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The response of soil N cycling and nitrous oxide emission to Free Air CO_2 Enrichment in a temperate forest, UK.

Fotis Sgouridis (1), Suparat Cotchim (2,3), Ernesto Saiz (4), Panote Thavarungkal (3), Warakorn Limbut (3), Alex Radu (4), and Sami Ullah (2)

(1) School of Geographical Sciences, University of Bristol, Bristol, United Kingdom (f.sgouridis@bristol.ac.uk), (2) Birmingham Institute of Forest Research, University of Birmingham, Birmingham, United Kingdom , (3) Department of Chemistry, Prince of Songkla University, Thailand, (4) School of Chemistry, Keele University, Keele, United Kingdom

Increasing atmospheric CO_2 concentrations in temperate forests may affect soil nitrogen (N) cycling processes due to the increased demand for nitrogen availability to support CO_2 uptake by trees through photosynthesis. This in turn can affect the emission of nitrous oxide (N_2O), a potent greenhouse gas, from the forest soil leading to a potential trade-off between the enhanced canopy CO_2 uptake and soil N_2O emission. Our current understanding of the response of N cycling processes and availability to elevated atmospheric CO_2 (eCO_2) in mature, unmanaged temperate forests is limited. The Birmingham Institute of Forest Research (BIFoR) established in 2017 a Free-Air CO_2 Enrichment (FACE) facility in a mature temperate oak dominated forest in Staffordshire, UK, to study under 'real world' conditions the risks of a changing climate to forest ecosystems and the services they provide. In April 2018, one year after the start of fumigation with 550 ppm CO_2, we collected soil samples (0 – 15 cm depth) from the three eCO_2 and three control plots. Being a N limited forest soil in spite of enhanced atmospheric reactive N deposition (22 kg N ha^{-1} y^{-1}), we hypothesized that N mineralisation will increase and N_2O emission will be down regulated to meet tree N demands under eCO_2. Soils were amended in the laboratory with 98 at % $^{15}N\text{-}NH_4^+$ and $^{15}N\text{-}NO_3^-$ (at $\sim$ 20 % of the ambient soil NH_4^+ and NO_3^- concentration) and were incubated in the dark for 24 hours. Gross N mineralisation and nitrification were estimated according to the isotope dilution technique, while N_2O emission from nitrification ($^{15}N\text{-}NH_4^+$ treatment) and denitrification ($^{15}N\text{-}NO_3^-$ treatment) were estimated according to the ^{15}N Gas-Flux method. Additionally, asymbiotic biological N fixation was measured with the $^{15}N_2$ direct assimilation method. Gross N mineralisation was significantly higher (t-Test: $P < 0.05$) in the eCO_2 plots (mean: 2.25 μg N g^{-1} d^{-1}) compared to the control plots (mean: 0.61 μg N g^{-1} d^{-1}) confirming our hypothesis, while there was no significant difference in gross nitrification rates. N_2O emission from both denitrification (mean: 2.85 ng N g^{-1} d^{-1}) and nitrification (mean: 0.18 ng N g^{-1} d^{-1}) was marginally higher in the eCO_2 plots, but the difference was not statistically significant (t-Test: $P > 0.05$). Denitrification was a stronger source of N_2O (16 times higher than nitrification) in the eCO_2 plots compared to the controls (denitrification 12 times higher than nitrification). Finally, asymbiotic biological nitrogen fixation was also significantly higher in eCO_2 plots. After one year of CO_2 fumigation, there is indication of enhanced cycling and N availability to support enhanced canopy CO_2 uptake. As more soil inorganic N becomes available a shift towards higher N_2O emission is to be expected and continuous multiannual *in situ* monitoring is needed to establish the balance between N availability for tree uptake relative to dissimilatory N losses including N_2O emission under eCO_2 to fully elucidate the implications of N availability for meeting tree N demands under future CO_2 enriched atmosphere.