UNKNOWNS ABOUT N-(C-) CYCLING IN AGROECOSYST

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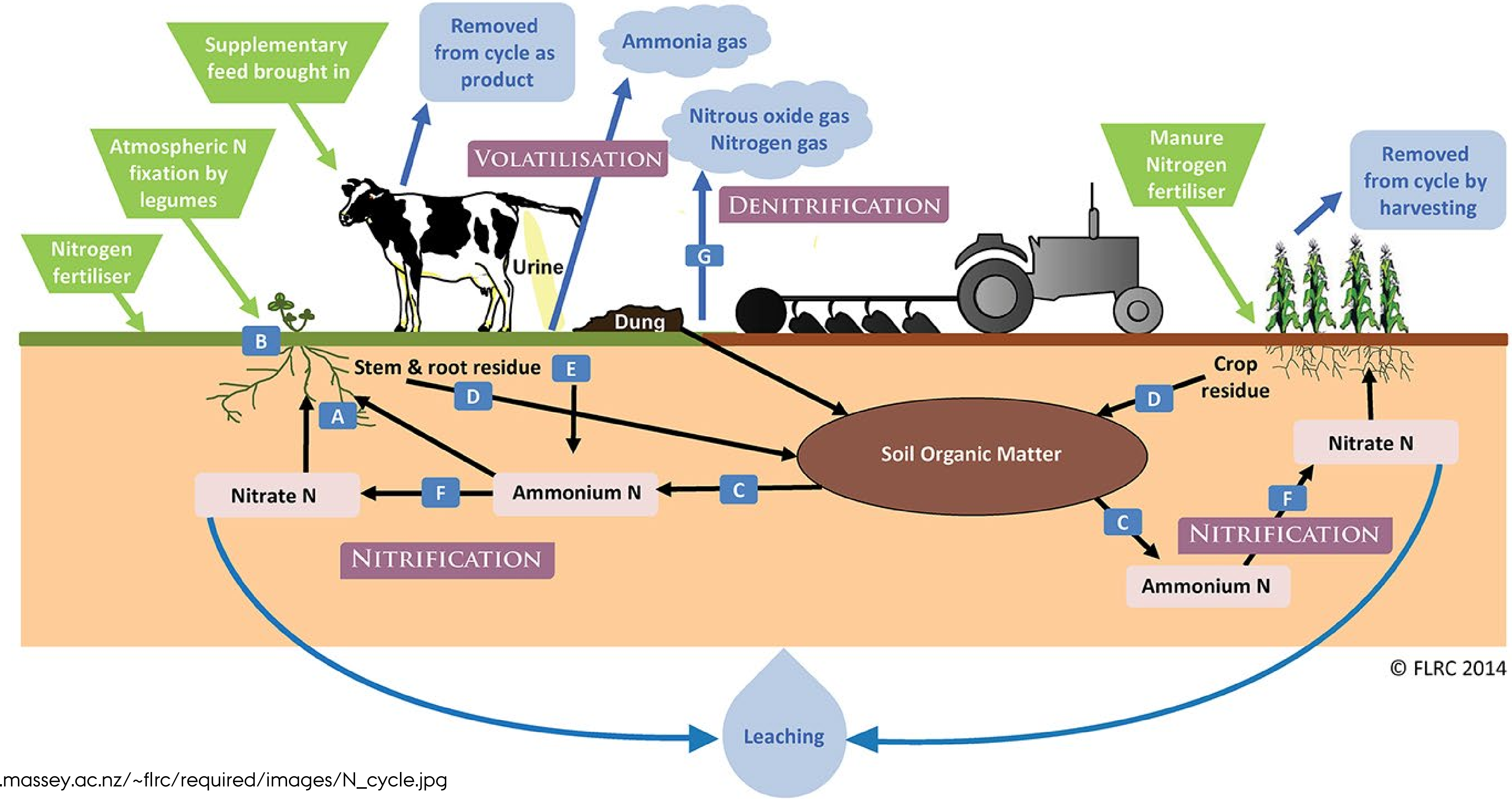
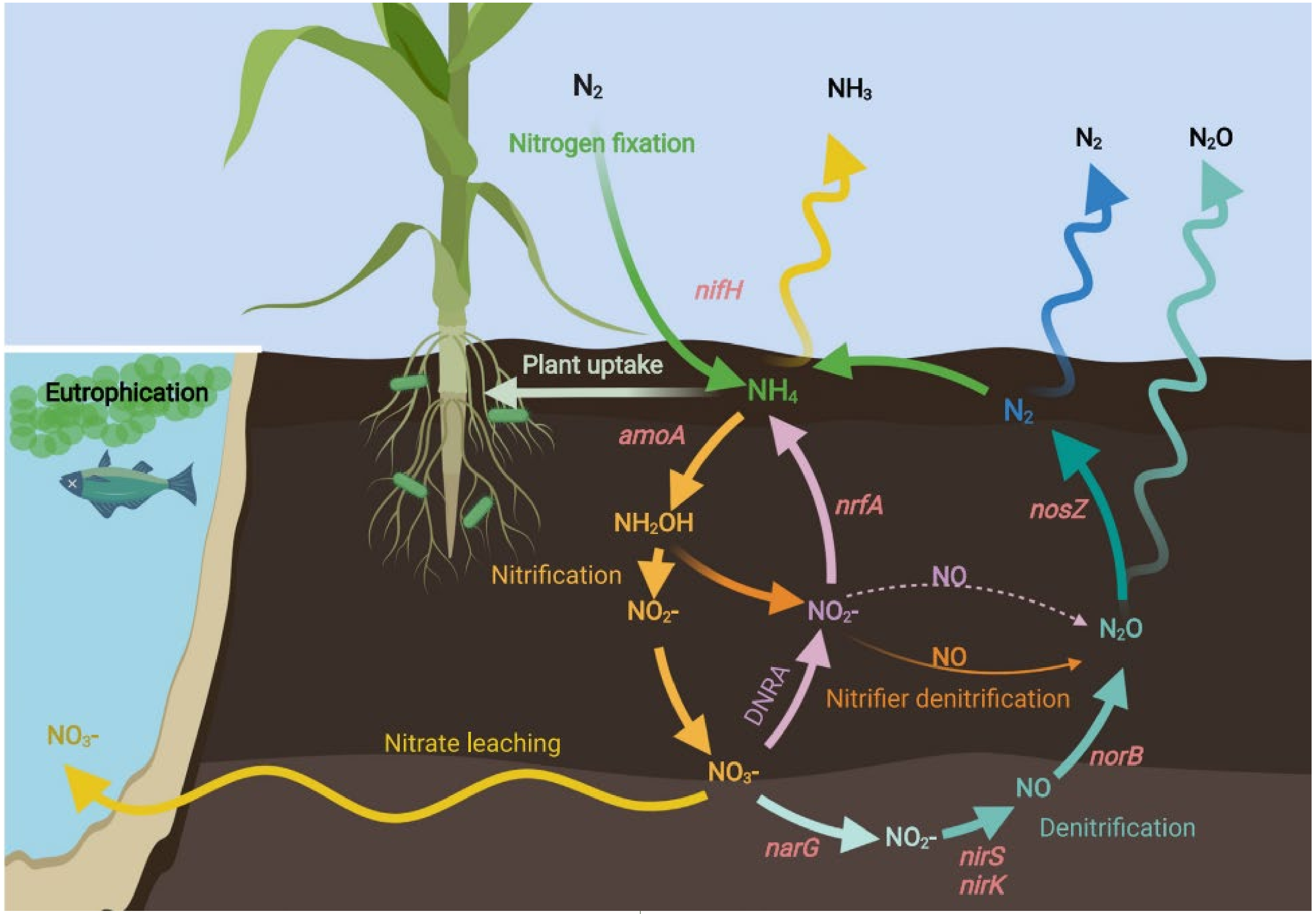
Land-CRAFT
Department of Agroecology, Aarhus University

NITROGEN CYCLING IN AGROECOSYSTEMS



https://www.massey.ac.nz/~flrc/required/images/N_cycle.jpg

SOCIETAL INTERESTS–ENVIRONMENTAL N LOSSES



Adapted from Klimasmith & Kent 2022, Trends in Microbiology

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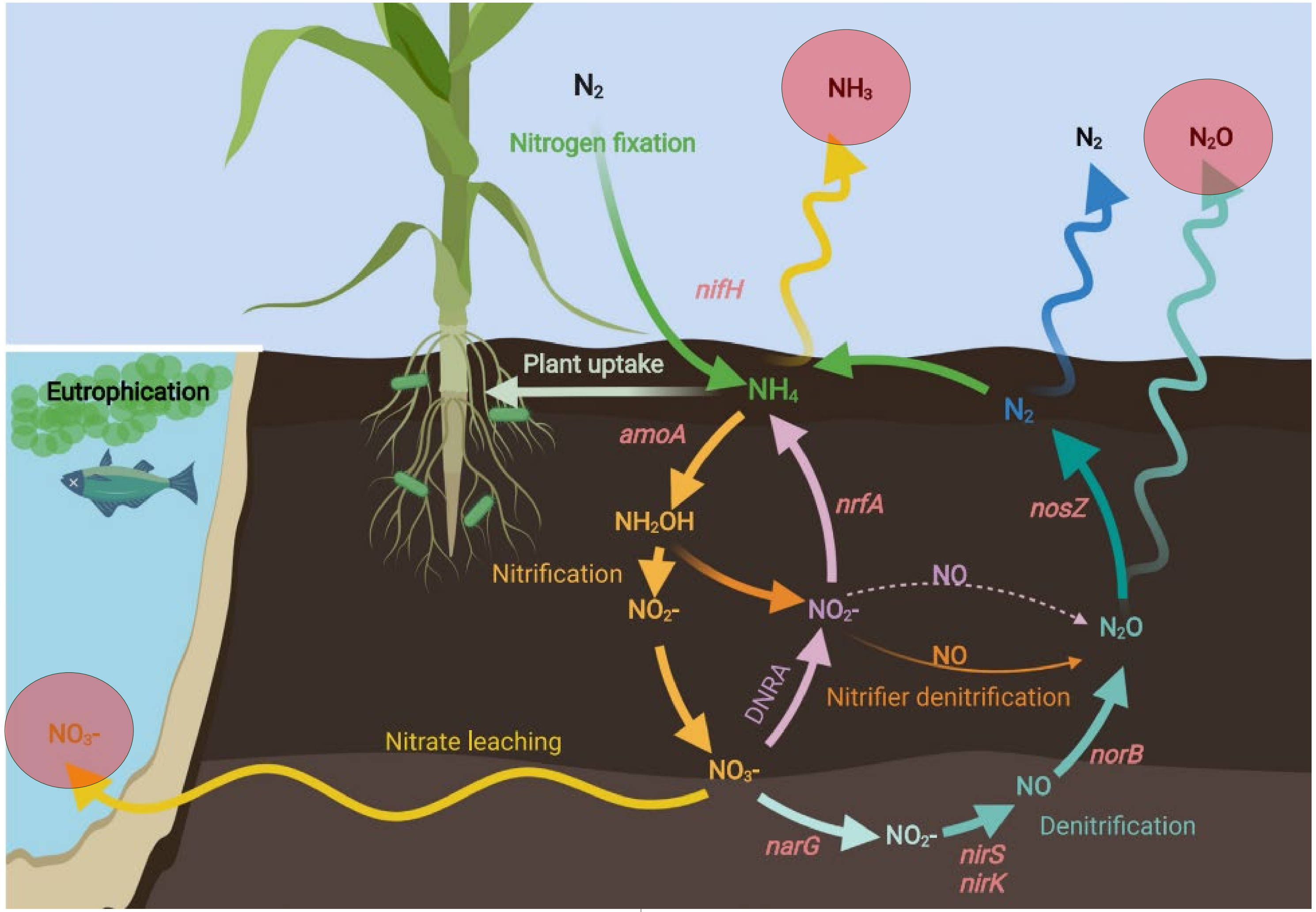
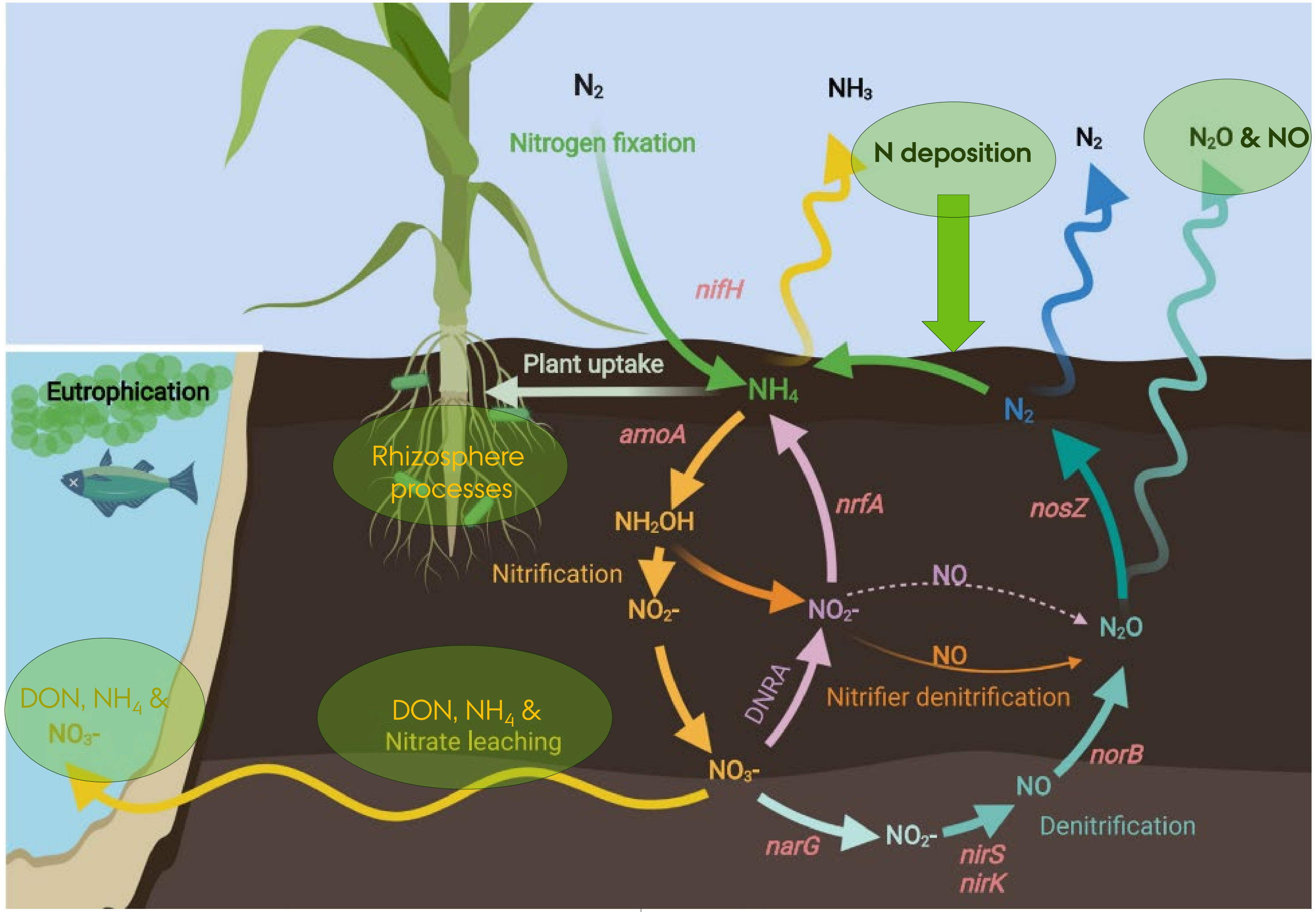


N_2O: About 1% of environmental N losses

Adapted from Klimasmith & Kent 2022, Trends in Microbiology

HOLISTIC VIEW IS MISSING



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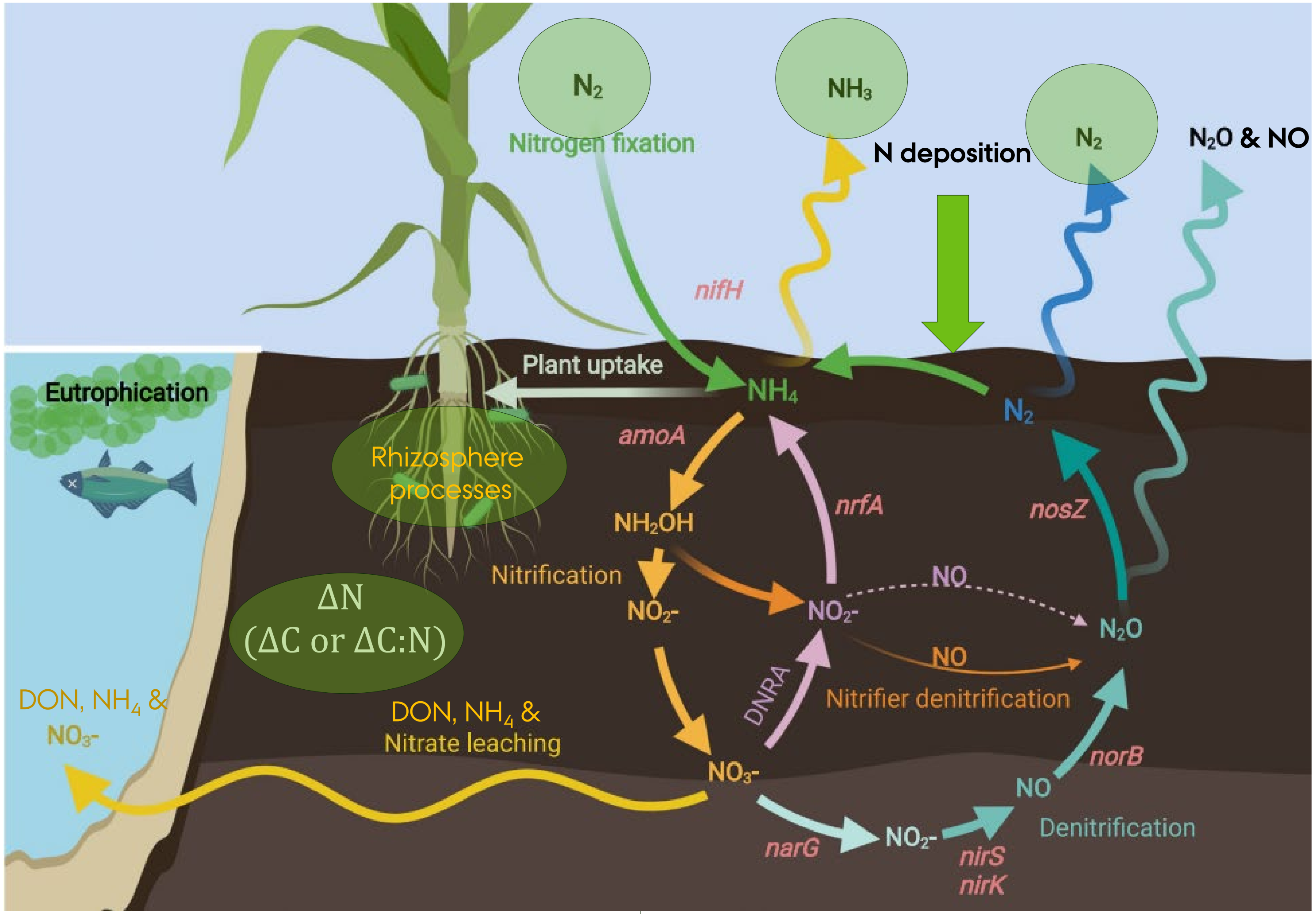
MAJOR UNCERTAINTIES



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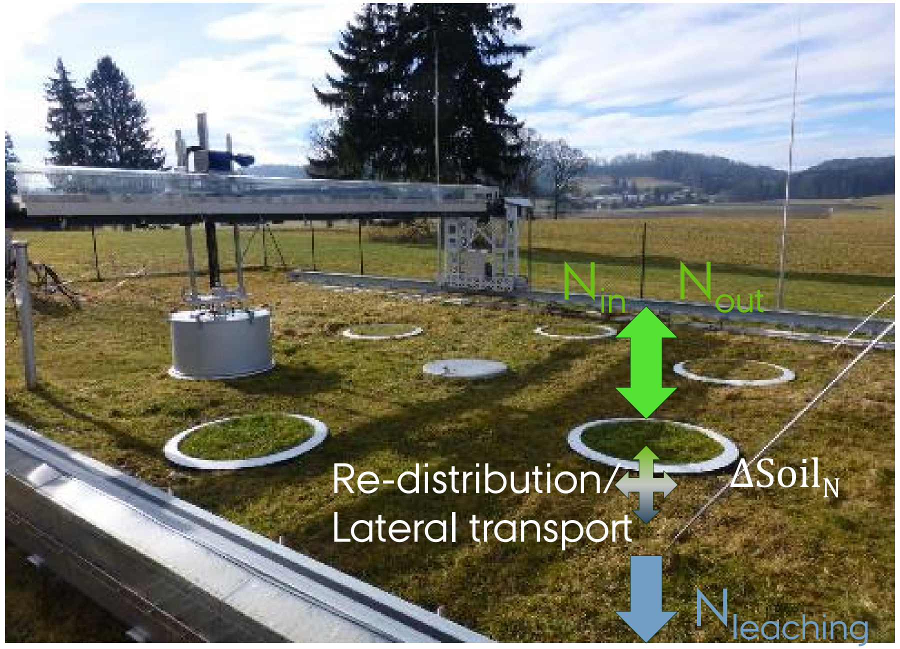
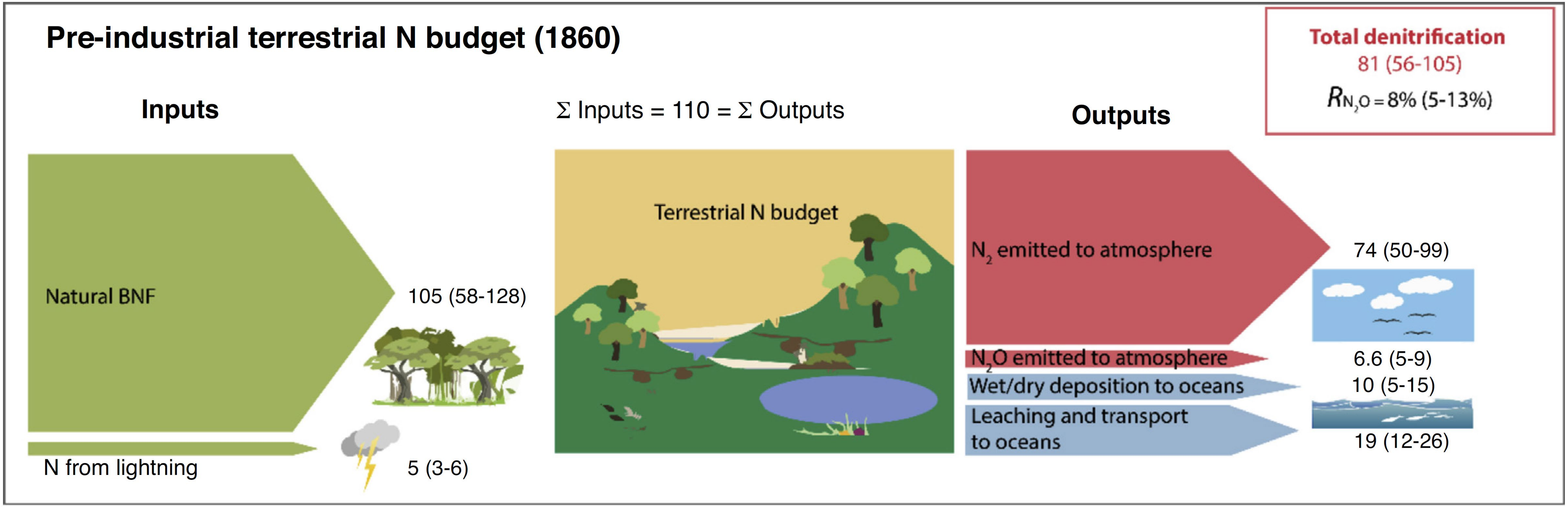
WHY IS IT IMPORTANT TO REDUCE UNCERTAINTIES?

- System understanding
- Nitrogen Use Efficiency
- Optimizing land management



DRIVER OF UNCERTAINTY – N LOSSES DUE TO DENITRIFICATION



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Estimating global terrestrial denitrification from measured N_2O:(N_2O + N_2) product ratios

Clemens Scheer[1,2], Kathrin Fuchs[1], David E Pelster[3] and Klaus Butterbach-Bahl[1,4]

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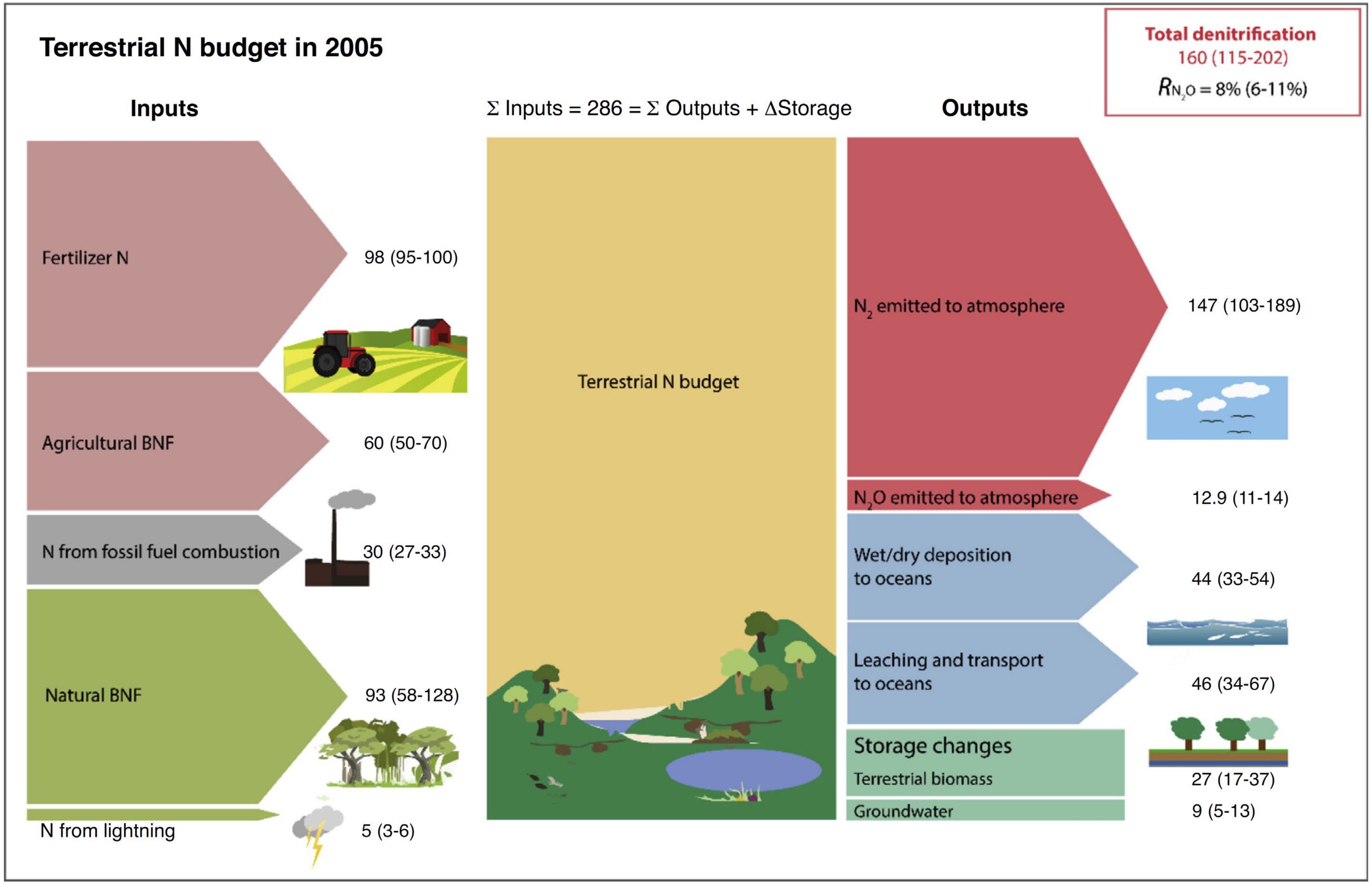

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METHODS FOR MEASURING DENITRIFICATION

(1) acetylene-based methods

(2) ^{15}N tracers

(3) direct N_2 quantification

(4) N_2:Ar ratio quantification

(5) mass balance approaches

(6) stoichiometric approaches

(7) methods based on stable isotopes

(8) in situ gradients with atmospheric environmental tracers

(9) molecular approaches

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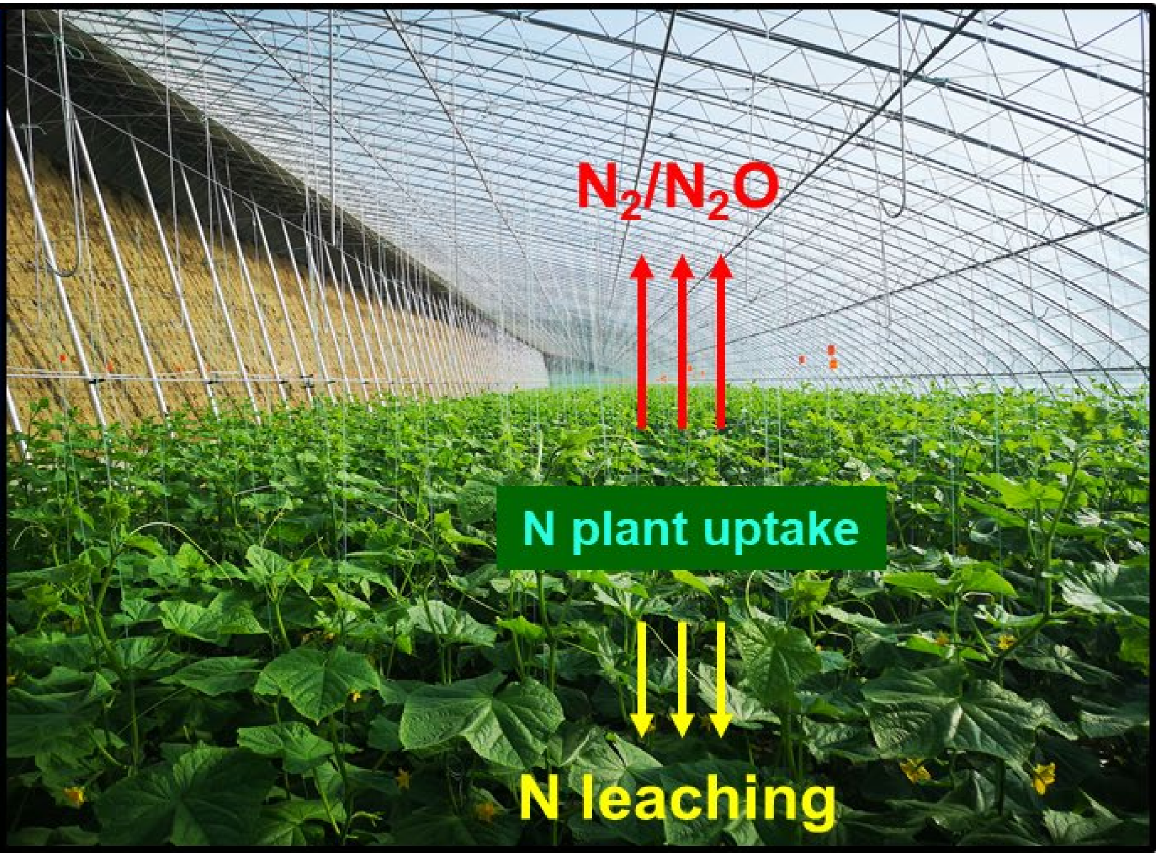
CLOSING THE N BALANCE FOR VEGETABLE SYSTEMS



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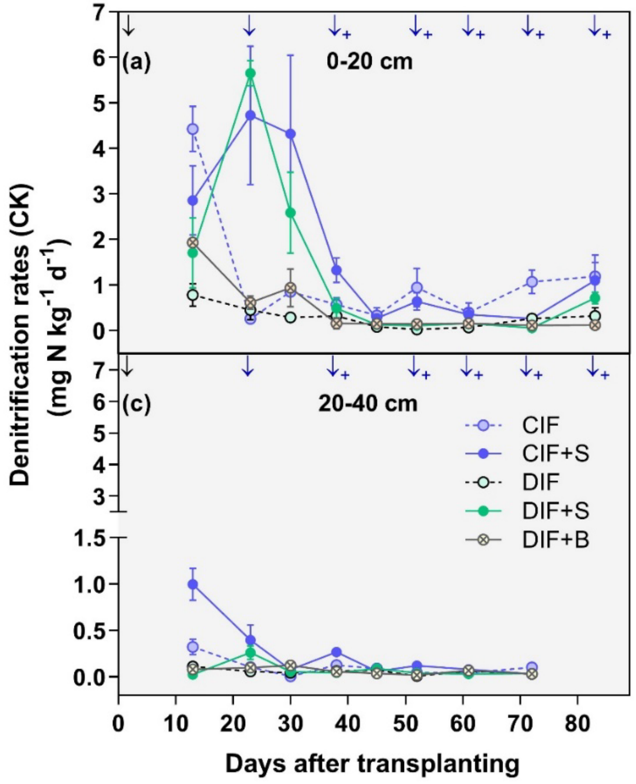

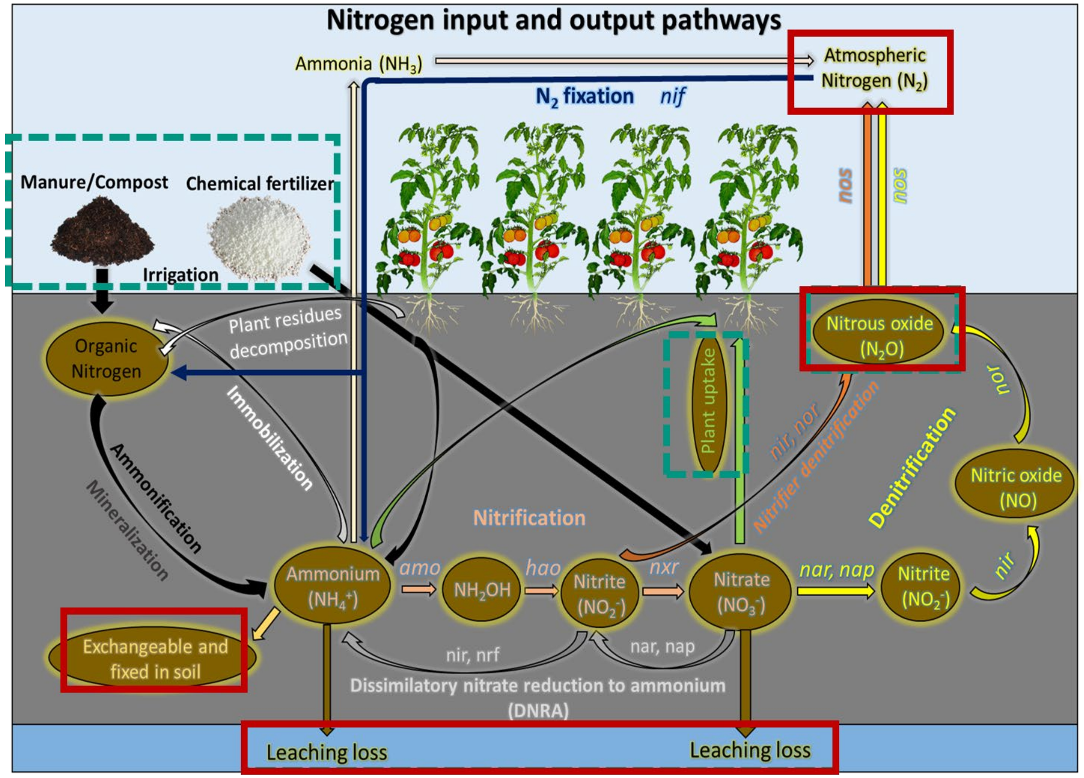

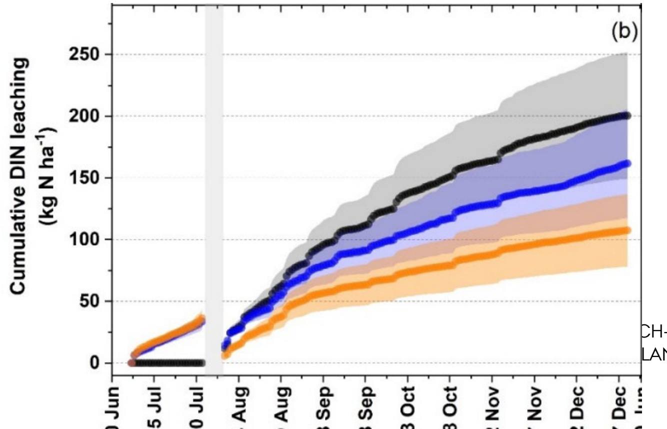

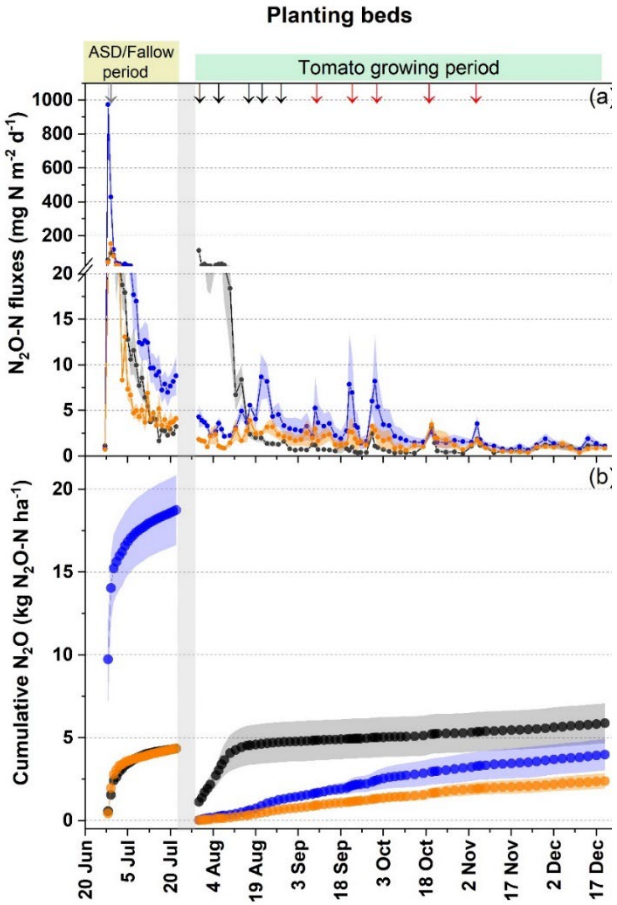

Qasim et al., 2022a, Plant and Soil 471, 157-174;
Qasim et al., 2022b, Sci.Total Environm., 830, 154673

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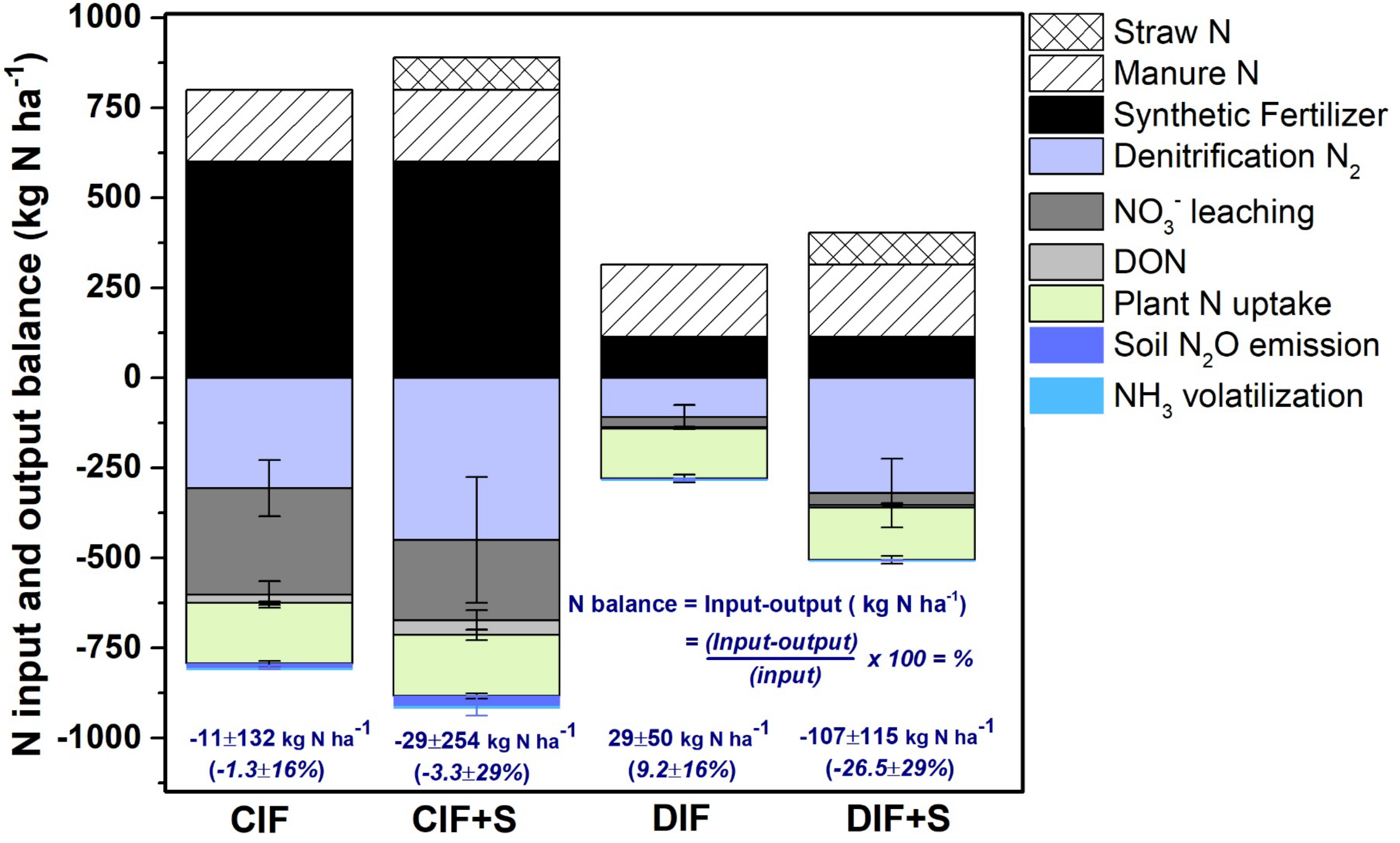

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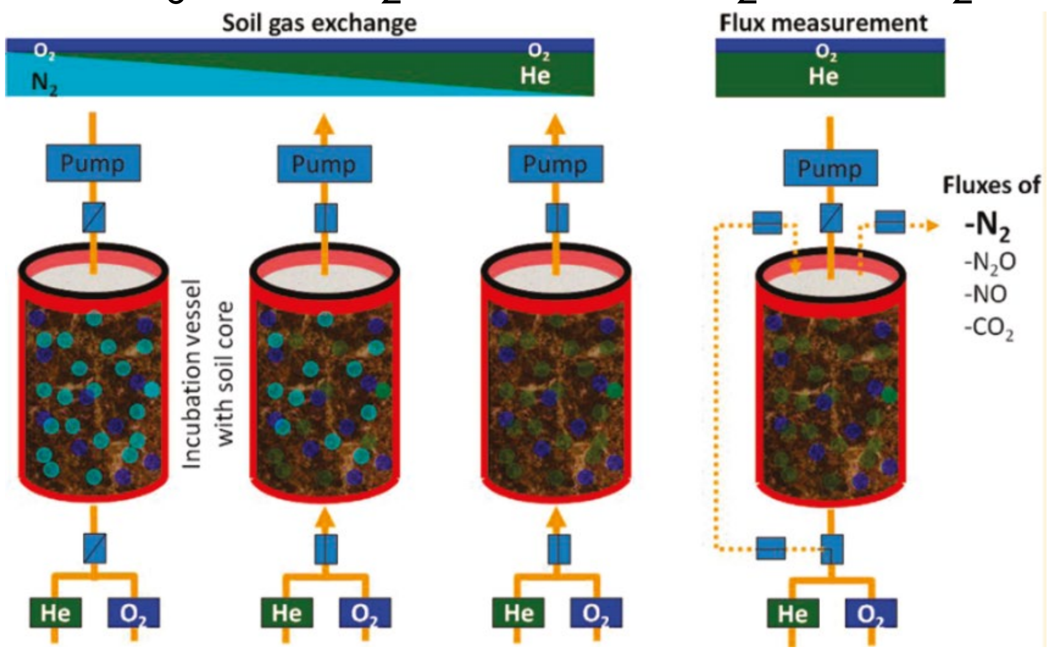
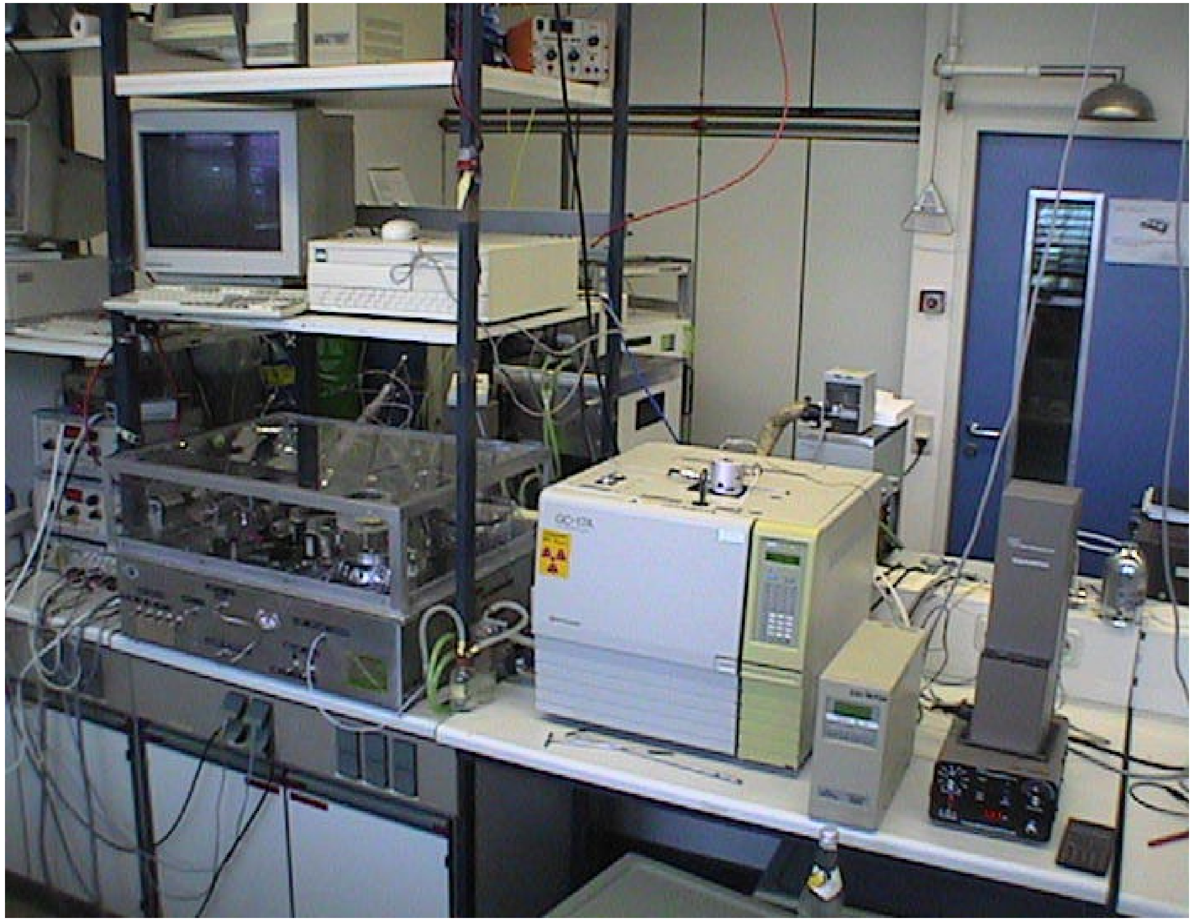
N_2 EMISSIONS FROM GRASSLAND SYSTEMS

$NO_3 \rightarrow NO_2 \rightarrow NO \rightarrow N_2O \rightarrow N_2$





Wang et al., 2011, Environ. Sci. Technol., 45, 6066–6072

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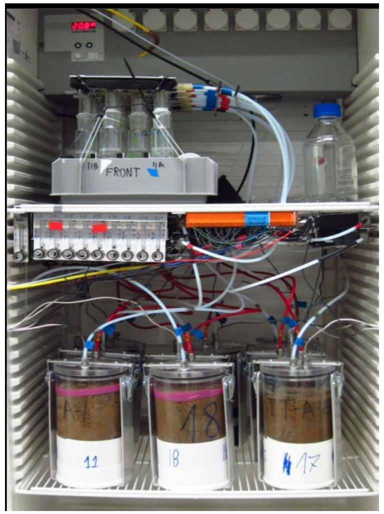

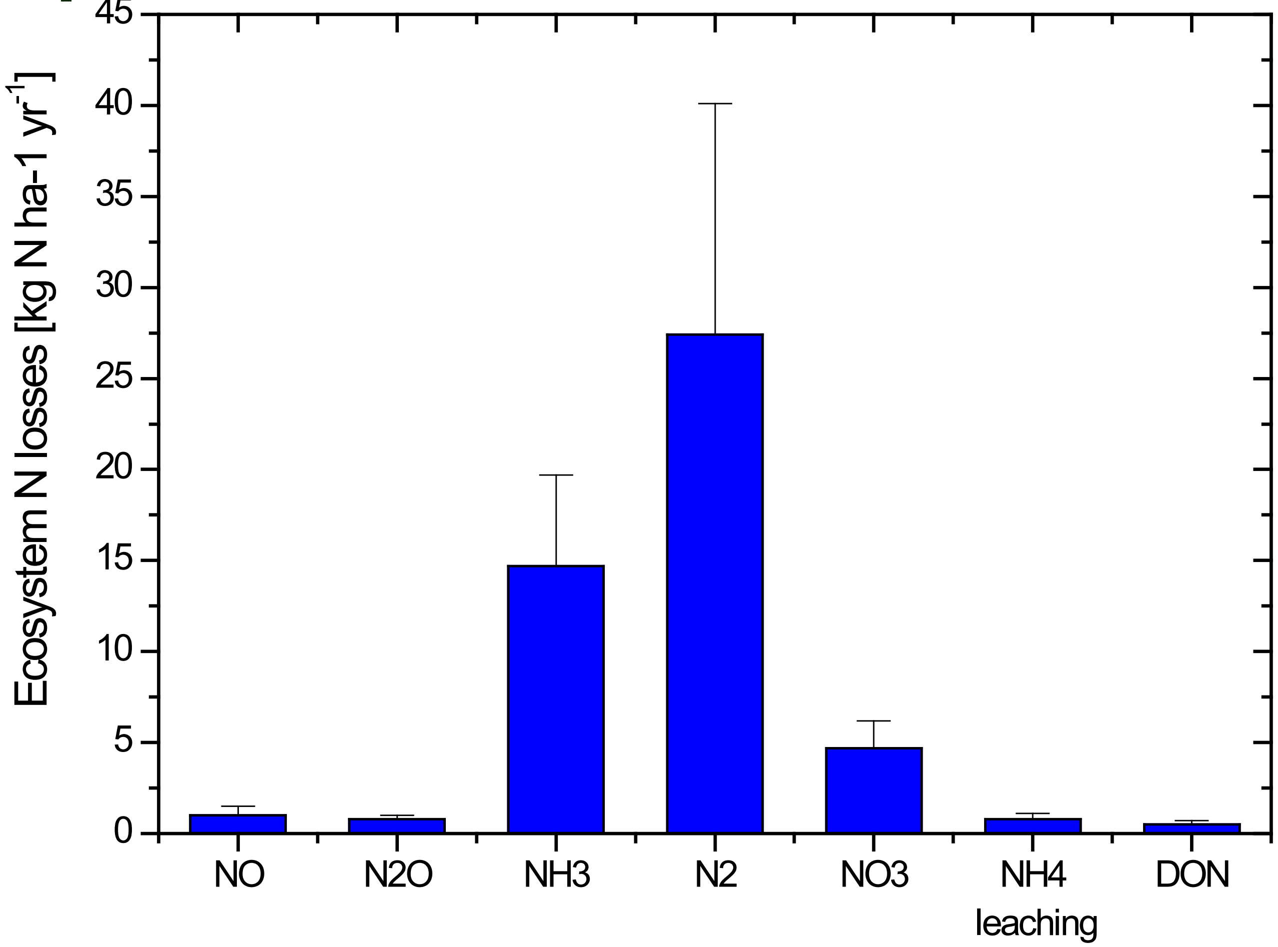

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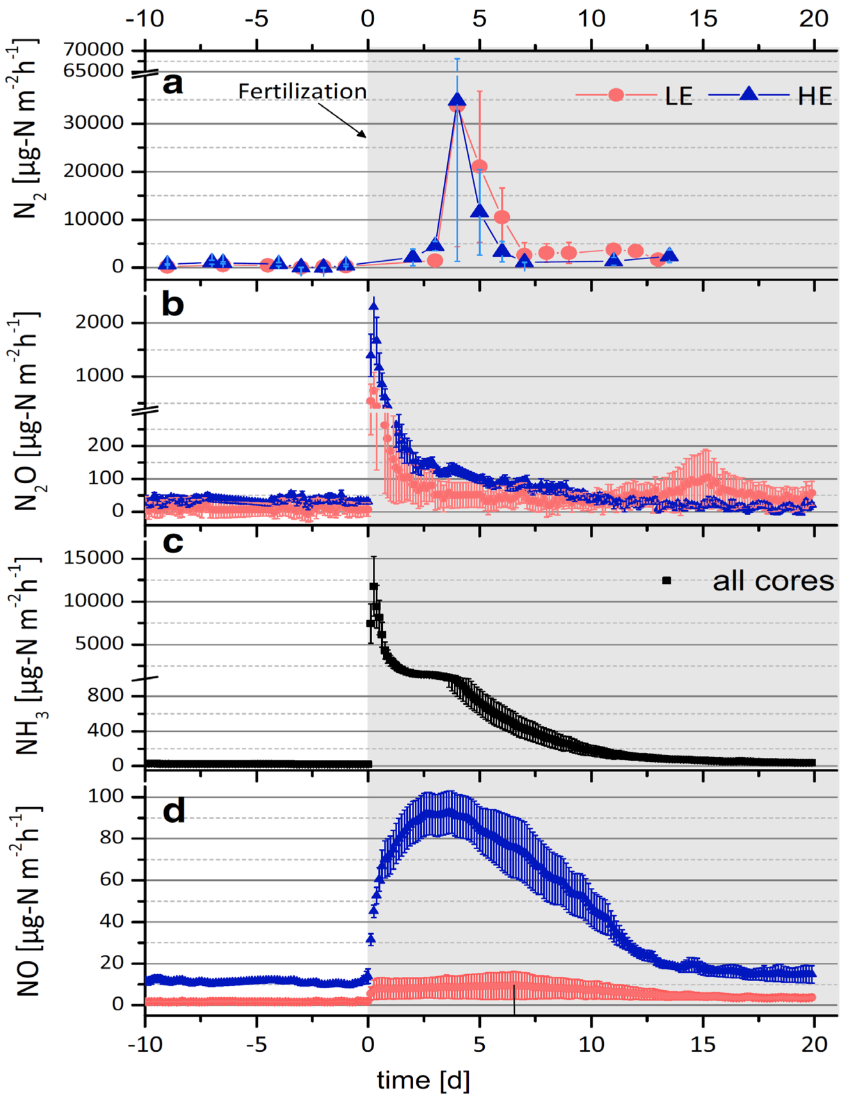
N-GAS EMISSIONS FOLLOWING SLURRY APPLICATION



	HE	[kg N ha^{-1}]
Manure-N application	51.2	
N_2 emission	16.1 ± 8.3 (31.4%)	
NH_3 emissions	3.6 ± 1.5 (7.1%)	
N_2O emissions	0.52 ± 0.04 (1.0%)	
NO emissions	0.24 ± 0.01 (0.5%)	
Total N gas emissions	20.6 (40.2%)	

Uncertainty is given as SE from then mean (n = 6)

Zistl-Schlingmann et al., 2019. Biogeochemistry 143, 15-30

$N_2 : N_2O$ STOCHIOMETRY & N_2 FLUXES FROM WHEAT SYSTEMS

1. Measurements of N_2O (NO) fluxes in the field + soil environmental parameters
2. Measurements of $N_2O:N_2$ ratios in the laboratory (He-O_2 approach) + soil environmental paramters
3. Parameterization of a Dual Arrhenius and Michaelis-Menten (DAMM) model
4. Field N_2O fluxes + soil environmental parameters + DAMM model = Field scale N_2 fluxes

Multivariate regressions between soil dinitrogen (N_2) and nitrous oxide (N_2O) emissions (μg N h^{-1} kg^{-1} dry soil) or the molar ratios of N_2O to N_2O plus N_2 emissions (R_{N_2O}) and soil factors.

$$y = A_1 \frac{[NH_4^+]}{k_1 + [NH_4^+]} \cdot \frac{[NO_3^-]}{k_2 + [NO_3^-]} e^{BW} e^{CT_c},\ y = A_2 \frac{[NH_4^+]}{k_1 + [NH_4^+]} \cdot \frac{[NO_3^-]}{k_2 + [NO_3^-]} e^{BW} e^{-E_a/(RT_k)}$$

Y	A_1/A_2	k_1	k_2	B	C	Q_{10}/E_a	n	r^2	P
N_2	$(2.98 \pm 10.5) \times 10^{-3}/(3.46 \pm 74.8) \times 10^9$	–	1.4 ± 1.7	0.071 ± 0.024	0.12 ± 0.09	$3.3 \pm 2.8/61 \pm 62$	20	0.65	<0.001
N_2O	$(1.07 \pm 2.27) \times 10^{-4}/(1.32 \pm 22.2) \times 10^8$	13.5 ± 4.8	4.5 ± 4.3	0.14 ± 0.01	0.13 ± 0.07	$3.8 \pm 2.6/60 \pm 45$	20	0.99	<0.001
R_{N_2O}	$(3.04 \pm 8.83) \times 10^{-2}$/-	3.1 ± 2.4	2.5 ± 3.4	0.048 ± 0.019	0.002 ± 0.082	–	20	0.92	<0.001

Wang et al., 2020. Soil Biol. Biochem. 148, 107904

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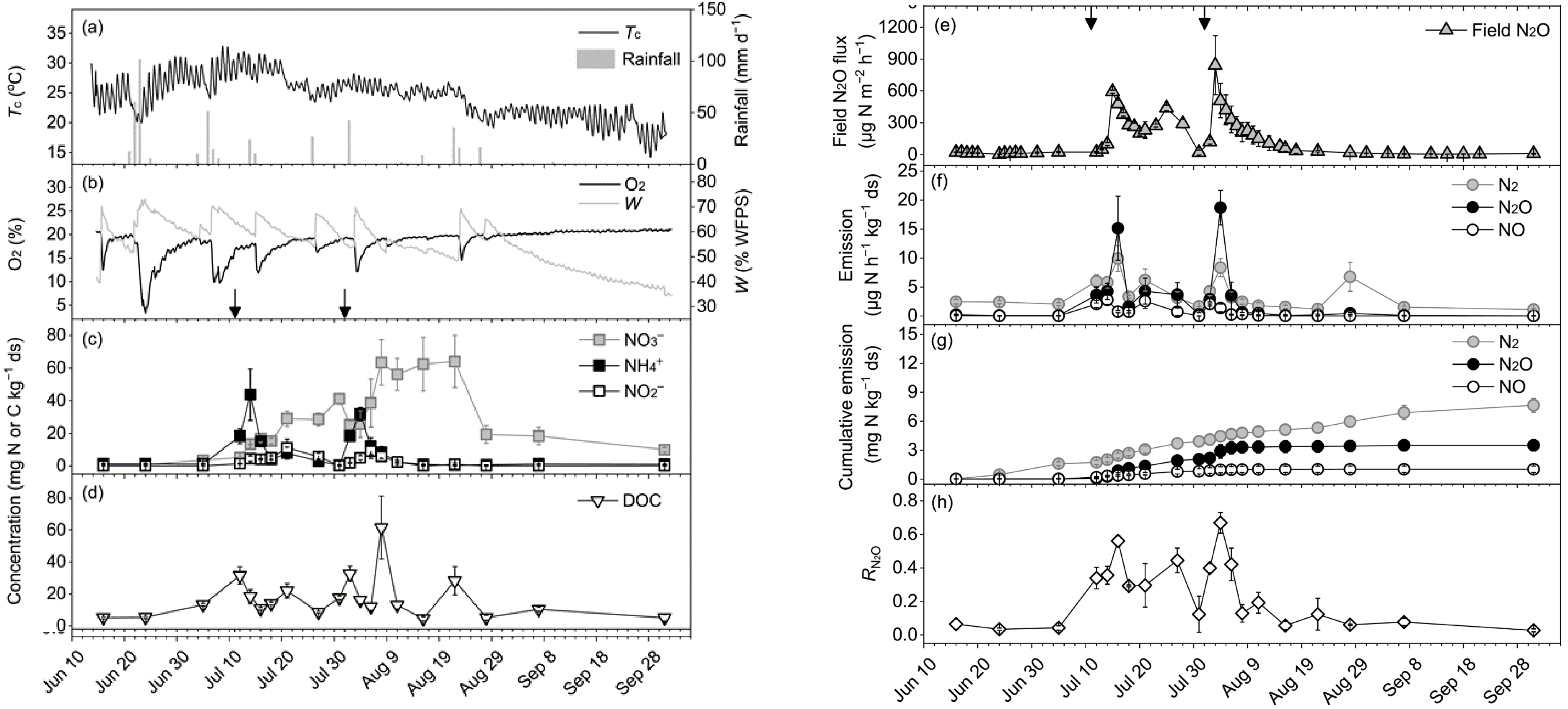

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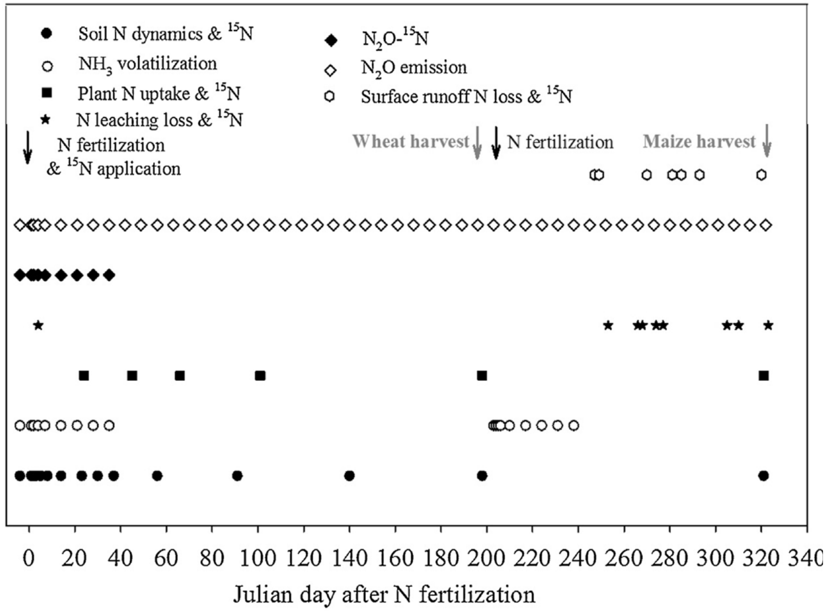
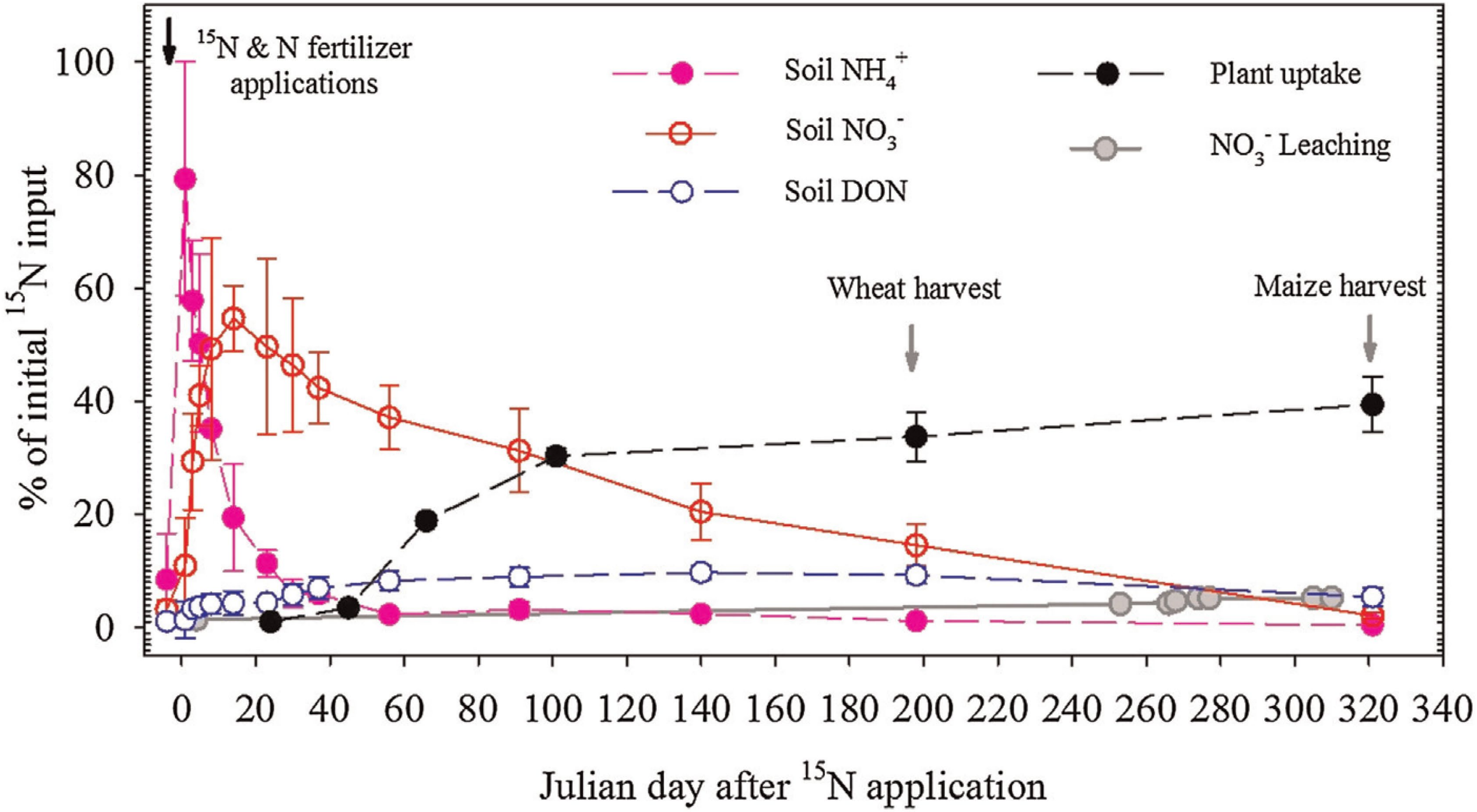
^{15}N LABELLING AND N BALANCES FOR WHEAT/ MAIZE ROTATION





Zhou et al., 2016. Agric. Ecosys. Envnvironm. 231, 1-14

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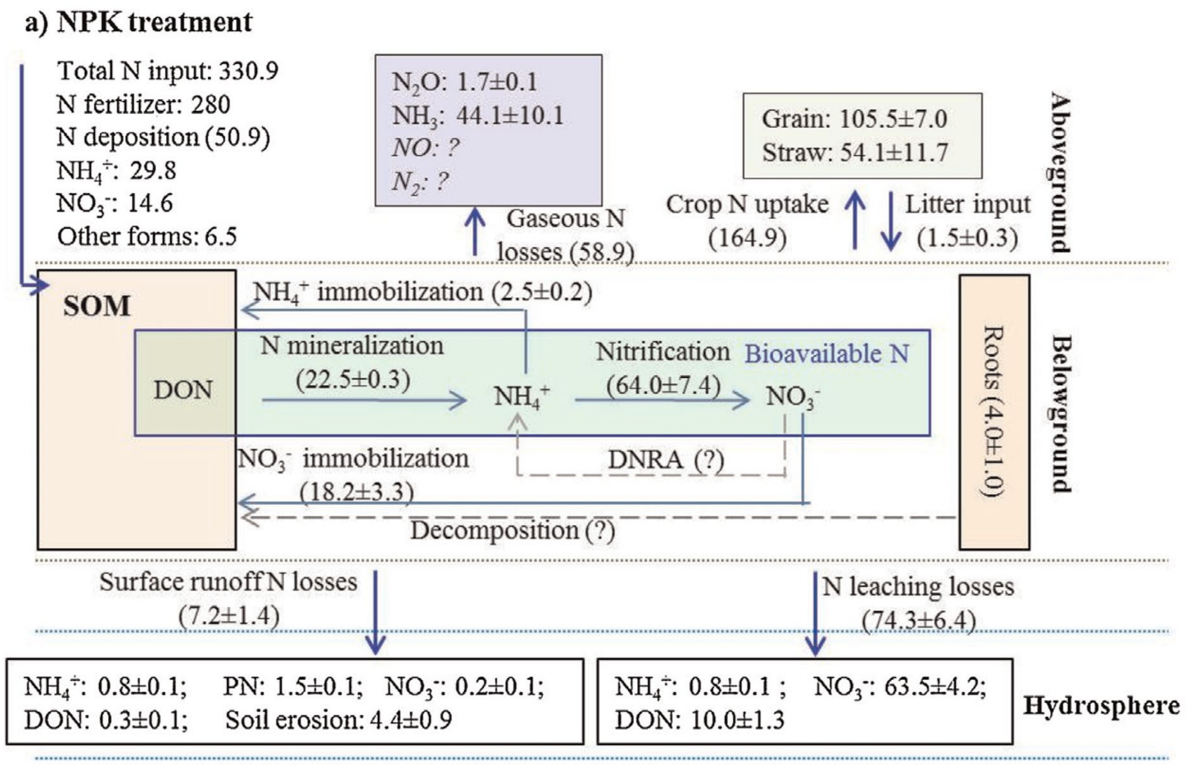

Zhou et al., 2016. Agric. Ecosys. Envnvironm. 231, 1-14

N balance component	CK	NPK	OM	OMNPK
N inputs				
N deposition	50.9	50.9	50.9	50.9
N fertilizer	0	280.0	280.0	280.0
N outputs				
Crop N uptake				
Grain	16.8 ± 2.4b	105.5 ± 7.0a	87.0 ± 11.9a	91.4 ± 10.8a
Straw	13.0 ± 2.5c	54.1 ± 11.7a	46.8 ± 12.3ab	35.3 ± 7.5b
Root	1.8 ± 0.2b	5.3 ± 0.8a	6.0 ± 0.8a	5.9 ± 0.5a
Leaching loss				
NH_4^+	0.7 ± 0.1a	0.8 ± 0.01a	0.8 ± 0.1a	0.8 ± 0.1a
NO_3^-	3.4 ± 0.3c	63.5 ± 4.2a	27.0 ± 3.5b	38.3 ± 4.6b
DON	1.6 ± 0.2c	10.0 ± 1.3a	4.7 ± 0.6b	3.2 ± 0.1b
Surface runoff				
NH_4^+	0.3 ± 0.1b	0.8 ± 0.1a	0.2 ± 0.1b	0.2 ± 0.1b
NO_3^-	0.1 ± 0.1a	0.2 ± 0.1a	0.1 ± 0.1a	0.2 ± 0.1a
DON	0.3 ± 0.1a	0.3 ± 0.1a	0.3 ± 0.1a	0.4 ± 0.1a
PN	0.5 ± 0.1b	1.5 ± 0.1a	0.6 ± 0.1b	0.7 ± 0.1b
Soil erosion	1.8 ± 0.9b	4.4 ± 0.9a	2.8 ± 1.1b	2.9 ± 0.7b
Gaseous N loss				
N_2O	0.2 ± 0.1c	1.7 ± 0.1b	2.6 ± 0.2a	1.9 ± 0.1ab
NH_3	15.7 ± 2.5c	54.1 ± 10.1b	72.3 ± 6.3a	66.8 ± 7.3ab
Total inputs	50.9	330.9	330.9	330.9
Total outputs	56.2	302.3	260.8	258.0
Total balance	−5.3	28.6	70.1	72.9

CONCLUSIONS

- At all scales, ecosystem N cycling and fate of added N not well constrained
- The denitrification challenge (where? When? Magnitude? Product ratios? Plant effects?)
- Not getting denitrification right hampers
  - understanding of environmental N losses, incl. N_2O fluxes
  - Understanding of soil C:N dynamics (ΔN, ΔC:N)
  - Development and testing of biogeochemical models
  - Development of strategies to increase NUE
  - …..
- Various approaches for quantifying denitrification → none of those are “cheap”
- Only few sites estimated total N budgets (incl. N flow components)
- Long-term trials (!) needed and may include establishment of detailed N balances

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