Reductions in photosynthetic nitrogen demand due to elevated CO_2 increases simulated future ecosystem carbon storage

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Leaf N is decreasing with elevated CO_2

Article | Open Access | Published: 13 March 2020

Increasing atmospheric CO_2 concentrations correlate with declining nutritional status of European forests

Josep Penuelas, Marcos Fernández-Martínez, Helena Vallicrosa, Joan Maspons, Paolo Zuccarini, Jofre Carnicer, Tanja G. M. Sanders, Inken Krüger, Michael Obersteiner, Ivan A. Janssens, Philippe Ciais & Jordi Sardans

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RESEARCH ARTICLE

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SCIENCE · 11 Dec 2020 · Vol 370, Issue 6522 · pp. 1295-1300 · DOI: 10.1126/science.abb7772

Article | Published: 22 October 2018

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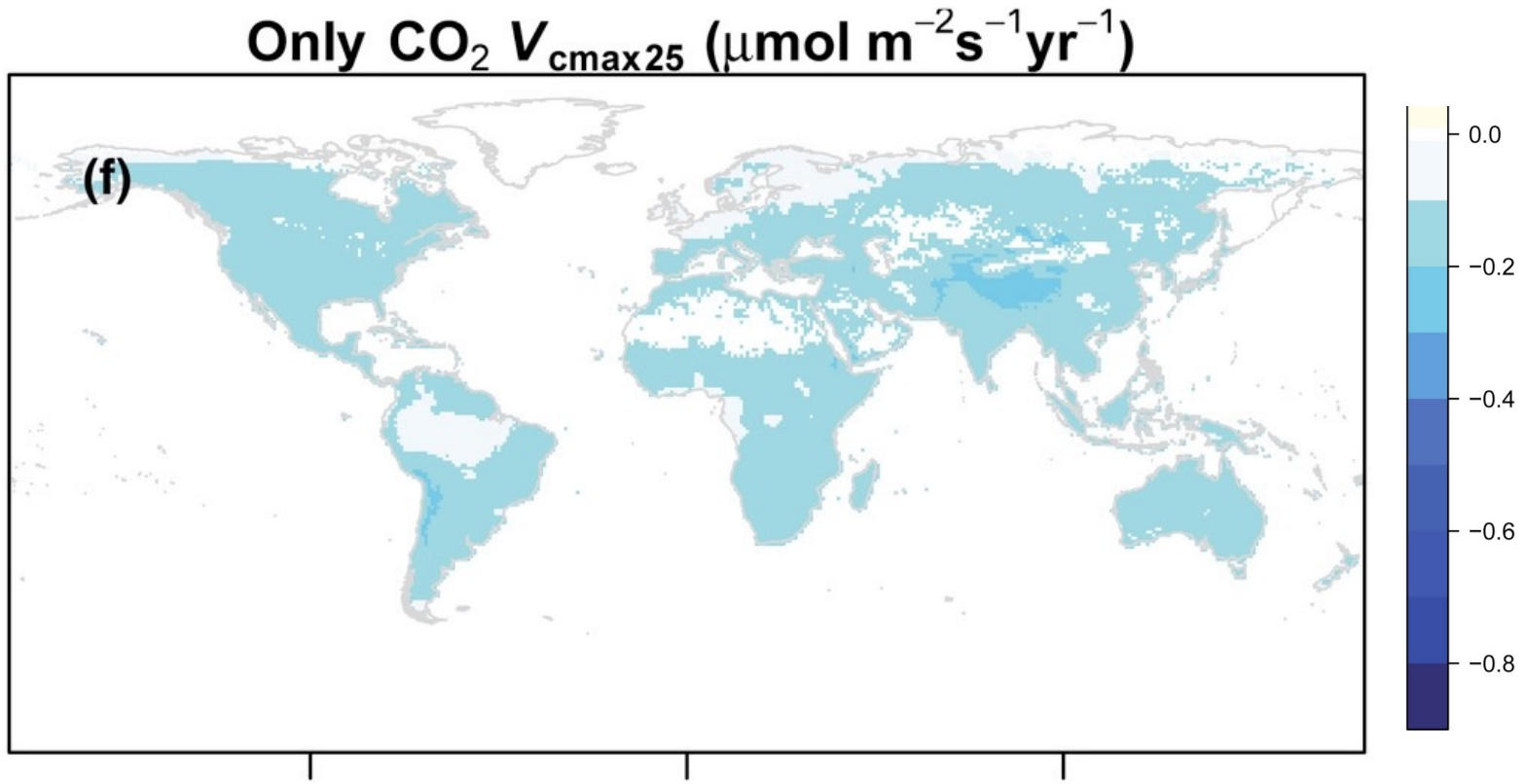
Leaf N demand decreases with increasing CO_2



Dong et al. (2022)

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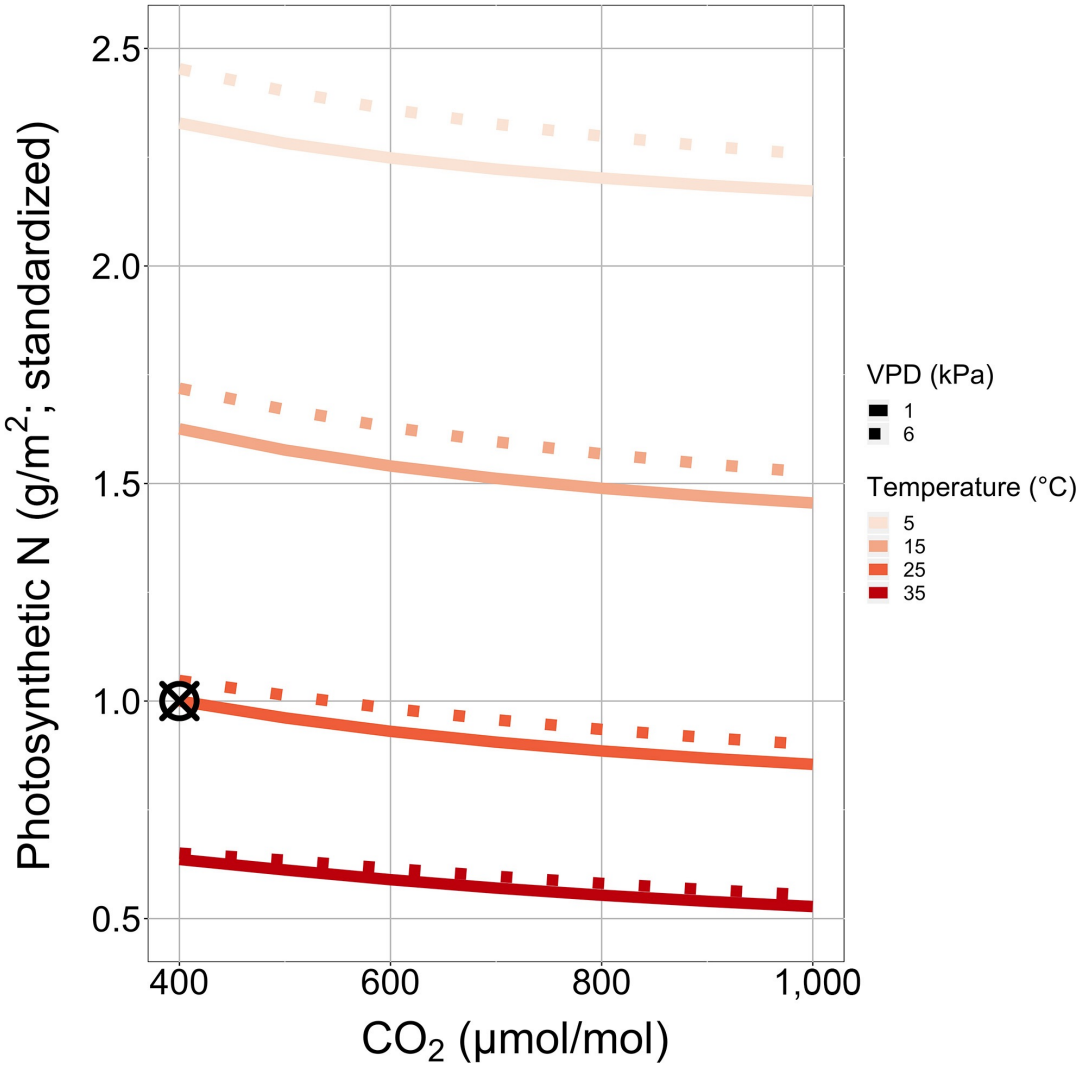
Leaf N demand decreases with increasing CO_2



Smith and Keenan (2020)

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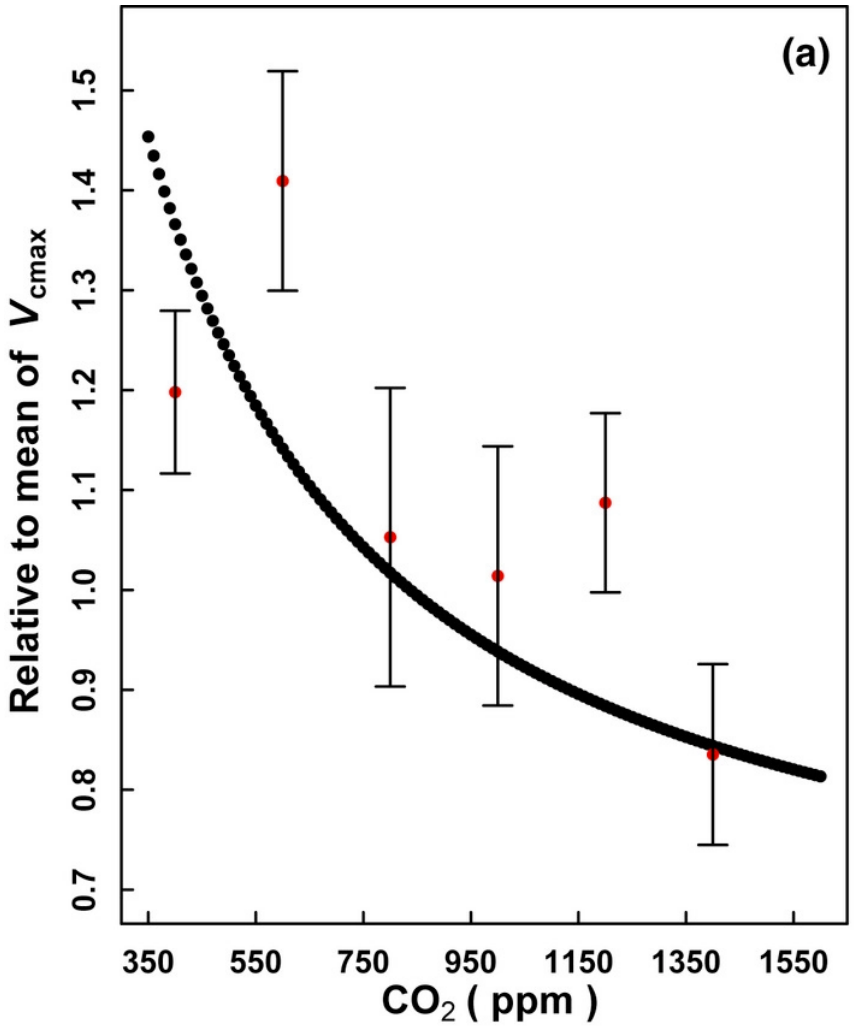
Eco-evolutionary optimality theory can predict CO_2-induced reductions in leaf N



Model: Dong et al. (2022)
Data: Zheng et al. (2019)

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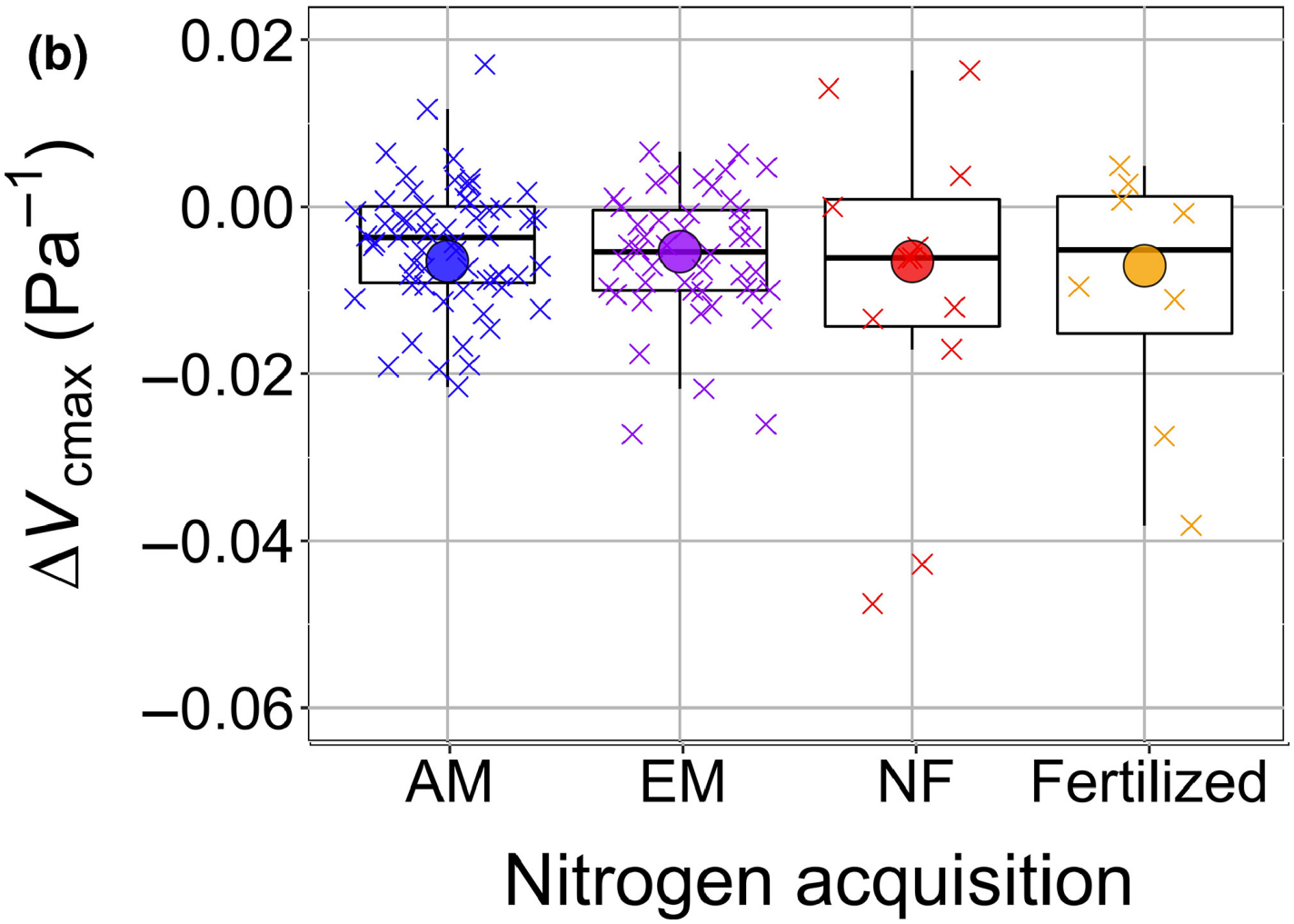
Eco-evolutionary optimality theory can predict CO_2-induced reductions in leaf N



Smith and Keenan (2020)

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What do reductions in leaf N demand mean for ecosystem C-N dynamics under future, elevated CO_2?

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ELM simulations

- All simulations included optimal V_{cmax} and J_{max} (Smith and Keenan, 2020)
- All simulations included dynamic carbon and nitrogen allocation (Zhu et al., 2019)
- 2 simulations with different N dynamics
  1. Leaf N is determined by N availability in soil
  2. Leaf N is determined by N demand for photosynthetic biochemistry

E3SM Energy Exascale Earth System Model

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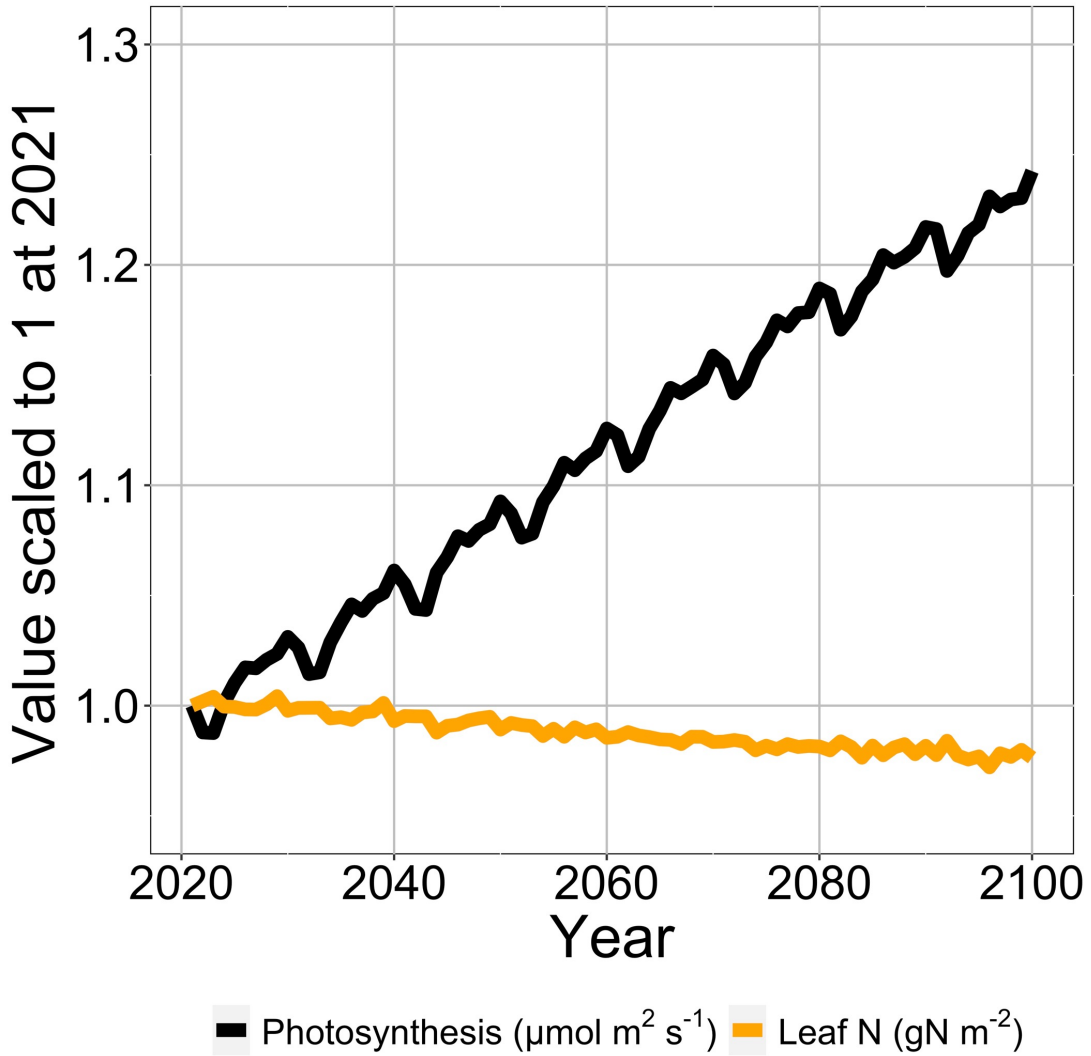
Result 1: Photosynthesis increases with elevated CO_2 at lower leaf N



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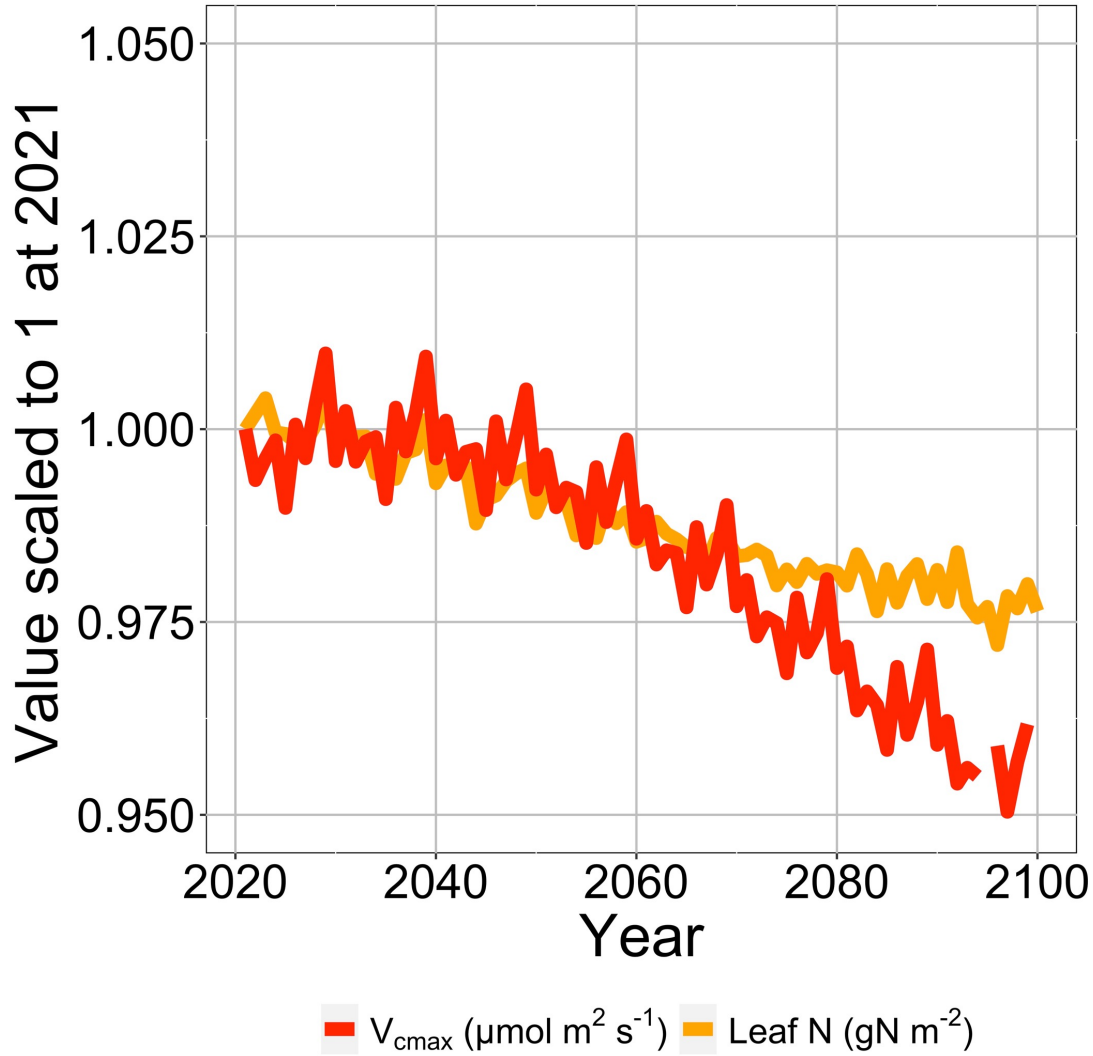
Result 1: Leaf N reduction is due to a reduction in photosynthetic capacity



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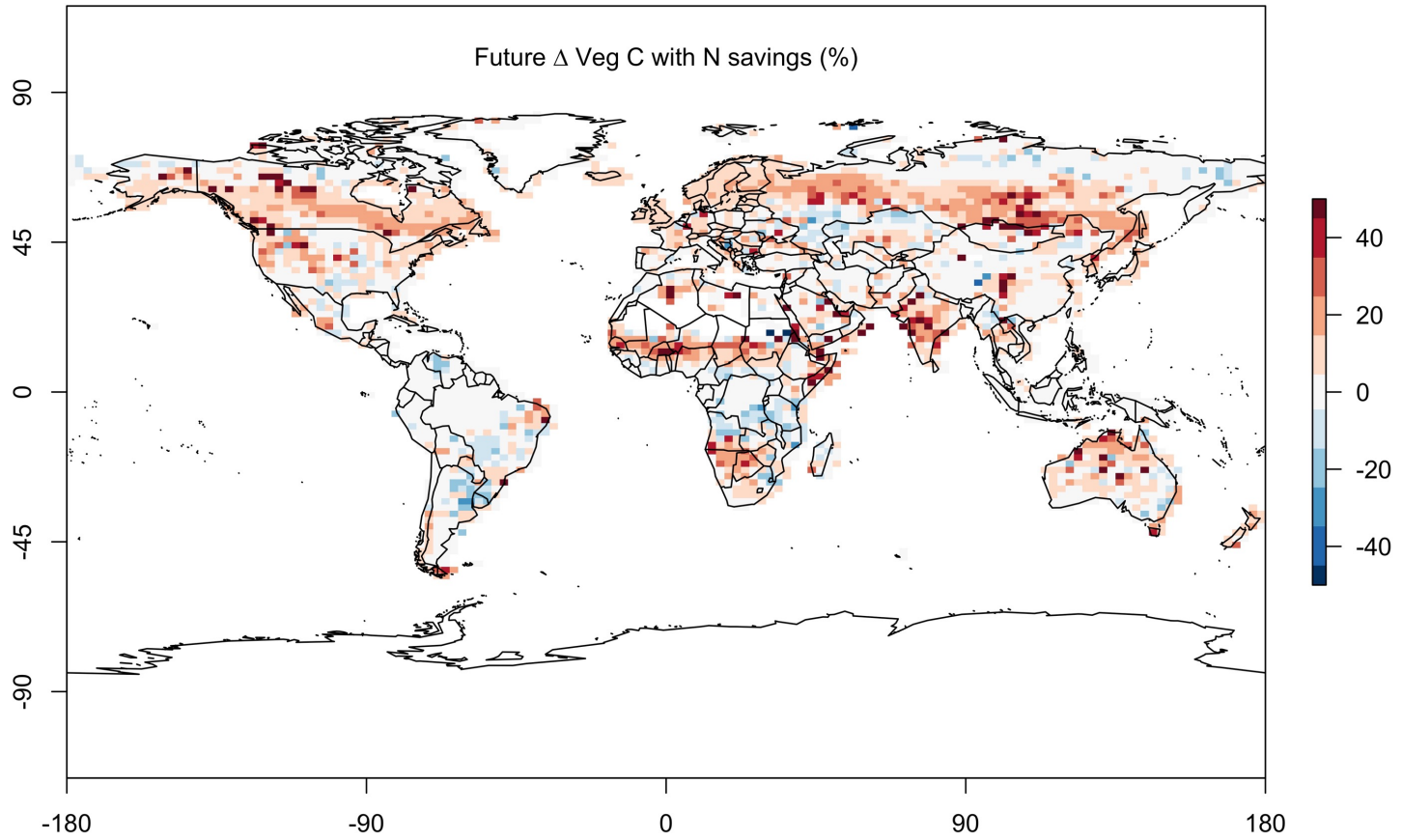
Result 2: Leaf N savings increases plant growth



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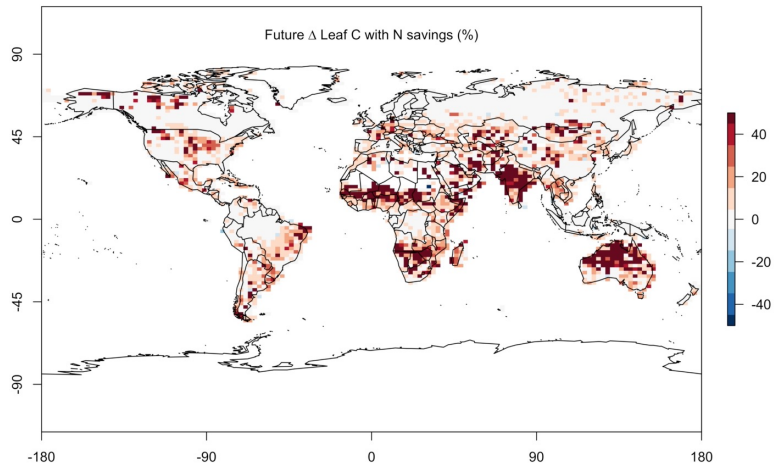
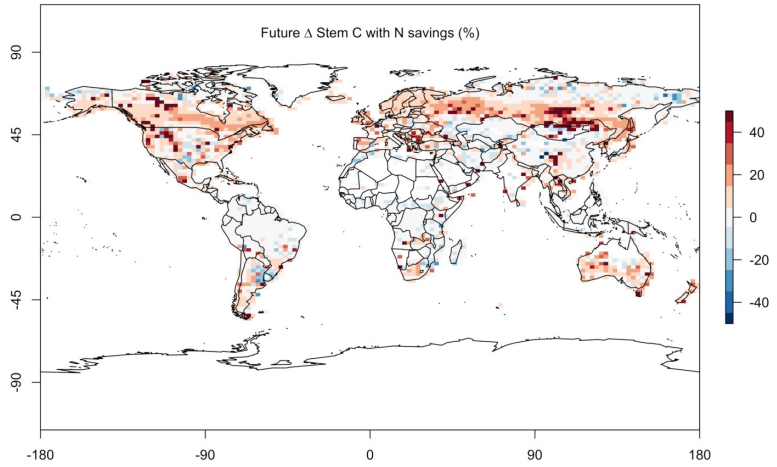
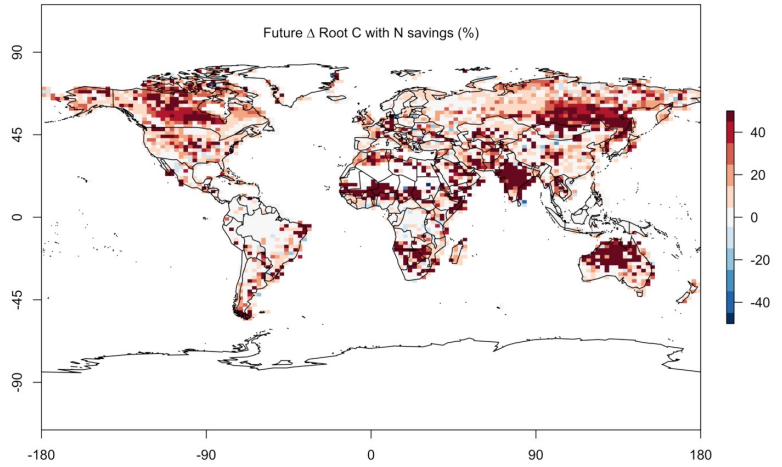
Result 2: Leaf N savings increases plant growth…most in leaves and roots







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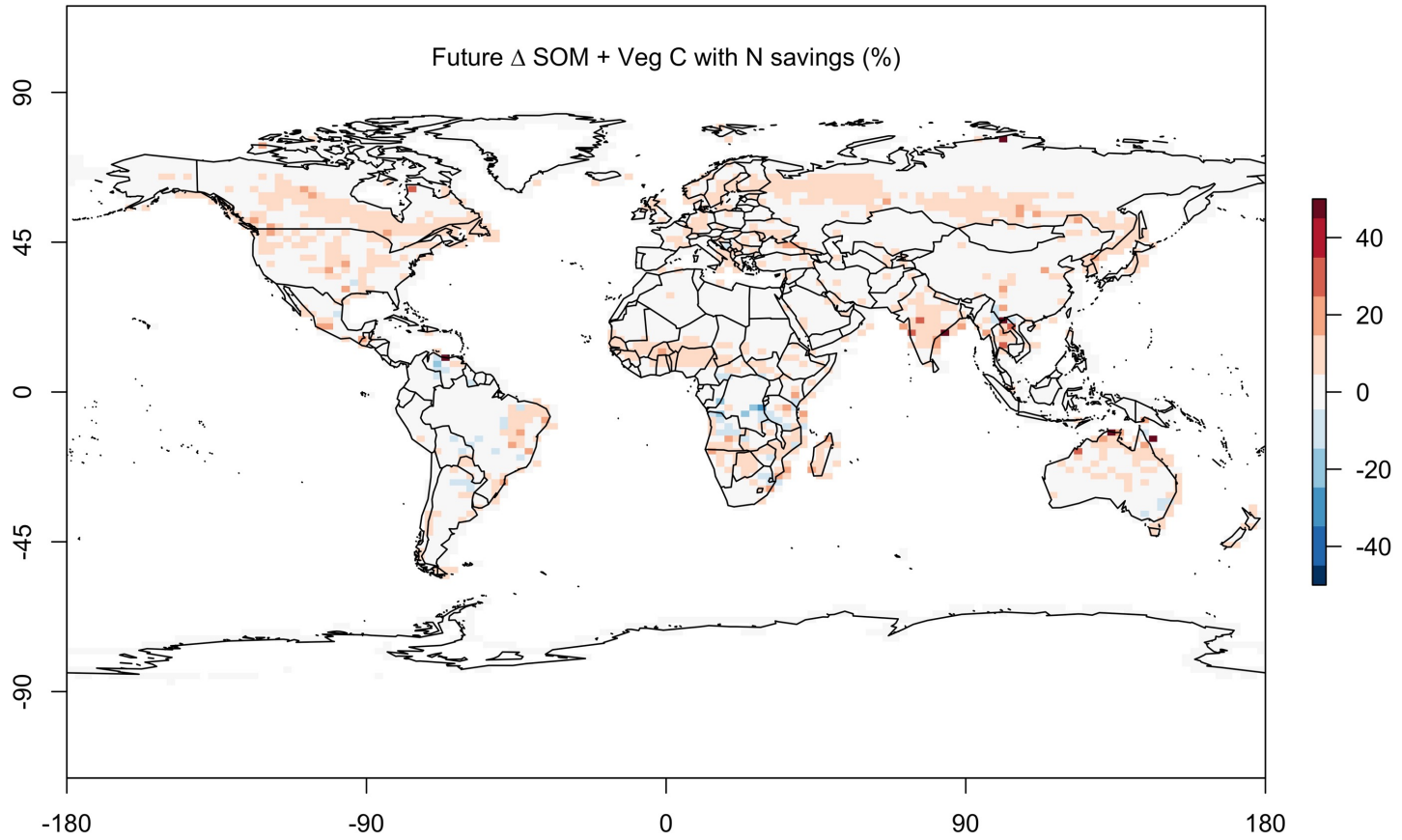
Result 3: Leaf N savings increases long-term ecosystem carbon stocks



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What does this all mean?

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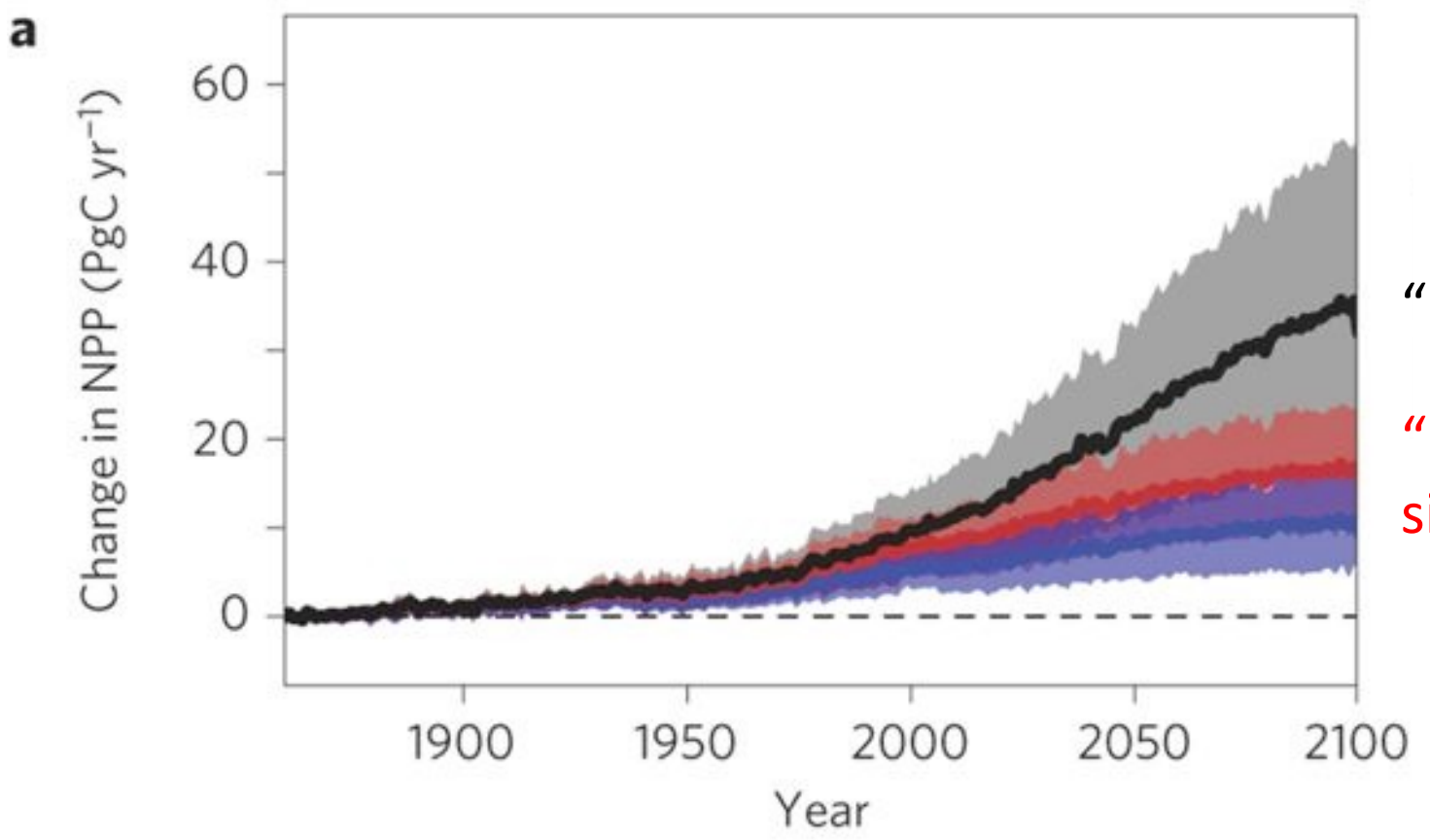
Future progressive nutrient limitation may be overestimated



"No limitation" simulation

"Nutrient limitation" simulations

Weider et al. (2015)

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Conclusions

- Photosynthetic N demand is reduced under future elevated CO_2 and temperature
  - Least cost optimality theory can predict this
- The theory can (and should) be incorporated into ESMs
  - No added parameters
- N savings increases projected ecosystem C
- Progressive nitrogen limitation may not be as strong as current models predict

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