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Disentangling the long-term foliar ^{15}N signal using a land surface model

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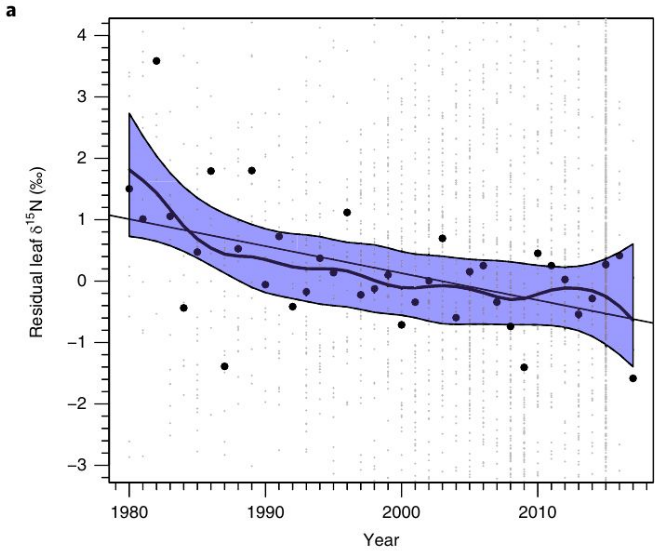
Aim: To identify the drivers behind observed trends in foliar $\delta^{15}N$, as described in Craine et al. 2018

Method: A land surface model (QUINCY) with the capacity to represent $\delta^{15}N$ processes, where alternative hypotheses can be tested separately.

Conclusions: Predicted decreases in foliar $\delta^{15}N$ are mainly driven by the effects of elevated atmospheric CO_2 over the last century. However, the magnitude of this trend is much smaller than the observed trend. Including a change in the $\delta^{15}N$ of anthropogenic N deposition in the model partially explains the discrepancy between model and data.



N limitation is very difficult to measure and $\delta^{15}N$ observations have been proposed as a tool to do this.

Previous studies have attributed the trend in time of foliar $\delta^{15}N$ to progressive nitrogen limitation under elevated atmospheric CO_2.

BUT while this observational dataset is very valuable, it cannot investigate the mechanisms behind the observed trend.

H1

Elevated atmospheric CO_2 drives ecosystem N limitation and therefore the change in foliar $\delta^{15}N$

H2

Plants have the capacity to alleviate N limitation through plastic responses, leading to less of a decrease in foliar $\delta^{15}N$

H3

Changes in sources of anthropogenic N deposition lead to a decrease in foliar $\delta^{15}N$

We use a land surface model to test these hypotheses and run the following model scenarios

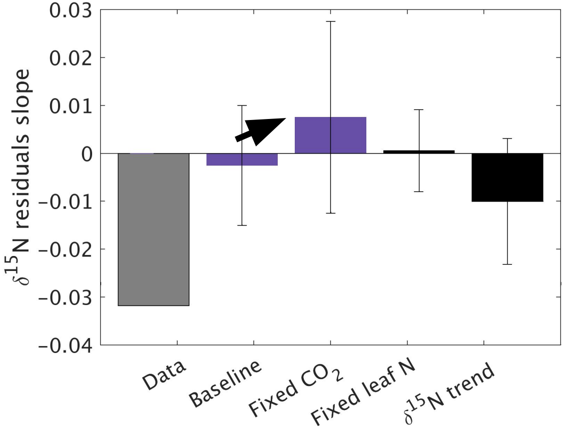
Feature / Name	Transient climate	Transient CO_2	Leaf plastic responses	$\delta^{15}N$ trend in anthropogenic N deposition
Baseline	●	●	●	
Fixed CO_2	●		●	
Fixed leaf N	●	●		
$\delta^{15}N$ trend	●	●	●	●

For more details on the methodology, see slides 10 and 11

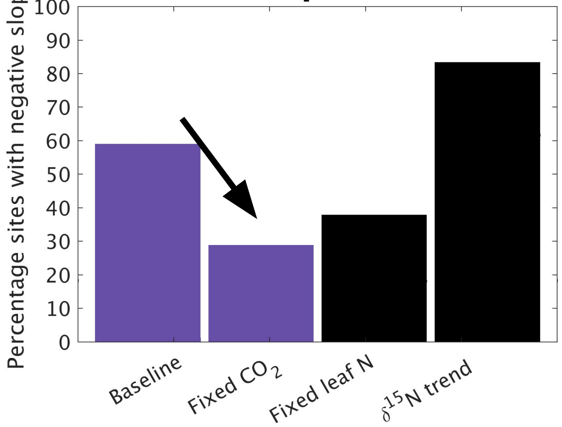
H1

Elevated atmospheric CO_2 drives ecosystem N limitation and therefore the change in foliar $\delta^{15}N$

Average slope across all sites



Percentage of sites with significant negative slopes



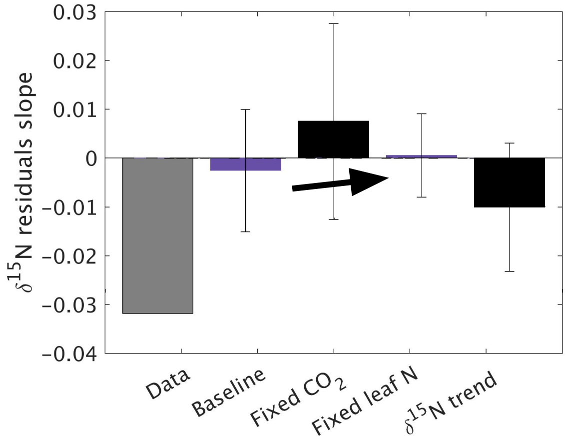
Fixed atmospheric CO_2 leads to a positive average trend in $\delta^{15}N$ residuals, confirming our hypothesis

Highlighted bars represent model versions relevant for this hypothesis

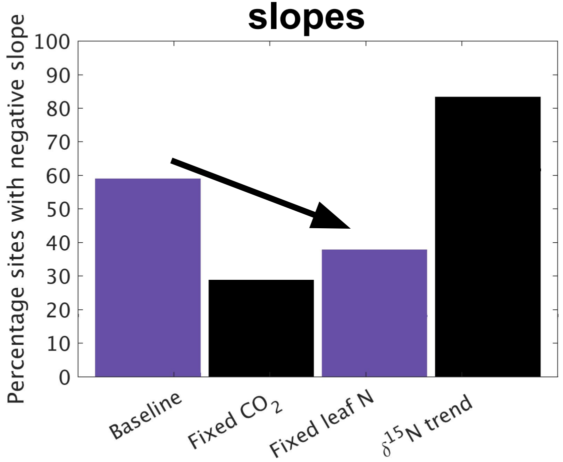
H2

Plants have the capacity to alleviate N limitation through plastic responses, leading to less of a decrease in foliar $\delta^{15}N$

Average slope across all sites



Percentage of sites with significant negative slopes

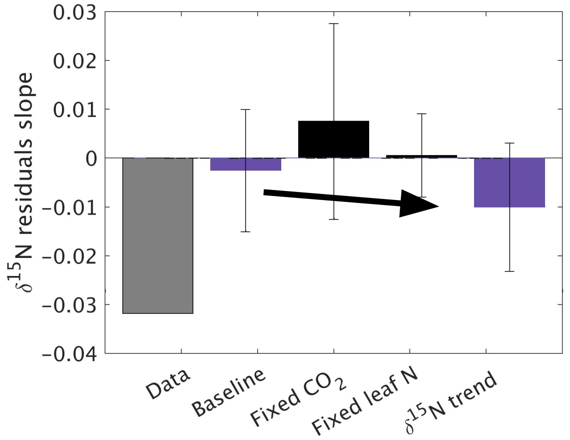


The baseline model can vary the leaf N content and biomass allocation in response to N limitation, Contrary to our hypothesis, we see a smaller decrease in δ1⁵N, at fewer sites, for a fixed leaf N, due to higher growth if plants are allowed plastic responses.

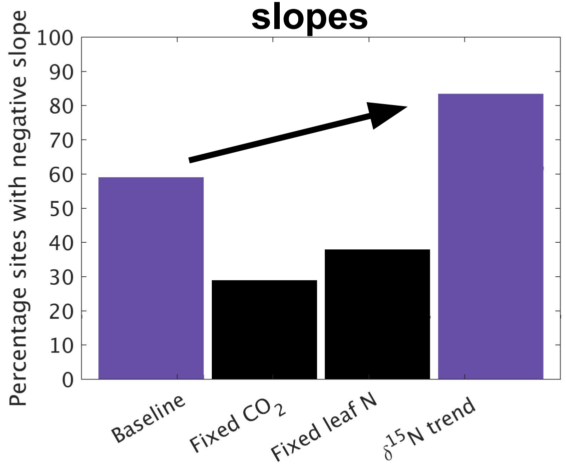
Highlighted bars represent model versions relevant for this hypothesis

H3 Changes in sources of anthropogenic N deposition lead to a decrease in foliar $\delta^{15}N$

Average slope across all sites



Percentage of sites with significant negative slopes



We introduce **a trend in $\delta^{15}N$ of N deposition** according to observations from Holtgrieve et al. 2011. This leads to a stronger trend and a larger number of sites with negative trends, confirming our hypothesis

Highlighted bars represent model versions relevant for this hypothesis

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Conclusions: Predicted decreases in foliar $\delta^{15}N$ are mainly driven by the effects of elevated atmospheric CO_2 over the last century. However, the magnitude of this trend is much smaller than the observed trend. Including a change in the $\delta^{15}N$ of anthropogenic N deposition in the model partially explains the discrepancy between model and data.

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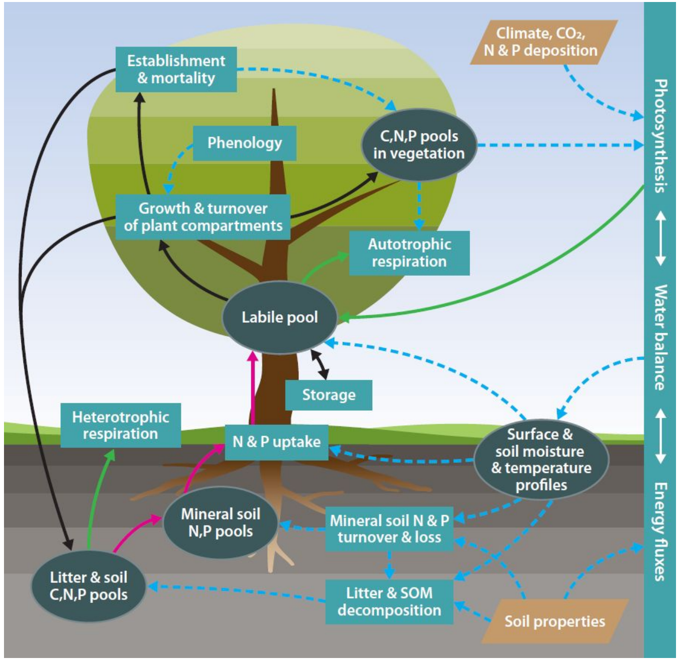
We use a land surface model to test these hypotheses, which cannot be done using data only



QUINCY is a novel land surface model with fully coupled C,N,P and water cycles, which has the capacity to represent C and N isotopic processes.

[Model description]

[Code availability]

Model simulations and comparison with data

We run QUINCY at ~400 sites distributed across climate zones and PFTs, for the period 1901-2018, with fully transient climate and CO_2.

We compare model results with the foliar $\delta^{15}N$ data from Craine et al. 2018, available here.

All values presented here, for both data and model, are residuals of mixed linear regression model accounting for variations in climate and leaf N content. This means that any trends are due only to changes in time and not spatial variations.