DENITRIFICATION AND NITROUS OXIDE EMISSIONS IN NATURAL AND SEMI-NATURAL LAND USE TYPES

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NATURAL ENVIRONMENT RESEARCH COUNCIL

NERC Macronutrient Cycles Programme

LTLS: Analysis and simulation of the Long-Term /Large-Scale interactions of C, N and P in UK land, freshwater and atmosphere

WP2: New Measurements and Data Gap-filling

Denitrification

Keele University

UCL

University of Liverpool

Lancaster University

The James Hutton Institute

BGS 1835

Rothamsted Research

CEH Centre for Ecology & Hydrology

Natural Environment Research Council

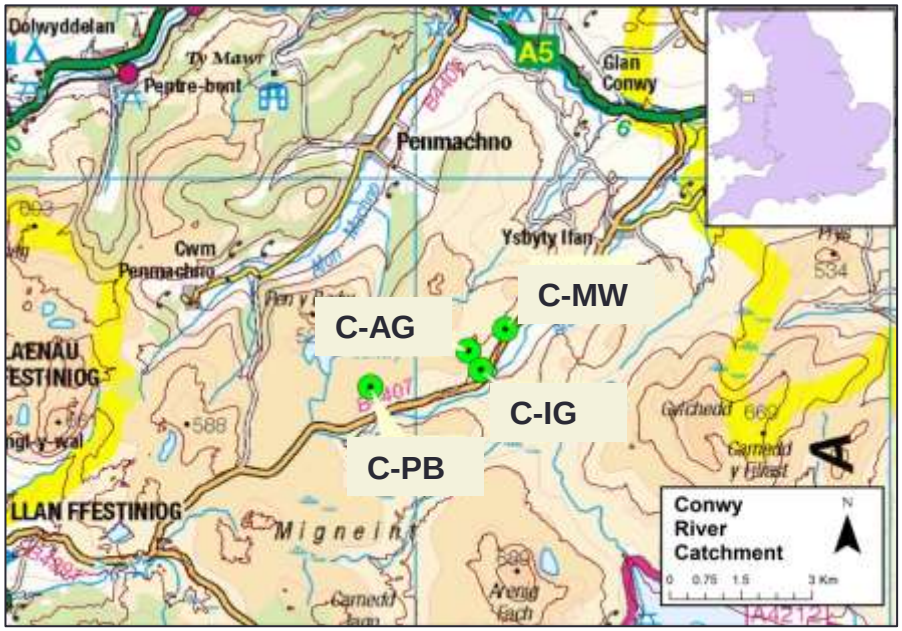
Objectives of the project:

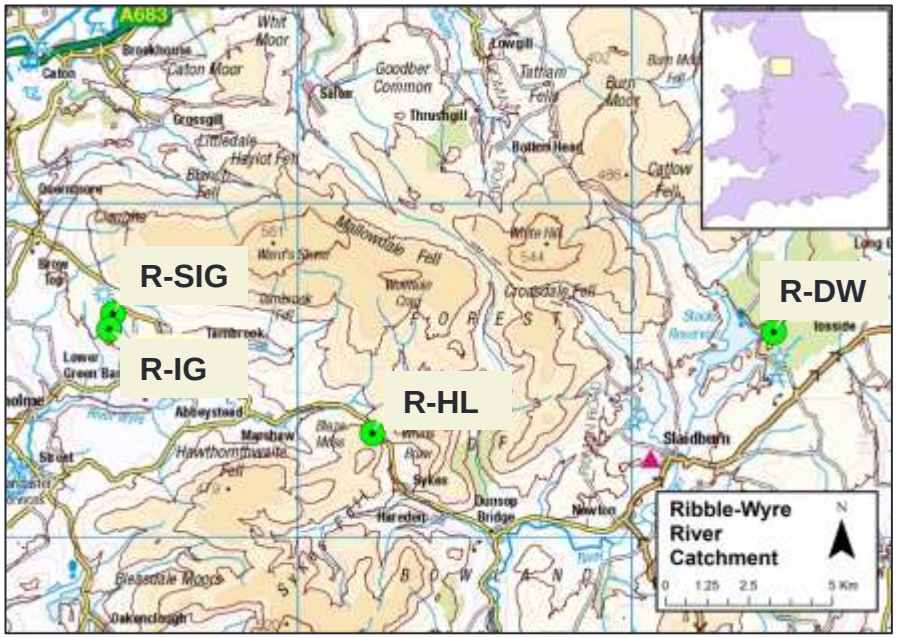
- Measure monthly *in situ* denitrification rates in natural and semi-natural land use types.
- Assess the relative controls of the denitrification process in relation to land use management.
- Estimate annual denitrification rates for input into the terrestrial N-model to be developed under the LTLS project.

Study sites

Conwy River Catchment (C):
IG – Improved Grassland
AG – Acid Grassland
PB – Peat Bog (Migneint)
MW – Mixed Woodland

Ribble-Wyre Catchment (R):
IG – Improved Grassland
SIG – Semi-Improved Grassland
HL – Heathland
DW – Deciduous Woodland





Methods: *In Situ* Denitrification

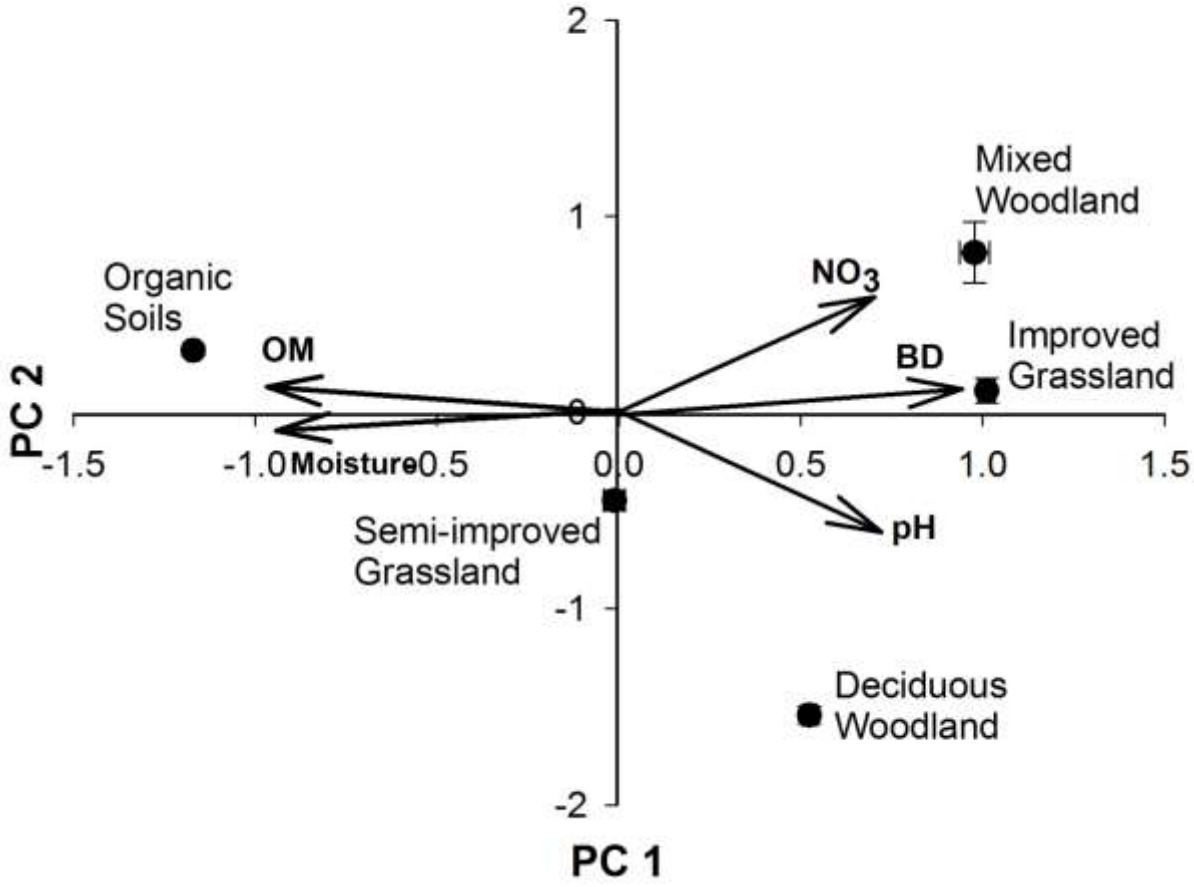
^{15}N Gas-Flux method
(Stevens & Laughlin, 1998; 2001)

- Direct measurement technique involving ^{15}N-tracer application in the field with minimum soil disturbance.

- Highly enriched (98 at%) ^{15}N-labelled KNO_3^- is injected at low application rates (0.03 – 0.5 kg N ha^{-1}) up to 10 cm depth and within 5% change of the soil VWC.

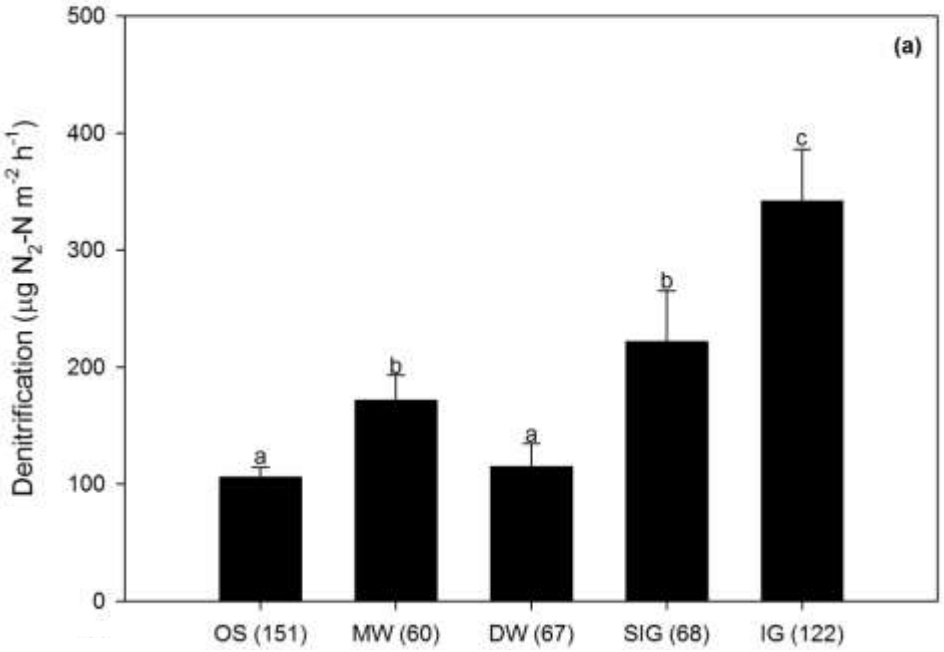
- Five plots per site (40 plots/month x 17 months). Minimum detectable flux rates: 4 µg N_2-N m^{-2} h^{-1} and 0.2 ng N_2O-N m^{-2} h^{-1}

Results: PCA on Soil Properties



- PCA explains 88 % of the variance between samples (n = 680) according to 5 environmental variables
- The samples are grouped into 5 clusters that represent distinct land use types

Results: *In situ* Denitrification



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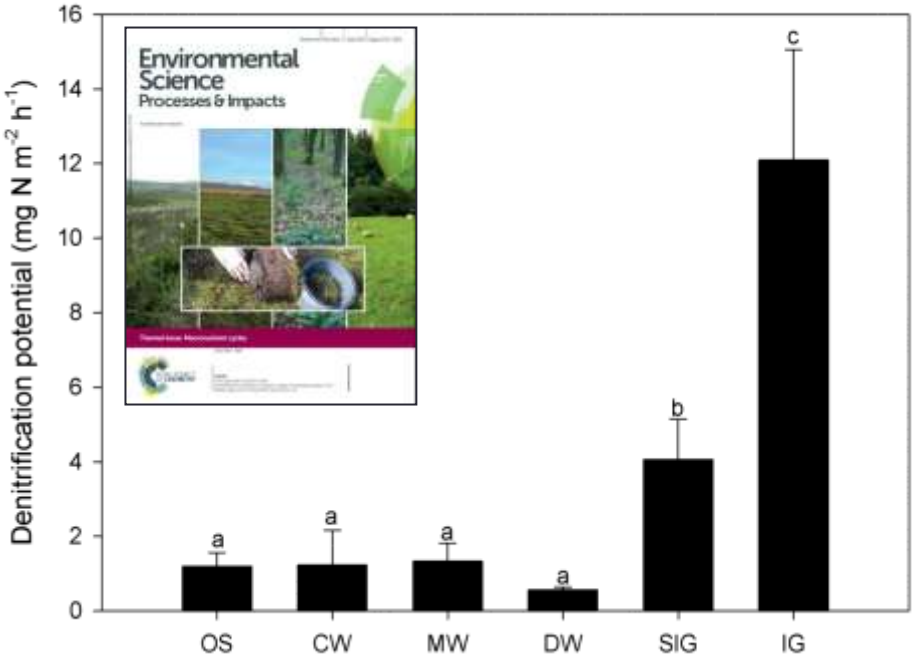
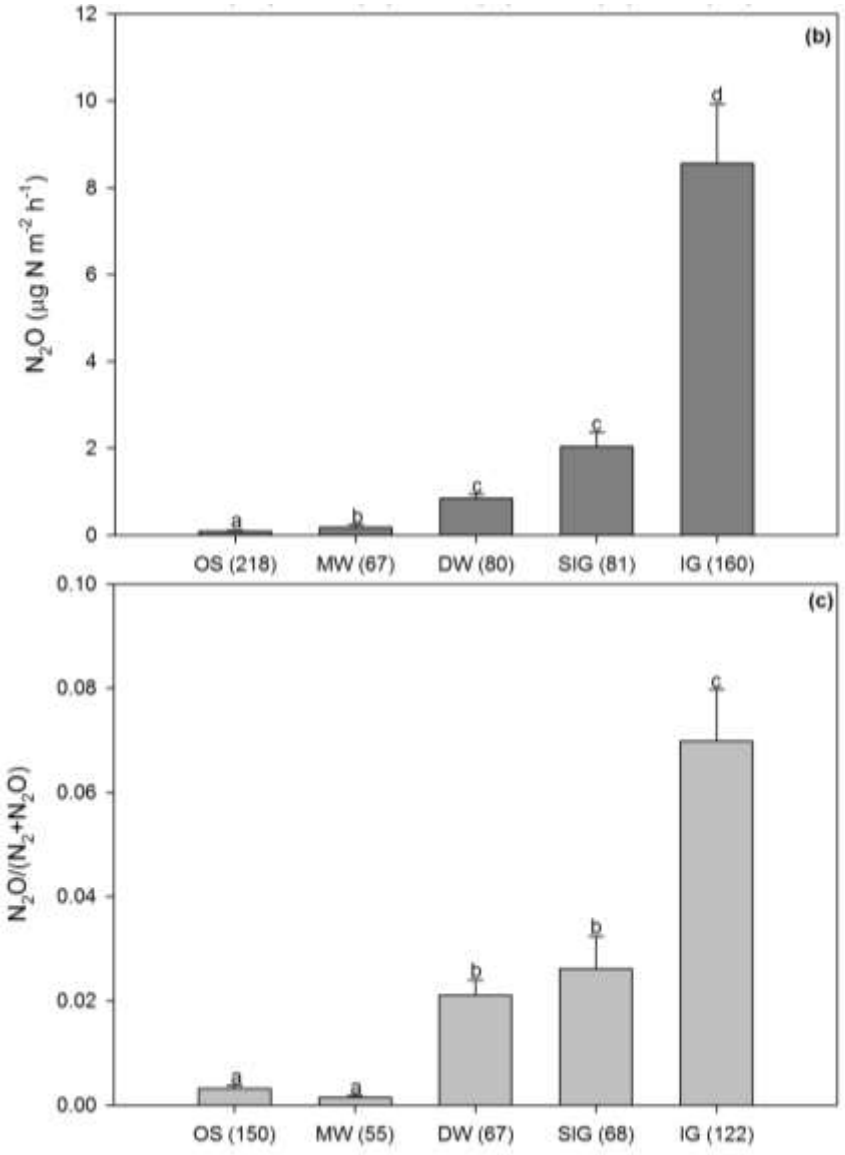


Sgouridis & Ullah. 2014. Environ. Sci: Processes & Impacts. 16: 1551-1562.

- *In situ* Denitrification (DNT) significantly influenced by land use type ($p<0.05$) : OS = DW < MW = SIG < IG
- The IG showed on average 3.5 times higher denitrification that the OS
- The trend is confirmed by a laboratory study of Denitrification Potential (DP) in the same land use types. DP was on average 20 times higher than DNT.

Results: N_2O Emissions



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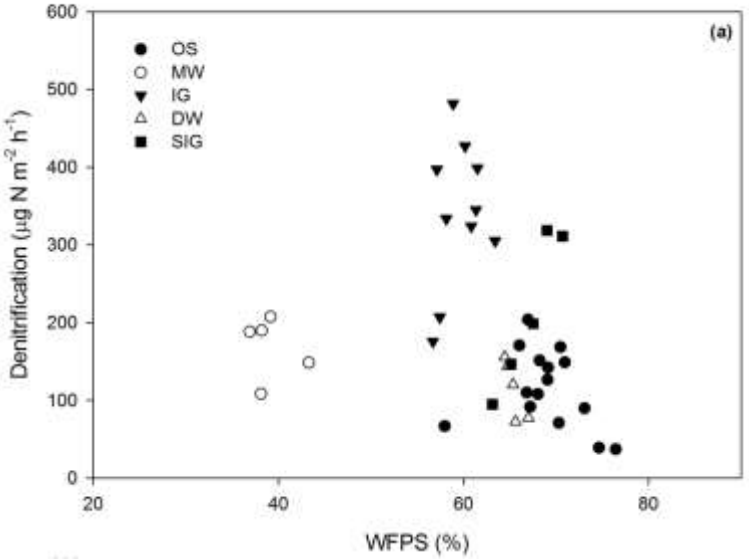
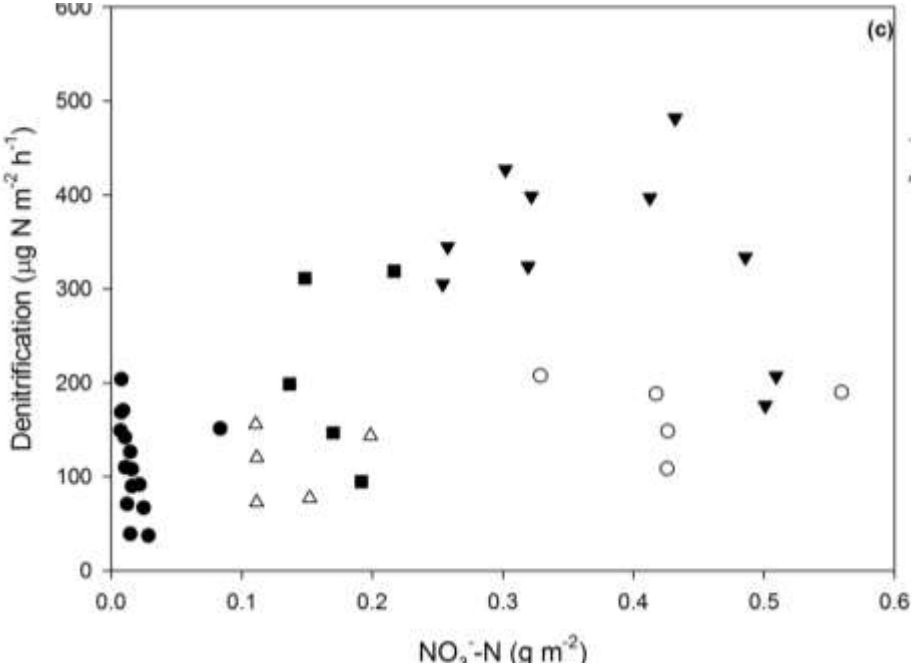
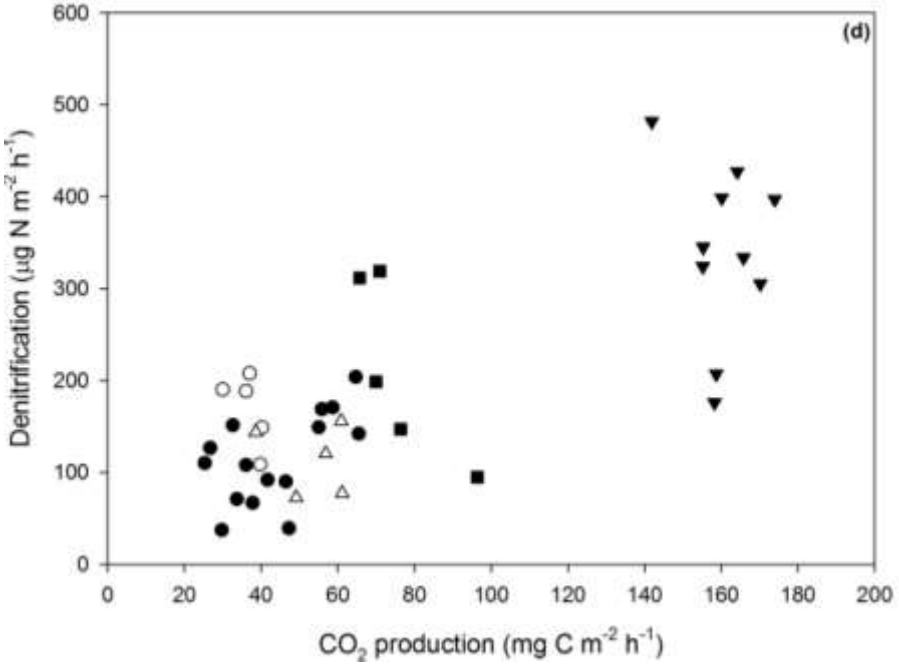
- N_2O emission from Denitrification followed a similar trend to DNT (r= 0.58, p<0.01) :
  OS < MW < DW = SIG < IG
- The improved grasslands emitted on average 100 times more N_2O than the organic soils and four times more than the semi-improved grassland
- The 'true' denitrification product ratio N_2O / (N_2 + N_2O) ranged between < 1 to 7 % and increased with increasing management intensity.

Results: Denitrification Controls

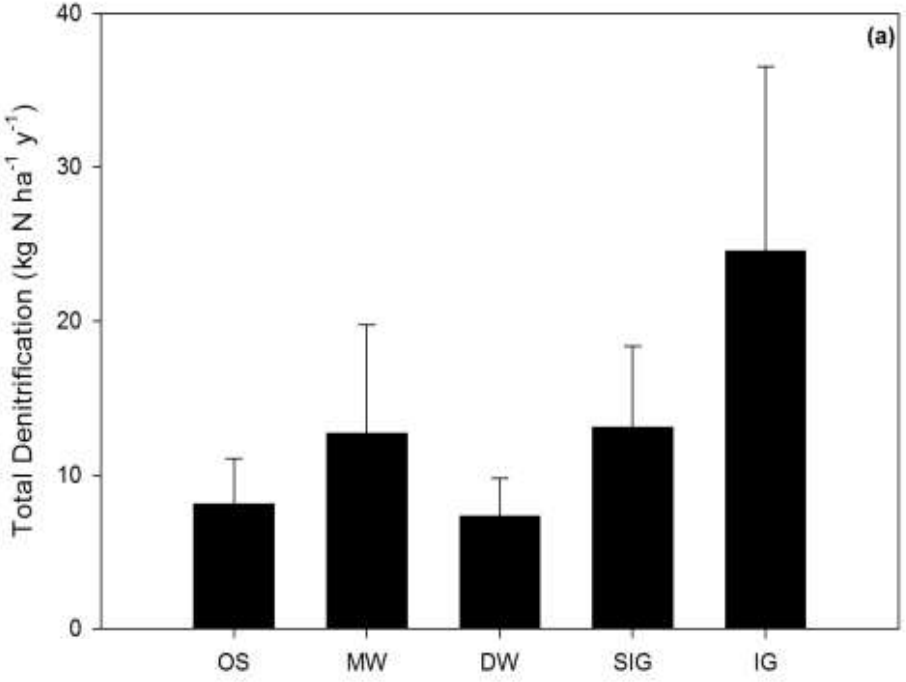


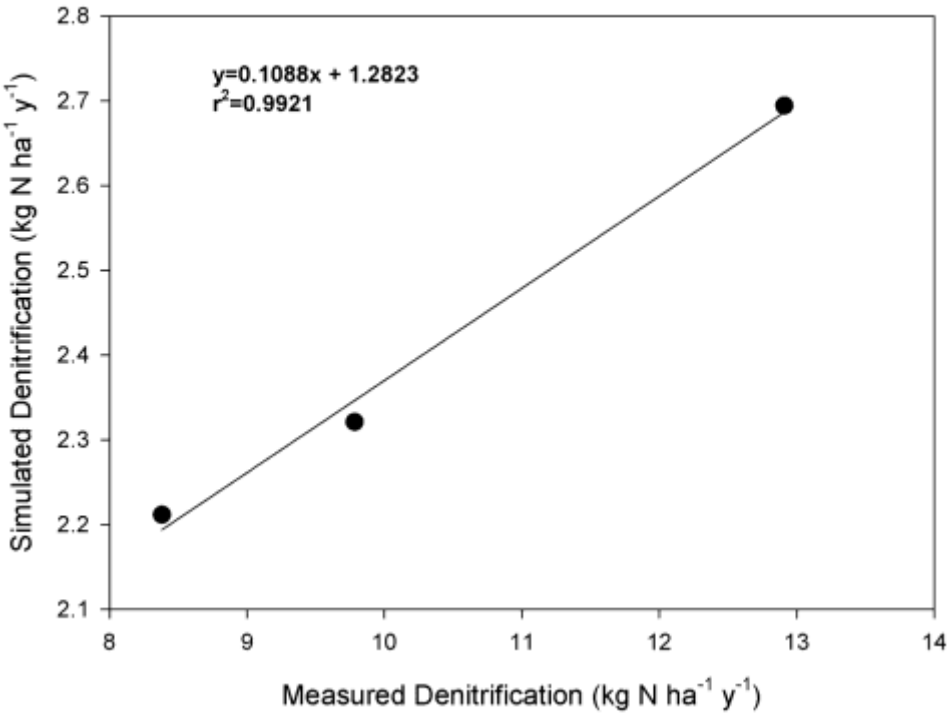
- Denitrification optimum at WFPS 60 – 70% (SIG, IG, DW)
- Denitrification follows a gradient of nitrate and carbon availability across land use types
- The combination of nitrate and carbon availability, pH and BD explains 61% of the variance at a broad temporal scale





Results: Annual Denitrification

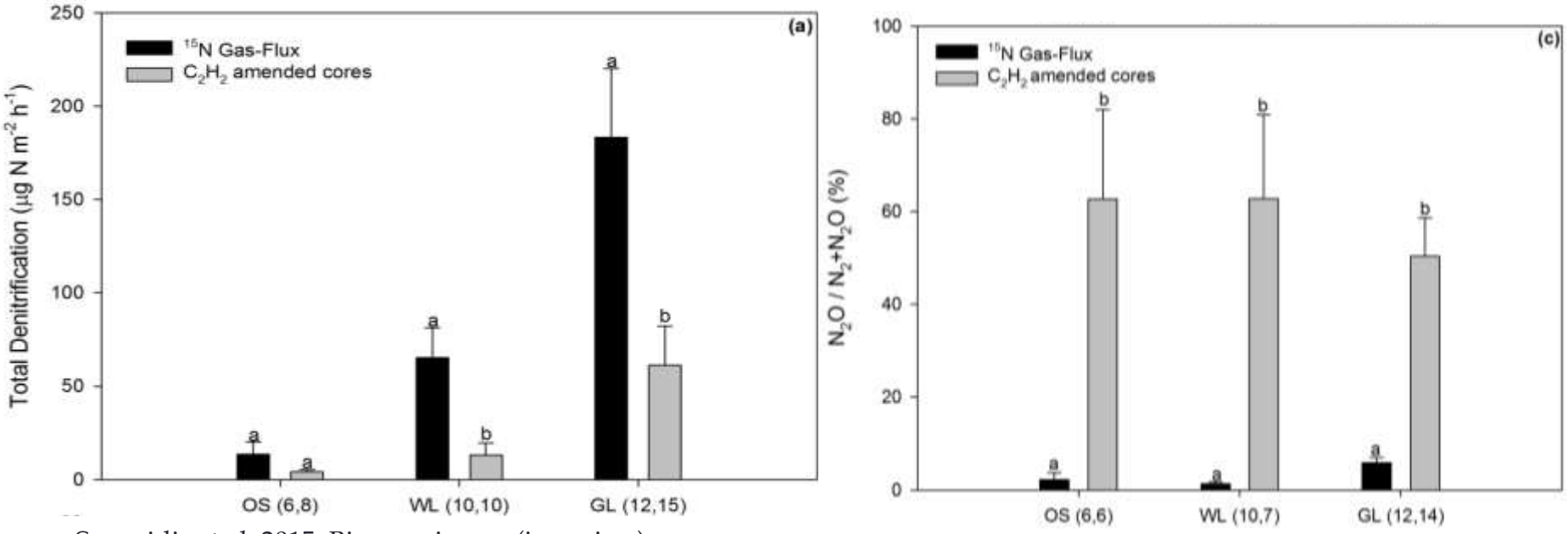




- Total Annual Denitrification (kg N ha^{-1} $year^{-1}$):
  - Organic Soil = 8, Woodlands = 10, Grasslands = 13 - 25

- **The contribution of denitrification to Nr removal in organic and forest soils is ~50 % of the contemporary annual atmospheric Nr deposition rates, making these natural ecosystems vulnerable to chronic Nr saturation alike fertilised grassland soils**

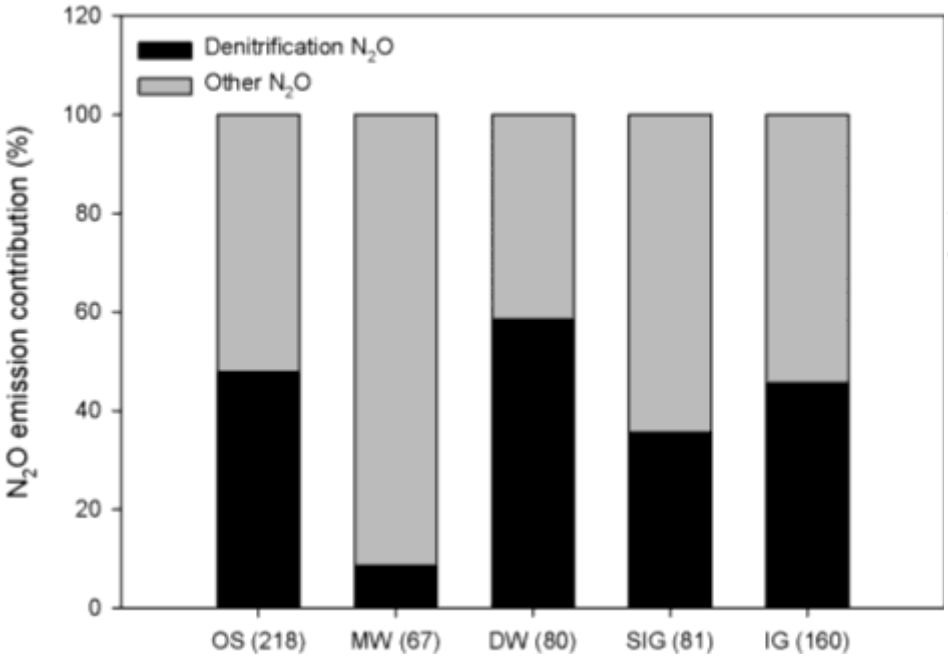
Results: ^{15}N Gas Flux vs AIT

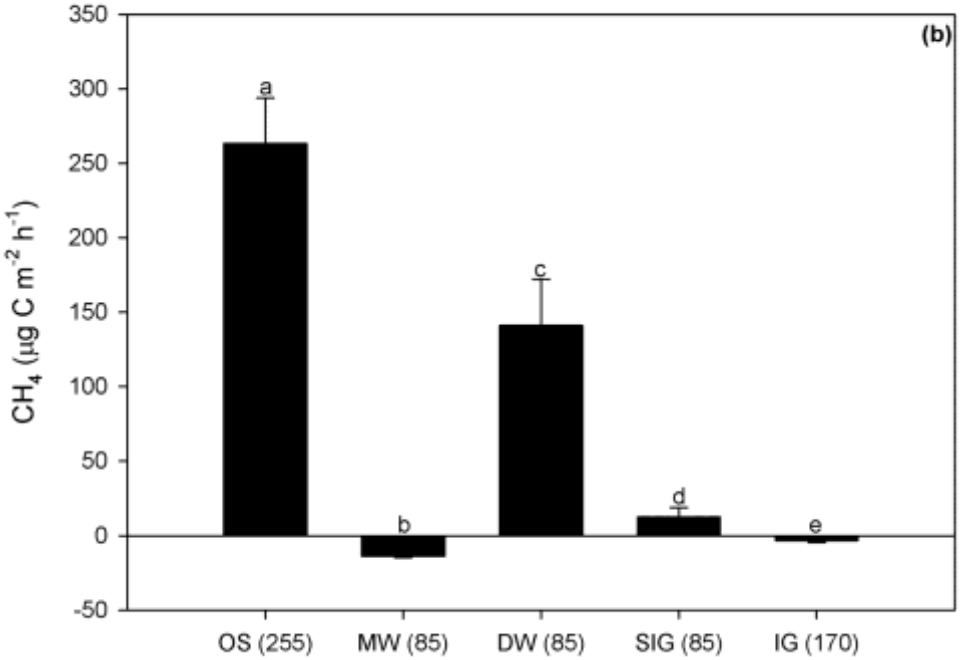


Sgouridis et al. 2015. Biogeosciences (in review)

- Total denitrification rates measured using the ^{15}N Gas flux and the C_2H_2 methods followed a similar trend across the sites (Pearson; r = 0.581, n = 25, p <0.01)
- Rates measured using the ^{15}N Gas flux method were between 3 and 5 times higher than the denitrification rates with the AIT
- The AIT overestimates the denitrification product ratio (range: 50 – 60%) since it cannot discriminate between sources of N_2O production.

Results: GHG fluxes





- The relative amount of N_2O contributed by denitrification varied across the sites, ranging from 0.2 to 75%
- Organic and wet deciduous woodland soils were significant sources of CH_4, while the dry mixed woodland was a minor sink.
- The grassland soils were either minor sources or sinks of CH_4 depending on the seasonal variability in soil moisture and temperature.

Sgouridis & Ullah. 2016. Biogeochemistry (in preparation)

Conclusions

- Improvements in analytical precision and the lower detection limits for both ^{15}N-N_2 and ^{15}N-N_2O analyses allowed us to measure reliable *in situ* denitrification rates in natural and semi-natural ecosystems, which was not previously possible
- The AIT confirmed the measured denitrification range by the ^{15}N Gas-Flux method, but significantly underestimated the rates due to the incomplete inhibition of N_2O reduction under ambient wet soil conditions
- Denitrification and N_2O emission rates across the natural and semi-natural land use types in this study appear to follow a nitrate and carbon availability gradient, which is influenced by both natural variability and land use management:

  Organic soils ≤ Forest soils <Semi-improved <Improved grassland

- The contribution of denitrification to Nr removal in organic and forest soils was ~50% of the contemporary annual atmospheric Nr deposition rates, making these natural ecosystems vulnerable to chronic Nr saturation
- Complex denitrification controls at the land use type scale need to be considered when modelling and/or predicting the response of denitrification to land use change within catchments

Acknowledgements

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