Nitrous oxide sources and different nitrification pathways under various soil and environmental conditions

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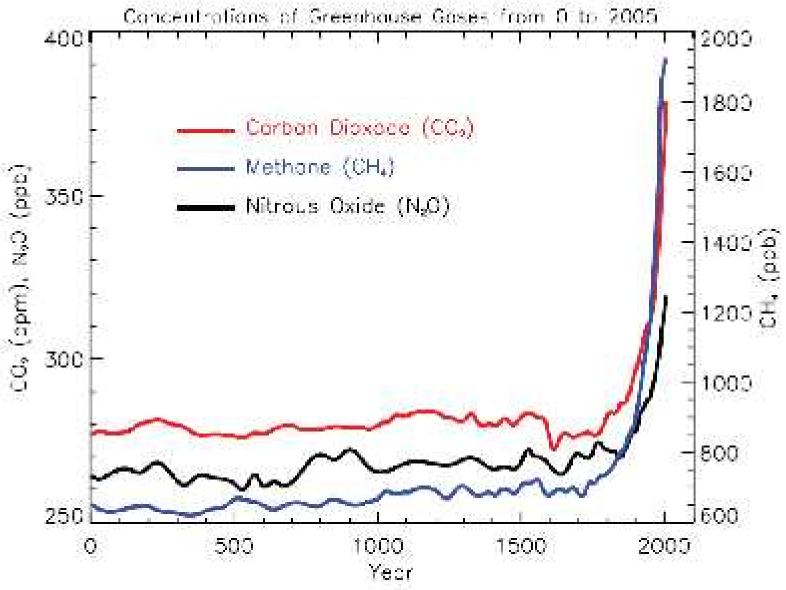
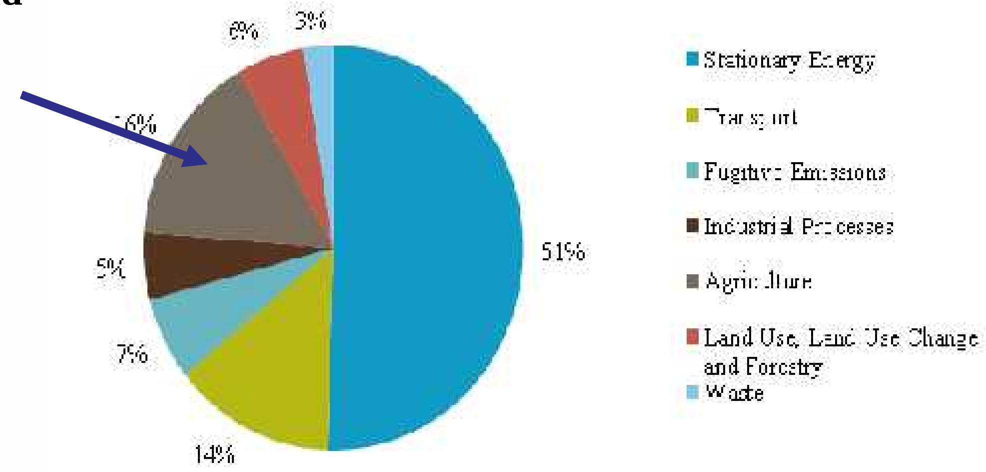
N_2O concentration in atmosphere increased exponentially over last 100 years

Concentration of greenhouse gases from 0 to 2005 *(Forster et al. 2007)*



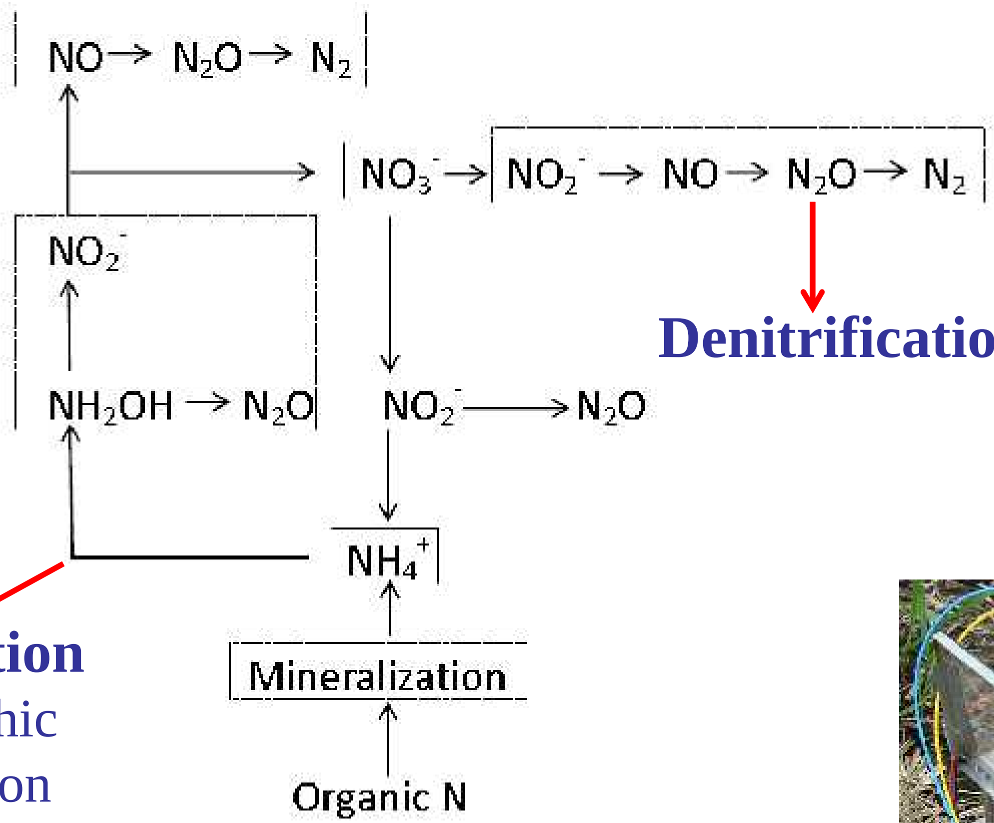
Agriculture is 2nd largest emitter:

75% CH_4 and 25% N_2O



(Dalal et al., 2003)

N_2O emission from soil



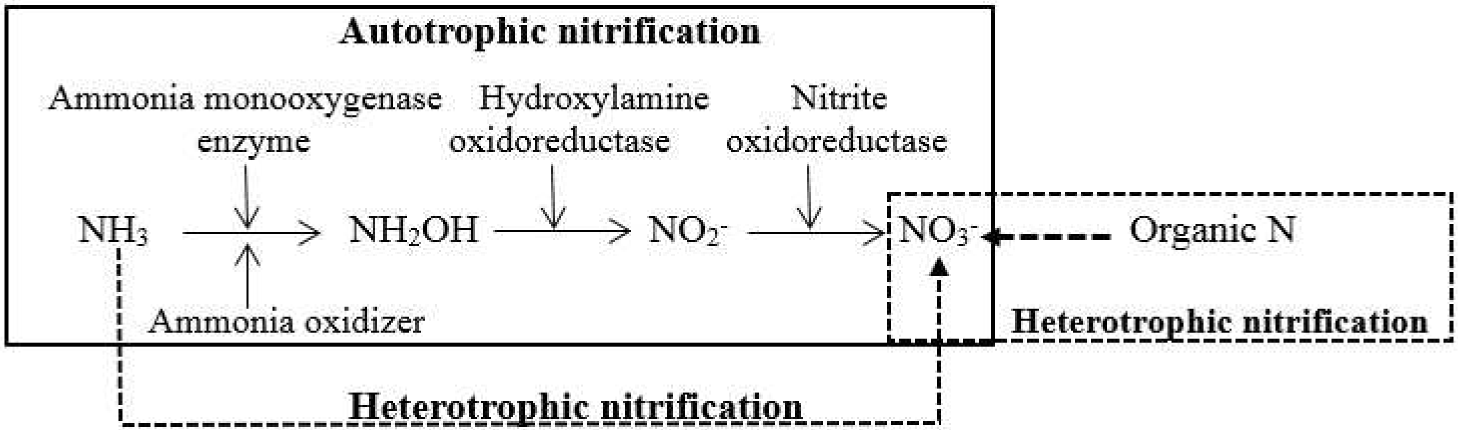
Denitrification

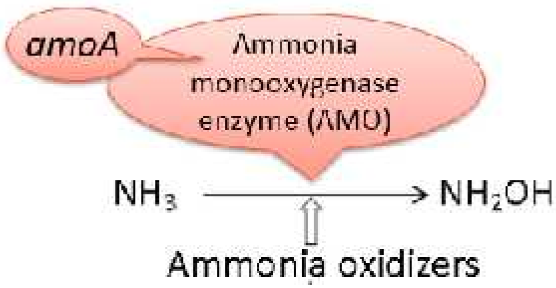
Nitrification

- Autotrophic nitrification
- Heterotrophic

A great challenge to partition the relative contributions of all sources

Autotrophic and heterotrophic nitrification process





Relative contribution of ammonia oxidizers to Nitrification

Ammonia-oxidizing archaea (AOA) VS **Ammonia-oxidizing bacteria (AOB)**

RESEARCH ARTICLE

Archaea rather than bacteria control nitrification in two agricultural acidic soils

Environmental Microbiology (2009) 11(7), 1658–1671 doi:10.1111/j.1462-2920.2009.01891.x

***Bacteria* rather than *Archaea* dominate microbial ammonia oxidation in an agricultural soil**

Their contributions to soil N_2O emissions and nitrification remain unclear!

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RESEARCH ARTICLE

Growth of ammonia-oxidizing archaea in soil microcosms is inhibited by acetylene

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nature geoscience LETTERS

Nitrification driven by bacteria and not archaea in nitrogen-rich grassland soils

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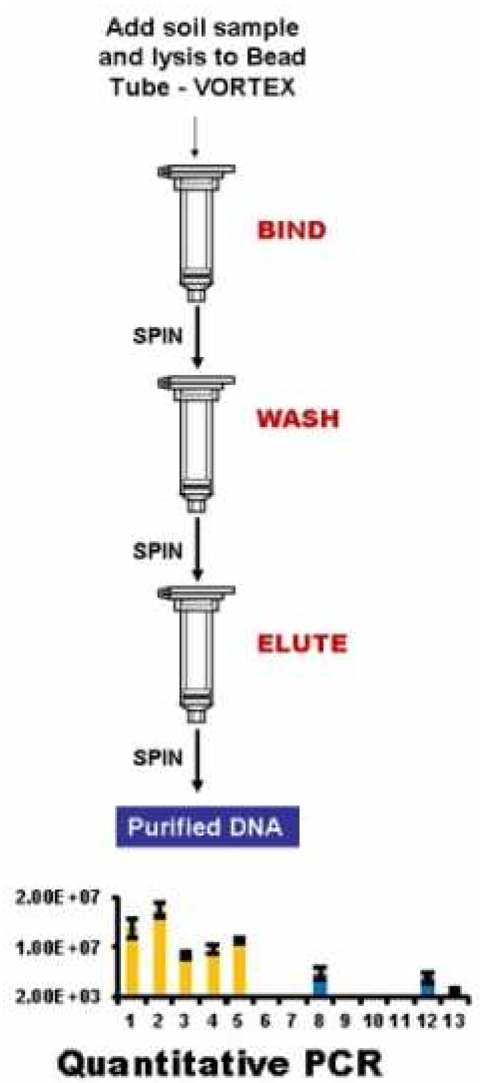
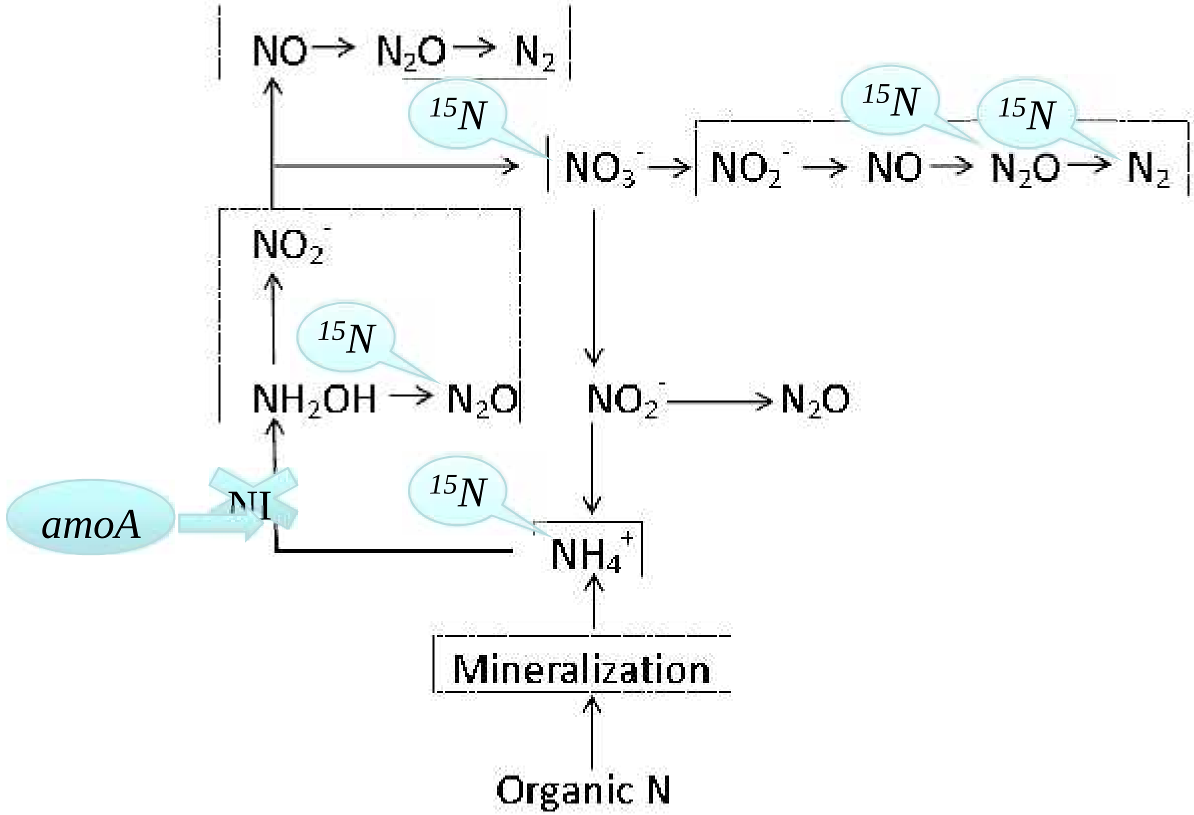
Introduction- Methods to separate N_2O sources





Molecular biotech approach

Research Questions

The contribution of microbial pathways to N_2O production in Australian agricultural soils:

- the importance of heterotrophic nitrification
- the key factors affecting N_2O emitted from nitrification
- the role of AOA and AOB in N_2O production

Laboratory microcosm incubations:

The relative contribution of biological pathways to N_2O emission from different temperature and moisture

The contribution of heterotrophic nitrification and autotrophic nitrification to total N_2O from different temperature and moisture

	15C		25C		35C	
	50%WFPS	70%WFPS	50%WFPS	70%WFPS	50%WFPS	70%WFPS
Total N_2O (ug/cm^{2})	0.11±0.03	1.38±0.68	0.21±0.05	15.39±6.45	0.46±0.40	64.42±1.20
Denitrification or heterotrophic nitrification (%)	100.00	32.6	67.4	65.4	76.2	91.8
Autotrophic nitrification (%)	0	67.4	32.6	34.6	23.8	8.9

(Liu et al. 2015)

The contribution of heterotrophic nitrification and autotrophic nitrification to total nitrification for different temperature and moisture

	50 % WFPS			70 % WFPS		
	15 °C	25 °C	35 °C	15 °C	25 °C	35 °C
Gross nitrification (μg NO_3-N g^{-1} soil day^{-1})	3.8 (1.1)	43.2 (7.9)	59.5 (6.4)	5.0 (1.3)	59.9 (5.2)	45.4 (1.4)
Heterotrophic nitrification (%)[a]	69.2	7.6	6.8	49.9	6.8	4.2
Autotrophic nitrification (%)	30.8	92.4	93.2	50.1	93.2	95.8

Values in brackets are standard deviation (*n*=3)

[a] Percent heterotrophic nitrification was calculated as heterotrophic nitrification rate/gross nitrification rate × 100 %

(Liu et al. 2015)

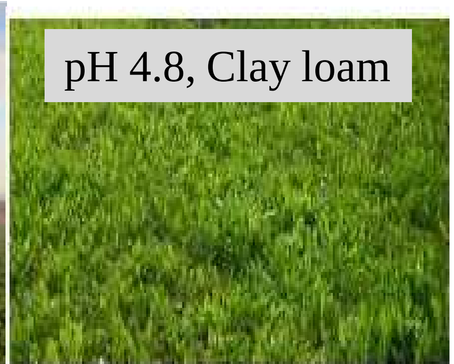
Laboratory microcosm incubations:

The relative contribution of biological pathways to N_2O emission from different agricultural soils

Sugarcane

Cropping

Vegetable



Dairy pasture

N_2O Derived from Nitrification

Land-use	Gross nitrification rate	Relative contribution %		N_2O_d	N_2O_n	P_{N2O} ‰
	mg N kg^{-1} d^{-1}	Deni	Nitri	µg N_2O-N cm^{-2} d^{-1}		
Sugarcane	1.70 (0.50)	3.30 (0.45)	96.67 (6.8)	0.80 (0.03)	23.40 (0.34)	0.030 (0.0016)
Vegetation	5.42 (0.43)	76.36 (9.2)	23.64 (3.91)	53.65 (7.03)	16.63 (3.30)	0.024 (0.0011)
Dairy Pasture	3.84 (0.78)	29.09 (4.1)	70.90 (4.97)	20.24 (1.22)	49.85 (8.34)	0.033 (0.0026)
Cropping	9.88 (2.30)	28.74 (8.6)	71.26 (1.82)	134.34 (4.06)	334.47 (6.63)	0.260 (0.0189)

[a] *The relative contribution by denitrification (Cd) to N_2O production*
[b] *The relative contribution by nitrification (Cn) to N_2O production.*
[c] *N_2O production from nitrification (N_2O_n).*
[d] *N_2O production from denitrification (N_2O_d).*
[e] *The proportion of nitrified N emitted as N_2O (P_{N2O}).*
Values in bracket are standard deviations.

(Liu et al. 2016)

Laboratory microcosm incubations:

The relative contribution of AOA and AOB to N_2O emission and nitrification

Correlations between soil mineral N levels, N_2O_n[a] and AOA and AOB abundances

Time	Factor	AOA (Log number)		AOB (Log number)	
		R	P-Values	R	P-Values
Before fertilizer applied	Exchangeable NH_4^+ concentration	0.454	0.138	0.089	0.779
	NO_3^- concentration	0.217	0.499	0.063	0.846
	N_2O_n	0.615	0.033	0.517	0.085
After fertilizer applied	Exchangeable NH_4^+ concentration	0.623	5.00E-05	0.535	0.008
	NO_3^- concentration	-0.622	5.07E-05	-0.369	0.027
	N_2O_n	0.346	0.038	0.578	0.0002

[a] means N_2O production from nitrification

(Liu et al. 2016)

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Conclusions

- ✓ Soil temperature and moisture significantly influenced the relative contributions of heterotrophic and autotrophic nitrification to total nitrification and N_2O emission
- ✓ The relative contributions of N_2O sources differed between soils.
- ✓ Soil moisture and temperature, and land-use influence the role of AOA and AOB in nitrification.
- ✓ Heterotrophic and autotrophic nitrification can not be separated by detecting *amo*A


Thank you!
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