillage)



Measures targeting a reduction of N_2O emissions

⇒ In view of using models to explore **mitigation options**, the ability of simulation models to account for the **effect of agricultural management practices** on N_2O emissions must be better assessed

Objectives of the workshop

In the context of croplands, the objectives of the workshop are to assess the ability of models to account for the influence of the main drivers on N_2O emission and prepare a model intercomparison (in relation with C-N cross-cutting group, CN-MIP). For this, we need to improve synergy between the modelling and data collection effort

This requires analysing the following :

- Identify the key management practices that influence N_2O emissions and offer levers for mitigation
- Assess the ability of models to account for their effects on emissions (from a conceptual point of view)
- Suggest improvements for these models
- Identify the available datasets to assess or compare models in this respect and make suggestions for improved protocols

Key questions to be addressed during the workshop

How agricultural management practices affect N_2O emissions?

- What are the key management practices that influence N_2O emissions, depending on the context?
- Do we have enough experimental results? Are they reliable? Is there some important pedoclimatic and/or agricultural contexts for which data are missing?
- Are interactions with climatic and soil conditions correctly understood?
- How to avoid the risk of abusive generalization?
- Have interactions between management practices received enough attention?
- Are there some technical options that warrant more studies (especially options that are used for mitigation goals like reduced tillage)?
- Has the risk of pollution swapping received enough attention?
- What are the best levers for mitigation?

Key questions to be addressed during the workshop

Do models correctly account for the effect of agricultural management practices on N_2O emissions?

- How to parameterize the effects of agricultural practices on N_2O emissions in crop/biogeochemical models?
- Have models been correctly evaluated in this respect?
- What is the required accuracy of predictions, depending on the objective of the modelling (interpret and compare experiments, explore mitigation options, inventory purposes,…)?
- How to better evaluate and improve models in this respect?
- What are the interests/drawbacks of other approaches (meta-analyses,…)?

Key questions to be addressed during the workshop

How to make the collective effort of data acquisition and model evaluation and improvement more efficient?

- can we make a synthesis of available datasets and identify their adequacy to assess or compare models (in collaboration with the CN cross-cutting group)?
- can we provide rules on how to measure N_2O emissions and ancillary variables to account for the effect of agricultural practices?
- in view of future call for proposals, do we have suggestions for a new project?