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The effect of soil moisture on nitrous oxide flux and production pathway in different soil types

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INTRODUCTION

Understanding the mechanisms leading to the emission of the potent greenhouse gas nitrous oxide (N_2O) is essential for accurate flux prediction and for developing effective adaptation and mitigation strategies in response to climate change (1). Even though the knowledge of how N_2O is produced and emitted from soils has advanced over the last several decades (2-4), there still remain surprising grey-areas in our understanding of the underlying mechanisms. One such grey-area is a more precise understanding of how N_2O production pathways (nitrification and denitrification) relate to soil moisture.

RESEARCH OBJECTIVES

With the use of a novel analytical technique (cavity ring down spectroscopy), our objectives are to:

- Precisely quantify the relationship between soil moisture and N_2O production by measuring $^{15}N_2O$ isotopomers;
- Evaluate the variability in this relationship based on differences in soil nutrient levels, organic matter, and texture.

METHODS

Soil collection and characteristics:

- Soil samples for the 0 – 10 cm depth were randomly collected at three sites (Dark Brown Chernozems), air-dried and sieved through a 2.00 mm mesh screen

Table 1. Soil characteristics and cropping history for three soil types studied.

Soil association	Crop type history	Texture	pH	Organic matter (%)	Nitrate-N (ppm)
Sutherland	Vegetable	Silty clay loam	7.6	5.9	112
Asquith	Fodder	Sandy loam	7.5	3.9	66
Bradwell	Field	Loam	7.9	2.7	16

Soil water holding capacity:

- The soil water holding capacity data were needed (5) to determine the initial range of soil moisture treatments

Soil incubation study:

- Randomized complete block design with 4 replicates
- 21.87 cm^3 petri dishes was completely filled with 22.0, 24.0, 29.0 g of soil with bulk densities of 1.01, 1.10, 1.33 g cm^{-3} for the Sutherland, Asquith and Bradwell soils, respectively
- Treatments established based on gravimetric moisture levels ranged from 20– 105% water filled pore space (WFPS)
- Sealed inside 1L mason jars, lids fitted with septa for gas sampling
- Incubated for 24-hrs in dark, at 21 ˚C
- Gas sampled for N_2O and $^{15}N_2O$; analyzed concentrations via GC (Bruker 450) and CRDS (Picarro G5131-*i* isotopic N_2O analyzer)
- Isotopomers are used to calculate site preference (SP) – this indicates nitrification vs denitrification

RESULTS & DISCUSSION

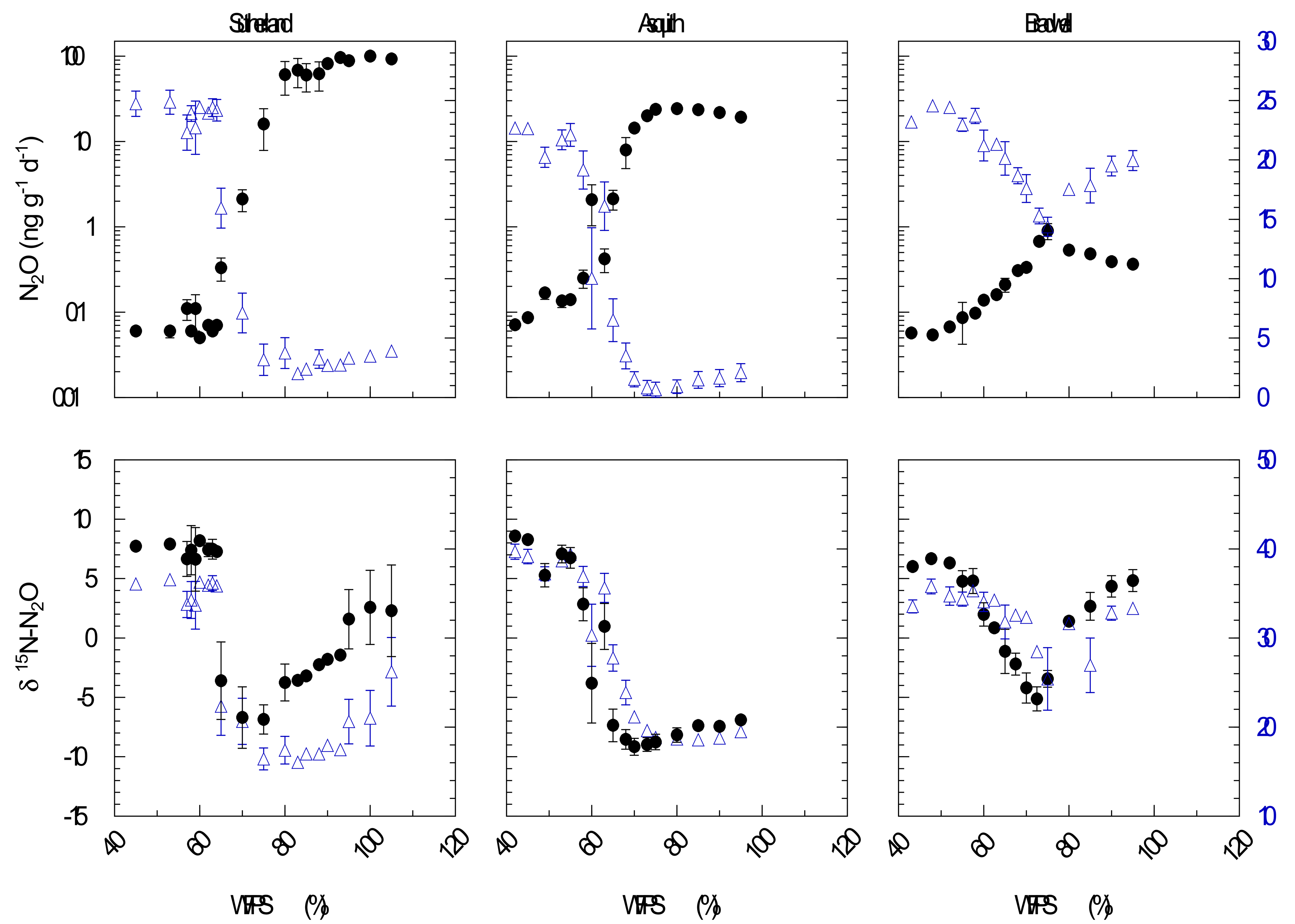

Fig. 1. Top panels: Nitrous oxide emissions (black points) and site preference values (blue points); Bottom panels: bulk δ^{15}N-N_2O (black points) and δ^{18}O-N_2O (blue points) under the wide range of soil water filled pore spaces (WFPS) for Sutherland, Asquith, and Bradwell soil associations.

- Regardless of the dramatically different magnitudes of N_2O flux across each soil types, there were similarities in how soil moisture influenced the relative amount of N_2O (Fig. 1)
- As N_2O fluxes changed with soil moisture, a mirrored change occurred for SP (Fig. 1)
- The δ^{15}N and δ^{18}O values decreased during the same soil moisture region that the SP values decreased (Fig. 1)
- N_2O production was attributed to nitrification when soil was relatively dry (below 58% WFPS)
- N_2O production transitioned from nitrification to denitrification with soil moisture levels from 58 to 83% WFPS
- N_2O production attributed to denitrification when soil was relatively moisture (exceeding 80% WFPS)

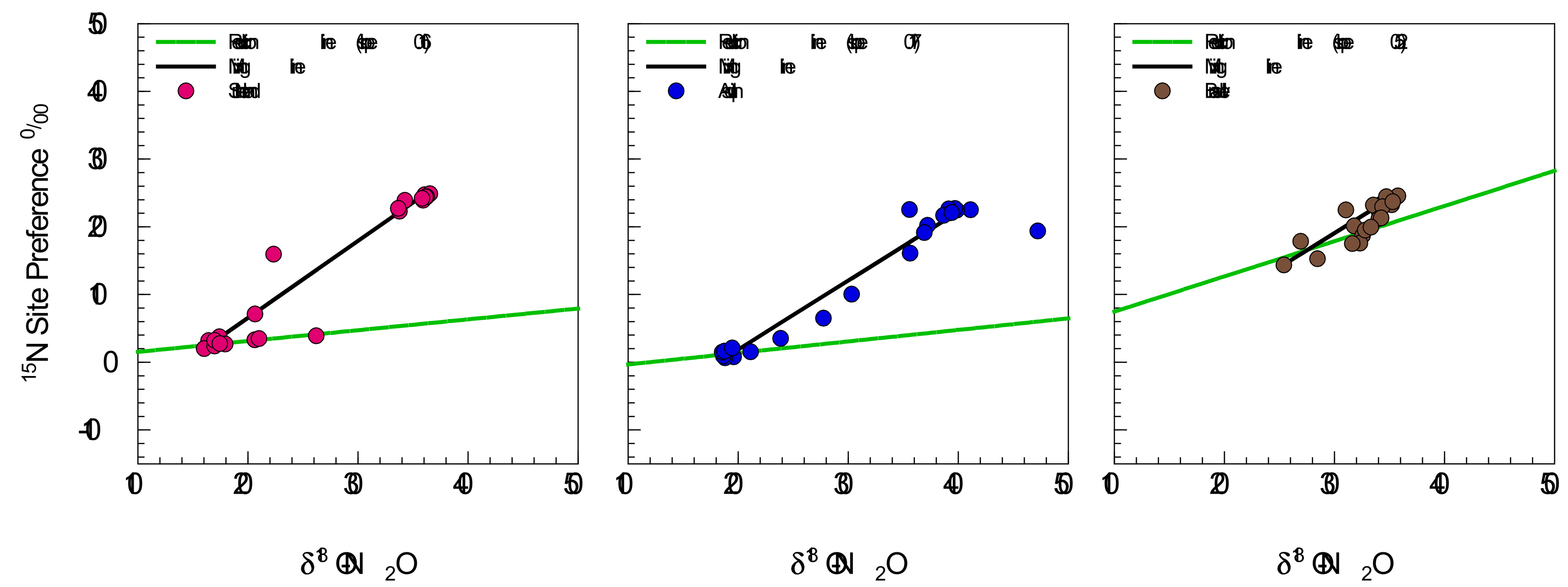

Fig. 2. Isotopomer map to determine the source partitioning of N_2O derived from nitrification versus denitrification using ^{15}N site preference (SP) and δ^{18}O of N_2O.

- The linear mixed model was developed based on a previously published method (6); with end-members and mixing lines derived from our data (Fig. 2)

RESULTS & DISCUSSION (continued)

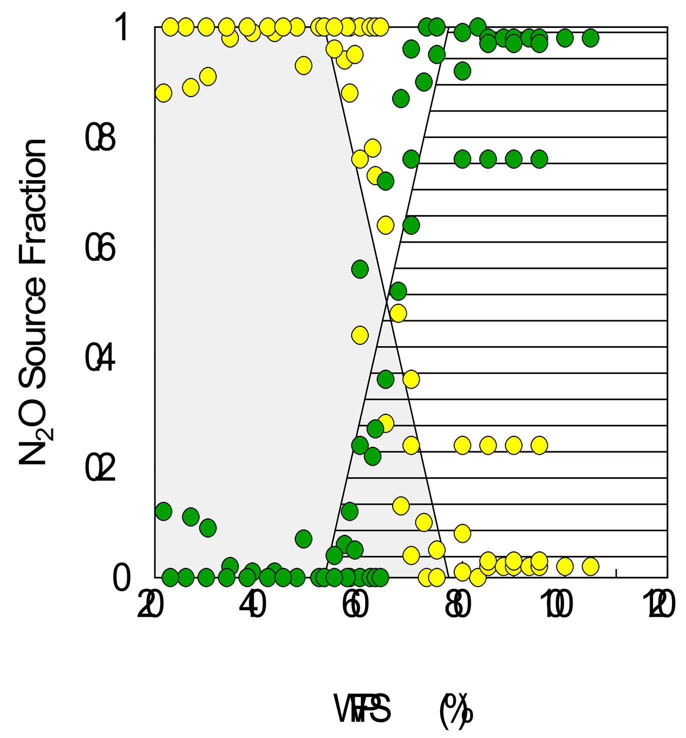

Fig. 3. Fraction of emitted N_2O that was attributed to nitrification (yellow points, shaded grey area) or denitrification (green points, lined area) based on the isotopomer mixing model.

At soil moisture levels below 53% WFPS:

- Nitrification was the dominated N_2O production pathway: $\mathbf{F_N = 1}$

Soil moisture levels ranging from 53 to 78% WFPS:

- Nitrification-derived N_2O decreased rapidly:
  - $\boldsymbol{F_N = 3.19 - 0.041x}$
- Denitrification-derived N_2O increased rapidly:
  - $\boldsymbol{F_D = -2.19 + 0.041x}$

At soil moisture levels exceeding 78% WFPS:

- Denitrification was the dominated N_2O production pathway: $\mathbf{F_D = 1}$

CONCLUSIONS

- The soil moisture level during 'the transition zone' is a key regulation of which pathway dominantly produces N_2O – be it nitrification or denitrification, or a mixture of both.
- $^{15}N_2O$ isotopomers are a powerful technique to more precisely quantify the relationship between soil moisture and N_2O-production pathway.
- $^{15}N_2O$ isotopomer results support earlier-known relationships between moisture and N_2O production (2), but can help move beyond inferences towards the quantification of relative source partitions.

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