Impact of climate change on nitric oxide and nitrous oxide emission from typical landuses in Scotland※

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INTRODUCTION

The impact of soil type, land use and climate on emission rates of nitric oxide (NO), a precursor of atmospheric ozone (O_3), and N_2O, a powerful GHG, as well as ratios of N_2O:NO are still not well understood in both natural and managed ecosystems.

The aim of this research was to identify soil NO and N_2O emission rates from typical land uses across Lowland and Highland regions of Scotland and estimate potential impacts of climate change, hypothesizing that warmer climate with irregular rain patterns (specifically longer drought periods followed by intensive rains) will entail larger NO and N_2O emissions.

METHODS

Soils were collected from the sites in the Highlands and Lowlands of Scotland (covering 9 typical land uses; 4 replicas each; Fig. 1), which are included in the eLTER network. A soil core air-flow-through incubation system coupled with a Teledyne NO_x analyser and Picarro G2508 instrument was used to measure NO and N_2O fluxes (Fig. 2). Soil samples were analysed for pH, soil moisture content (SMC), total C and N upon sampling (Table 1) and concentrations of NH_4^+ and NO_3^- (Fig. 3).

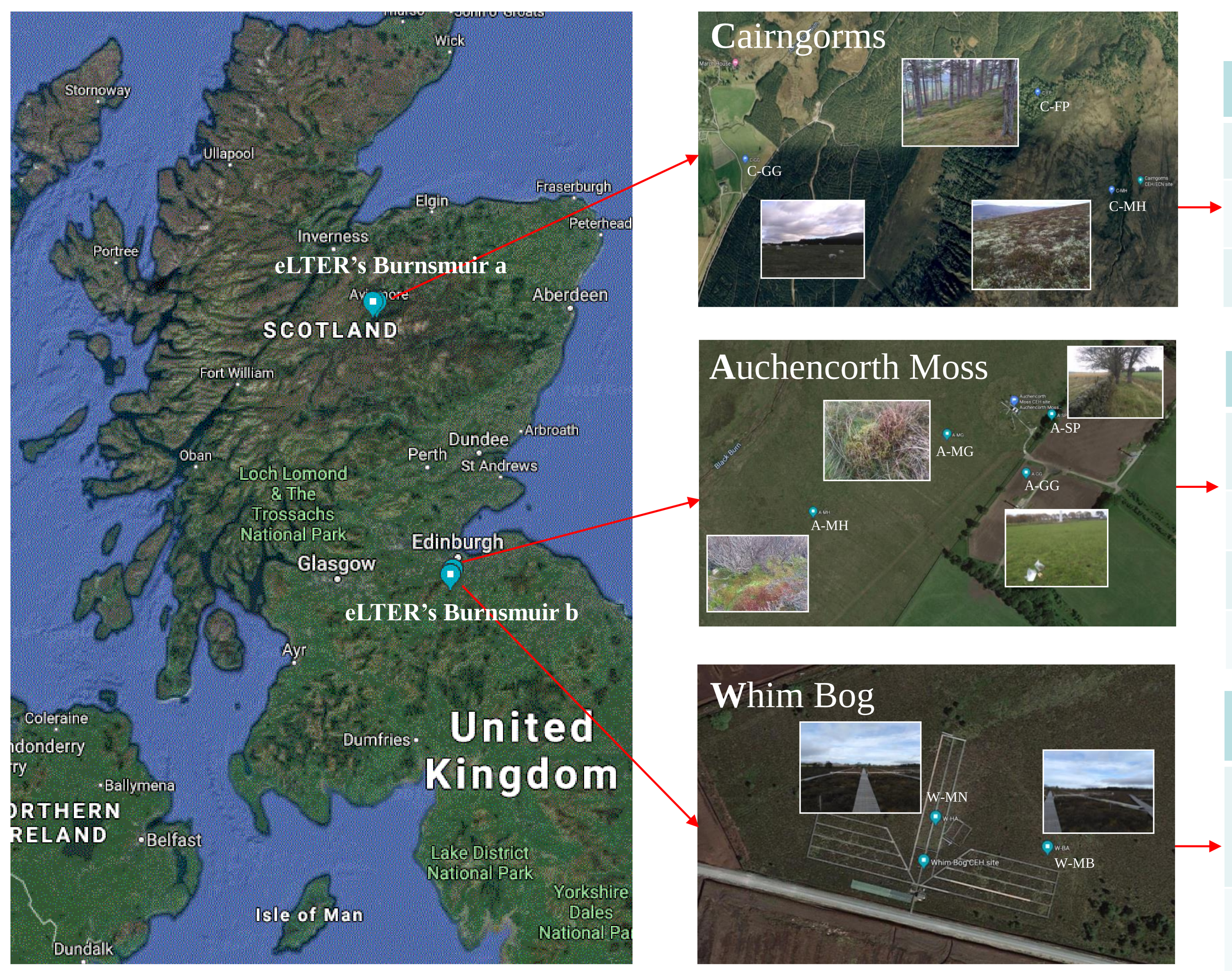

Fig. 1. Location of sampling sites

Table 1. Soil properties of sampling sites

Sampling site/ landuse	pH	SMC (%)	TC (%)	C/N	N input*
C-MH: Moorland (Heather)	4.5	45.6	26.3	35.0	4.3[a]
C-FP: Woodland (Pine)	3.4	64.0	42.9	31.0	4.3[a]
C-GG: Grazed Grassland	5.6	28.9	8.6	17.8	>155[a+b]
Landuse	**pH**	**SMC (%)**	**TC (%)**	**C/N**	**N input***
A-MH: Moorland (Heather)	3.6	84.1	42.7	23.1	16.8[a]
A-MG: Moorland (Grass)	3.9	78.7	43.3	30.0	16.8[a]
A-SP: Shelterbelt (Pine)	4.1	33.0	19.4	19.6	16.8[a]
A-GG: Grazed Grassland	6.0	35.3	9.4	19.9	>165[a+b+c]
Landuse	**pH**	**SMC (%)**	**TC (%)**	**C/N**	**N input***
W-MB: Peatland (Peat, Heather) (Background N Deposition)	3.6	87.3	42.3	29.5	8-11[a]
W-MN: Peatland (Peat, Heather) (Simulated high N deposition rates equivalent to nearby livestock buildings; long-term experimental site)	3.6	85.6	43.4	26.4	50-70[aa]

** kg N ha-¹ yr-¹; [a]Atmospheric deposition; [aa]Simulated NH_3 deposition; [b]Manure; [c]Sewage farm product*

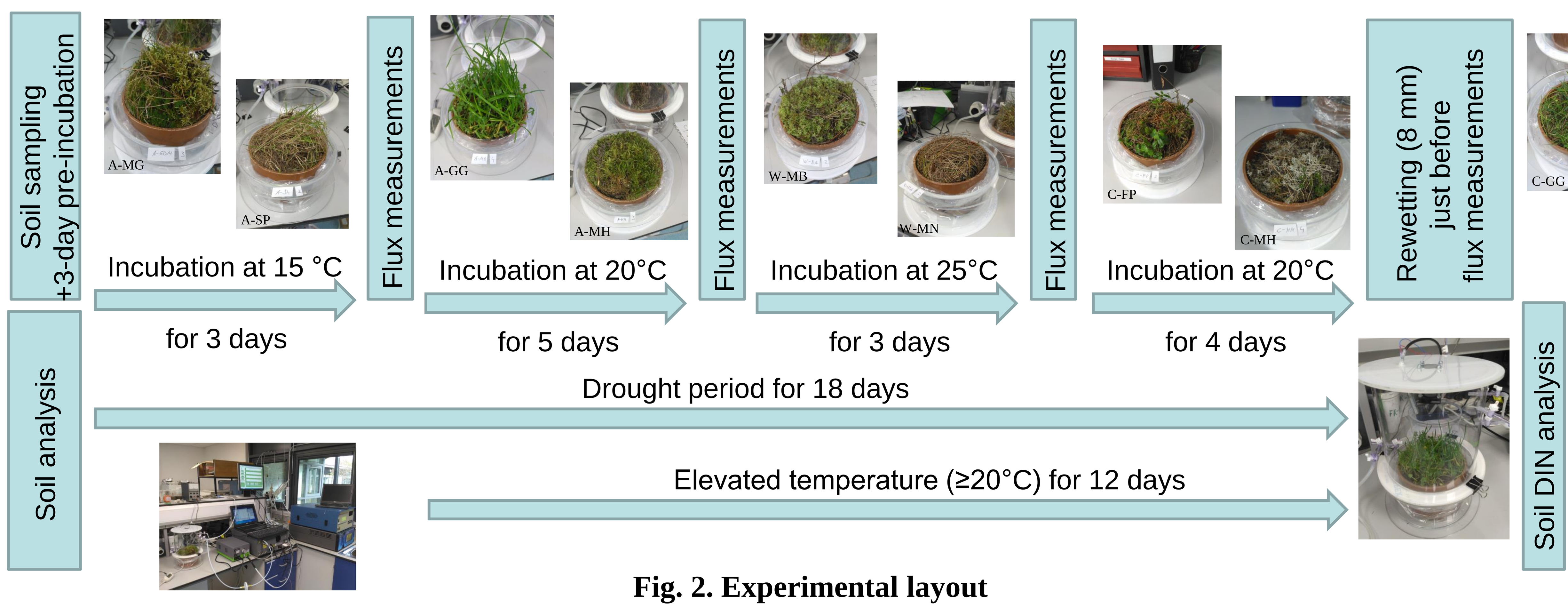

Fig. 2. Experimental layout

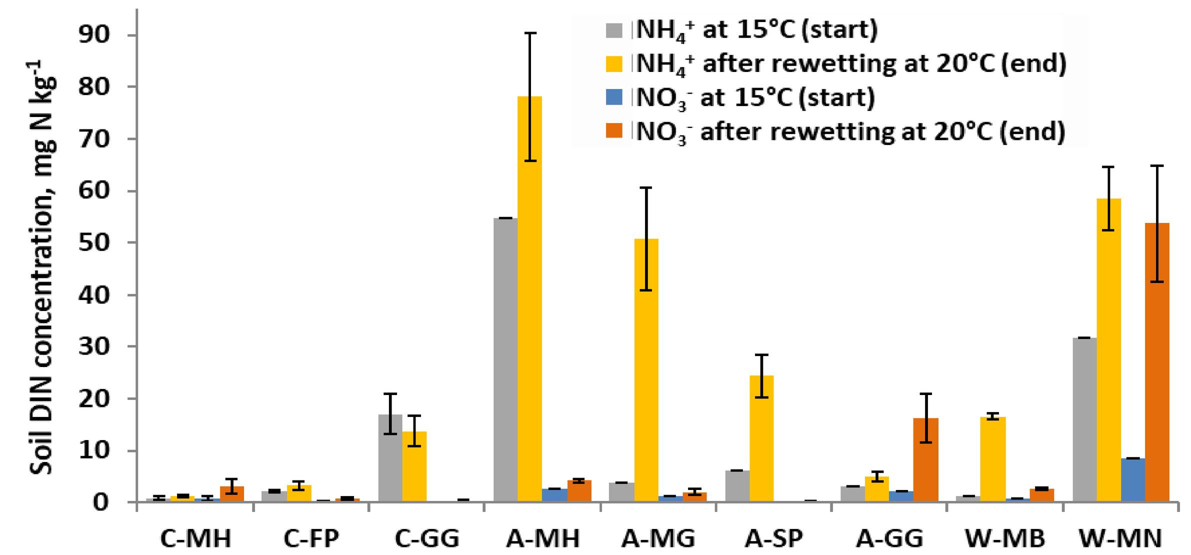

Fig. 3. NO_3^- and NH_4^+ concentrations (±SE) in studied soils

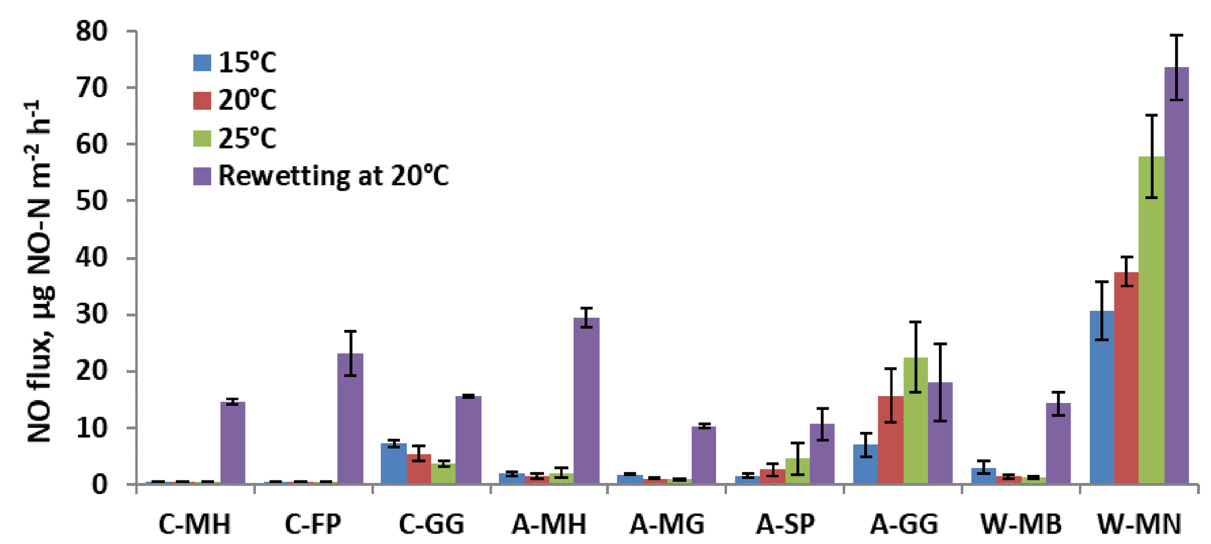

Fig. 4. NO emissions (±SE) upon different treatments

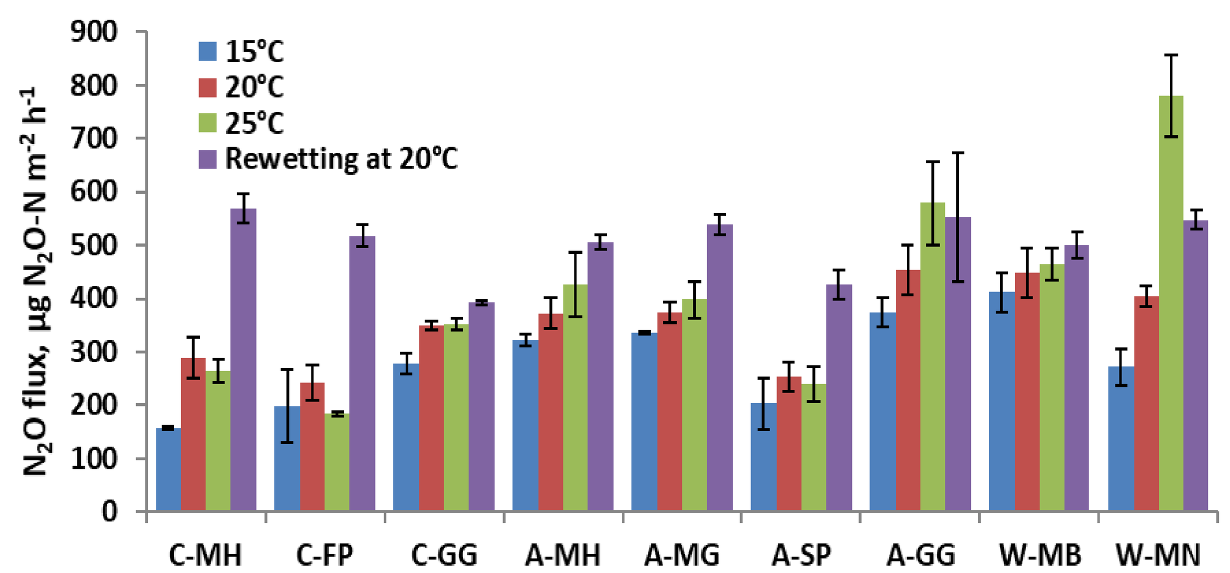

Fig. 5. N_2O emissions (±SE) upon different treatments

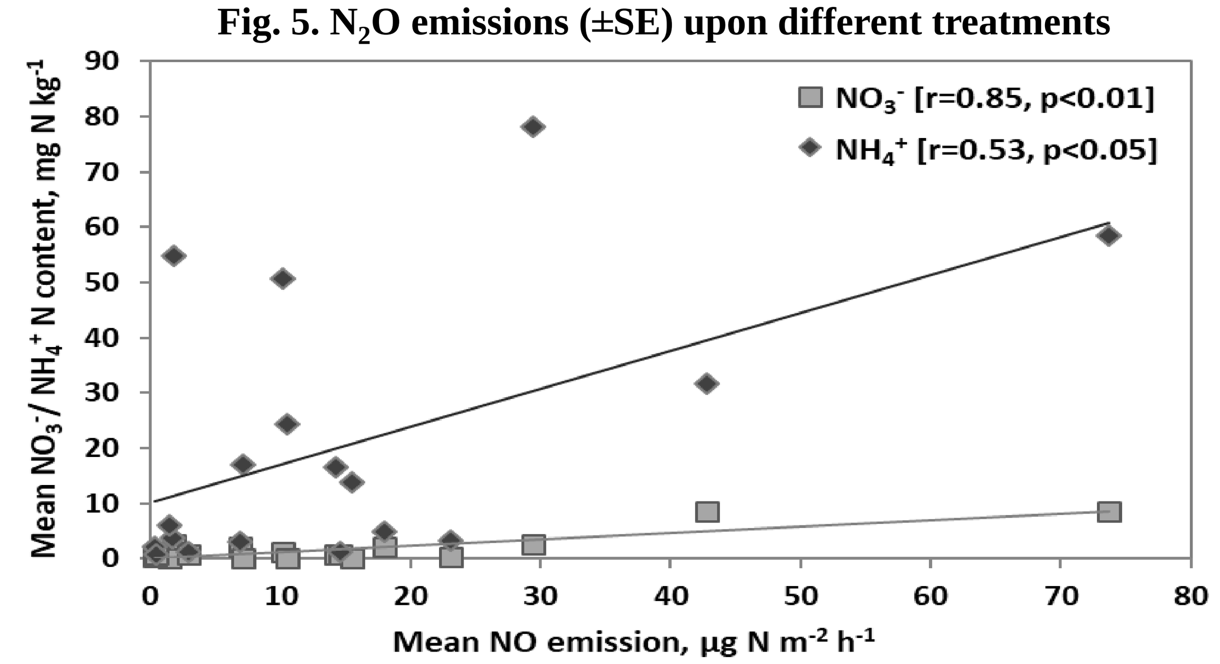

Fig. 6. Correlation between soil NO_3^- & NH_4^+ concentrations and NO emission

RESULTS

Soil NH_4^+ and NO_3^- concentrations (upon collection) (grey & blue bars)

- **NH_4^+ content was significantly larger than NO_3^- in all soil samples** at the beginning of experiment [Fig. 3]
- **High NH_4^+ and NO_3^- were found nearby** (A-MH) **and within** (C-GG for NH_4^+ and A-GG for NO_3^-) **grazing lands** and in the **experimental peatland** (W-MN) receiving **large NH_3 deposition rates** [Fig. 3]

Drought with temperature increase (DT) (blue, red & green bars)

- **DT significantly increased NO and N_2O emission in the Lowland sites receiving high N input** *(A-GG, W-MN)* compared the remaining sites [Fig. 4]
- **Smallest NO and N_2O emission were released from the natural Highlands** (C-MH, C-FP) **as well as the unmanaged A-SP** (for N_2O only) **under DT** [Fig. 4]
- **DT reduced NO emission (>2-fold) from the water-saturated natural Lowland moorlands** (W-MB, A-MG), **whereas N_2O emissions increased only by 1.3-1.6 times between 15°C and 25°C** [Fig. 4, 5; see details in Medinets et al., 2021]
- **Release of N_2O was associated (p<0.01) with soil NO_3^- concentrations** [Fig. 3, 5; see details in Medinets et al., 2021]

Rewetting after drought with elevated temperature (red & purple bars)

- **Rewetting increased soil NH_4^+ and NO_3^- concentrations at most sites** [Fig. 3; yellow & orange bars]. Notably **NO_3^- increase was higher than that of NH_4^+ in all soils** *except A-MG and W-MB* [see Medinets et al., 2021]
- **Rewetting significantly increased both NO and N_2O emissions** in all sites *except A-GG (for NO and N_2O) and W-MB (for N_2O only)* [Fig. 4, 5]
- **The largest NO response to rewetting** was observed at all Highland sites, and the Lowland heather moorland (A-MH) [Fig. 4]
- **The largest N_2O response to rewetting** was found in the **natural moorland site** (C-MH) **and pine forest** (C-FP) in the Highlands [Fig. 5]
- **Mean ratio** (rewetting/20°C) **for NO emissions** (2.9) **was larger than that for N_2O** (1.3) [see Fig. 4, 5]; **increase in NO pulses was 31-fold higher compared to N_2O** [see Medinets et al., 2021]

Relationships of fluxes with environmental drivers

- **NO emissions/ pulses strongly depended on soil NO_3^- content** [Fig. 6]
- **N_2O emissions were negatively correlated with the amount of water draining through the soil cores** (r=-0.79, p<0.01; see Medinets et al., 2021)
- **Changes in NO and N_2O emission rates were always controlled** (positively) **by WFPS differences** (see explanation in Medinets et al., 2021)

CONCLUSION

- **Typical land uses in Scotland are significant sources of N_2O and low-to-moderate sources of NO emissions to the atmosphere**
- **Climate warming and extreme events, such as drought and intensive rain events, appear to increase soil NO pulses and N_2O emissions from both natural and managed ecosystems**
- **Soil NO emissions were much smaller (6-660 times) than N_2O, but their impact on air quality (esp. during dry-wet transitions) is likely to increase relative to combustion sources of NO_x, which are declining as a result of successful mitigation strategies**

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