



Precipitation frequency constrains N₂O source-sink dynamics in an N-saturated subtropical forest: Insights from natural abundance N₂O isotopes

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Subtropical forest soils are global hotspots of nitrous oxide (N₂O) emissions and are increasingly exposed to extreme meteorological variation. Episodic drying-rewetting events can strongly alter N cycling, yet the mechanisms by which event-scale precipitation frequency at constant precipitation amount regulate N₂O production and reduction in N-saturated forests remain poorly constrained. Here, we conducted an *in situ* precipitation simulation after a summer drought at the Tieshanping forest site in Southwest China under three treatments: Control without adding water, single heavy precipitation event (30 mm on the first day), and multiple precipitation event (10 mm d⁻¹ over the first three days; same total amount as the single precipitation event).

We measured N₂O fluxes together with the natural abundance N₂O isotopes, $\delta^{15}\text{N}^{\text{bulk}}$ and $\delta^{15}\text{N}^{\text{SP}}$ (i.e. $^{15}\text{N}^{\alpha} - ^{15}\text{N}^{\beta}$), as well as soil moisture, KCl-extractable mineral N and water-extractable organic carbon. Isotopocule-based mapping and end-member mixing were used to partition production pathways and quantify the N₂O reduction to N₂. The single precipitation event rapidly increased water-filled pore space (WFPS) to more than 90% and triggered a pronounced N₂O emission peak (more than 200 $\mu\text{g N m}^{-2} \text{h}^{-1}$) which was dominated by denitrification, while N₂O reduction remained limited. Under multiple precipitation events, the peak N₂O flux was delayed and followed by strong negative fluxes ($-130 \mu\text{g N m}^{-2} \text{h}^{-1}$), accompanied by a marked increase in $\delta^{15}\text{N}^{\text{SP}}$ ($\sim 40\text{‰}$), indicating enhanced N₂O reduction. Notably, cumulative N₂O emissions during this 5-day simulation were highest under single precipitation events (5 mg N m⁻²), followed by control treatment and multiple precipitation events (3.7 and 0.8 mg N m⁻², respectively).

Across all treatments, soil moisture together with availability of soil nitrate and labile carbon controlled the shifts in N₂O sources and sinks we observed. Our findings provide process-level constraints on how event-scale precipitation frequency reshape N₂O source-sink dynamics in N-saturated subtropical forests, and highlight the importance of incorporating precipitation frequency and intensity into predictions of forest N₂O responses under future extreme climate events.