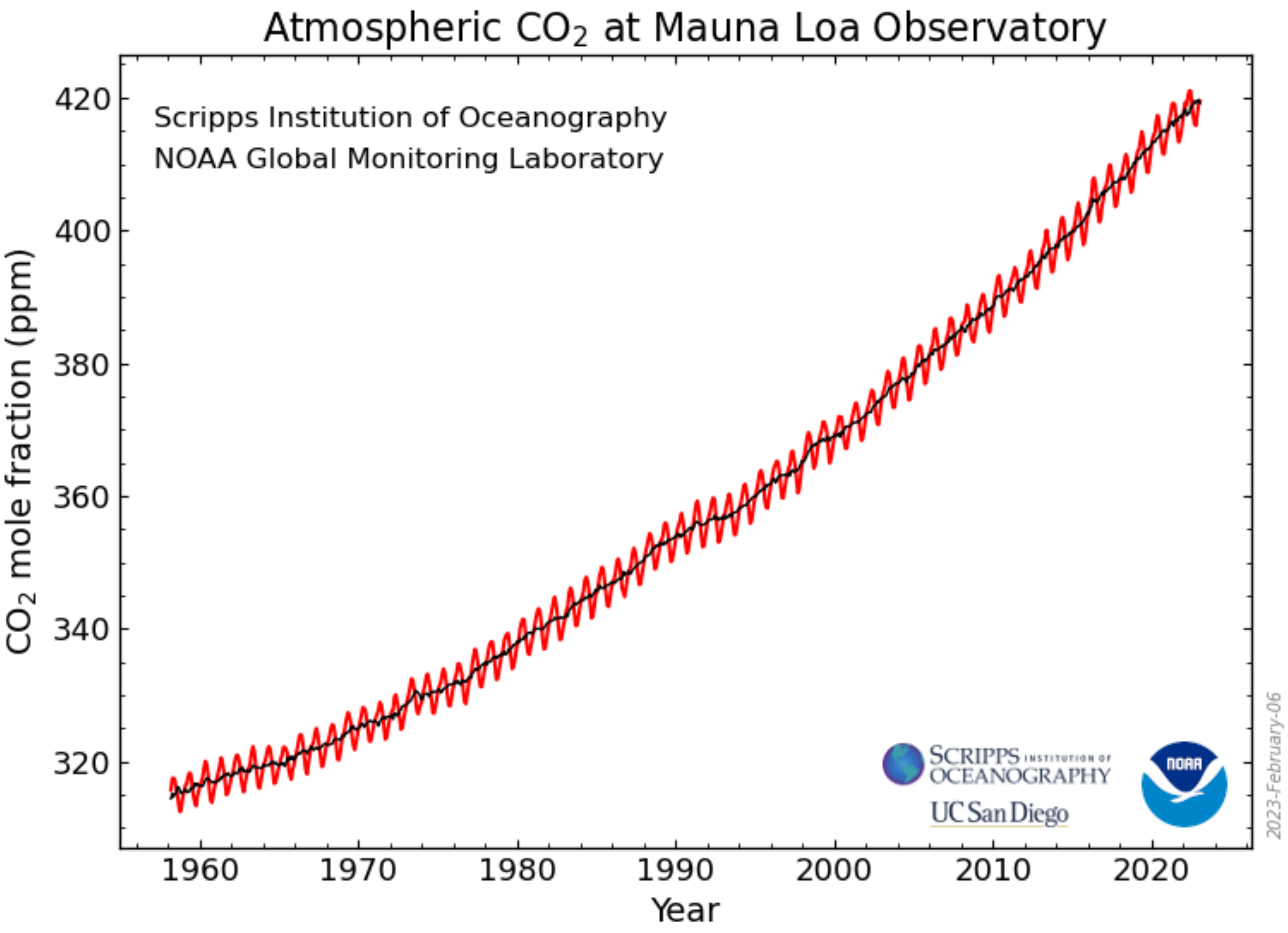
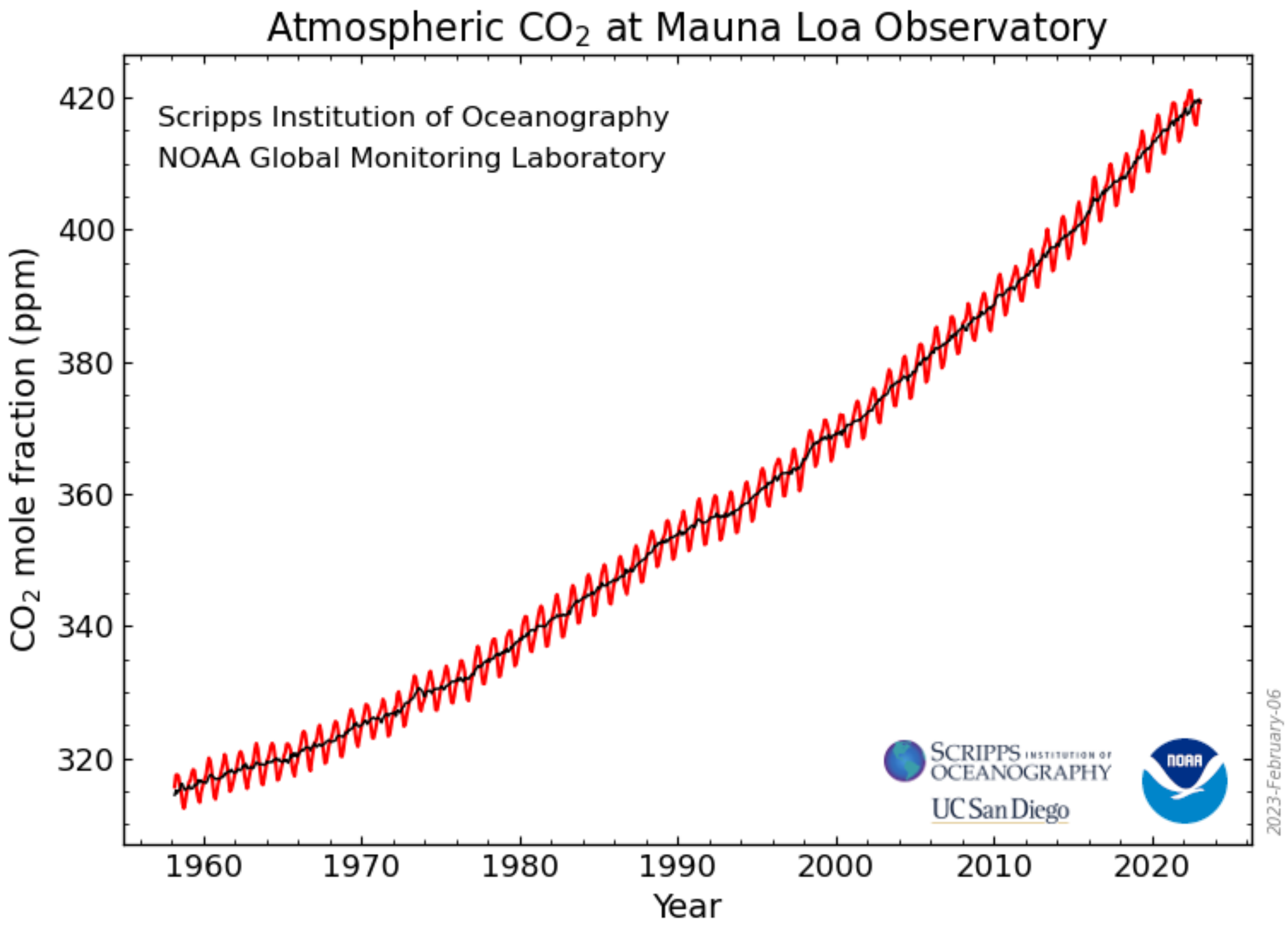
Nitrogen supply and demand control plant responses to elevated CO_2 at difference scales

Evan A. Perkowski
Ezinwanne Ezekannagha
Nicholas G. Smith



https://gml.noaa.gov/ccgg/trends/

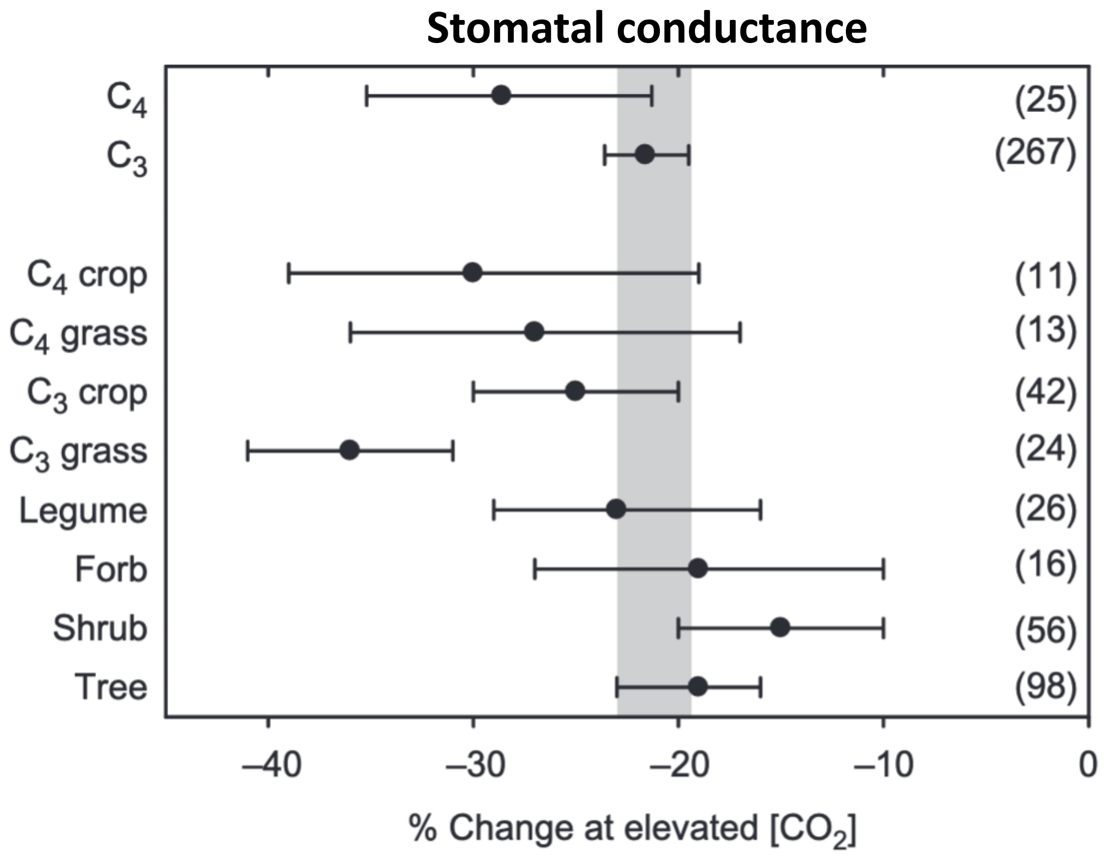


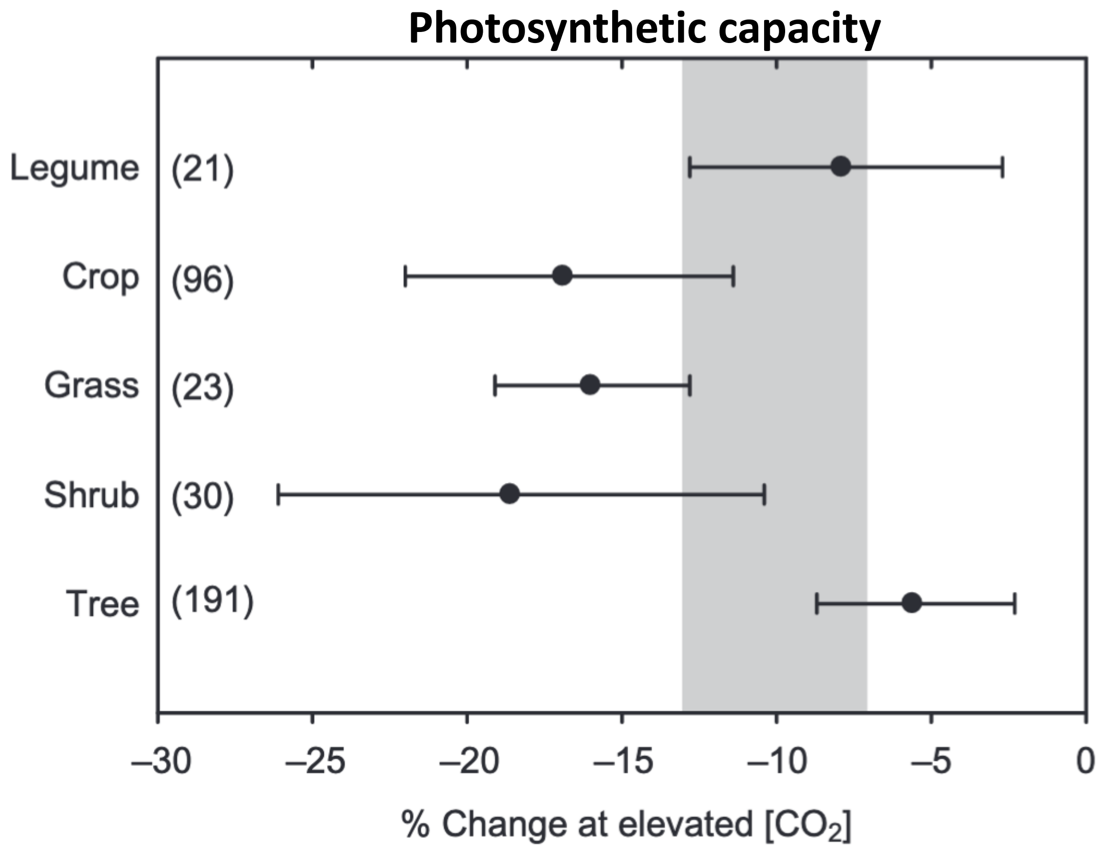
33% increase in CO_2 concentration since 1960

61% of this increase has occurred since 1990

https://gml.noaa.gov/ccgg/trends/

Plants grown under elevated CO_2 exhibit **reductions** in stomatal conductance and photosynthetic capacity

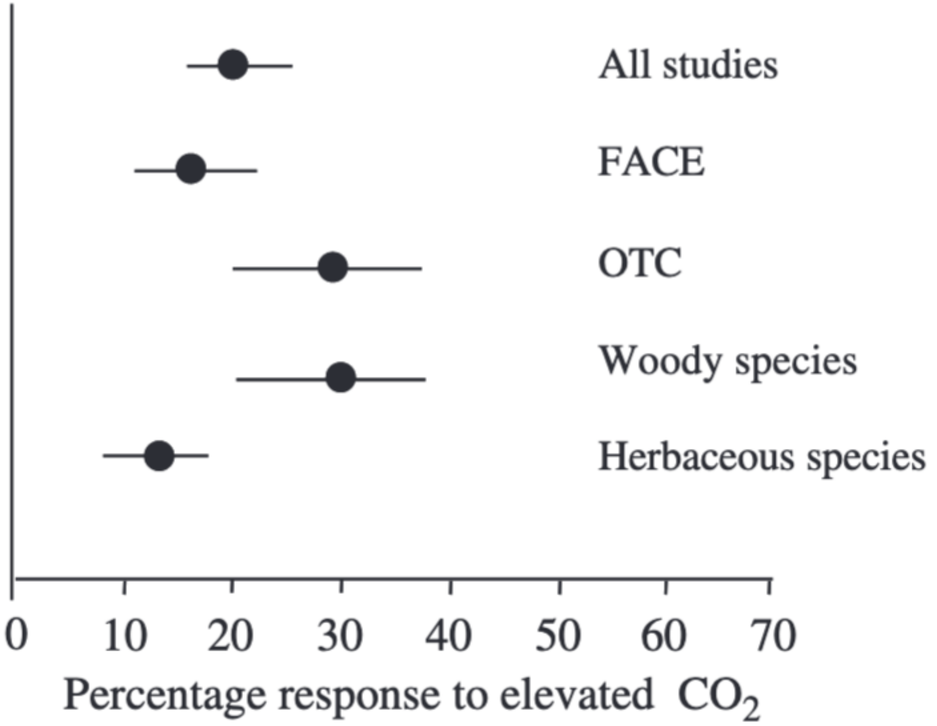




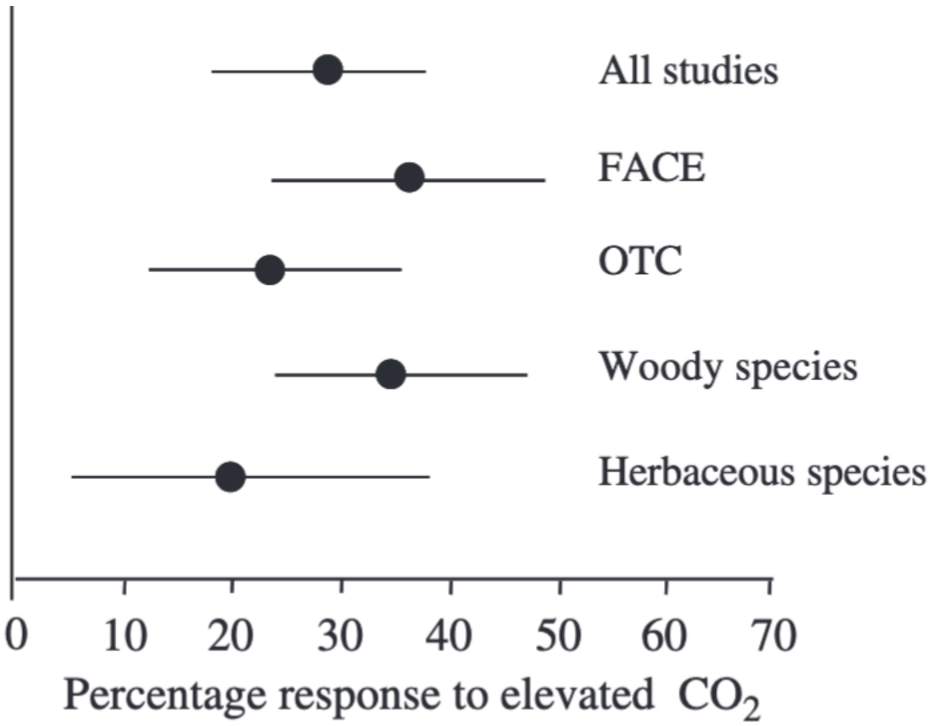
Ainsworth & Rogers (2007) *PC&E*

Leaf responses to elevated CO_2 correspond with **increased whole-plant growth**

Aboveground biomass



Belowground biomass



de Graaf et al. (2006) *Global Change Biology*

As nutrient availability commonly limits net primary productivity…

Ecology, 89(2), 2008, pp. 371–379

NITROGEN LIMITATION OF NET PRIMARY PRODUCTIVITY IN TERRESTRIAL ECOSYSTEMS IS GLOBALLY DISTRIBUTED

David S. LeBauer[1,3] and Kathleen K. Treseder[2]

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[2]*Department of Ecology and Evolutionary Biology, University of California, Irvine, California 92054 USA*

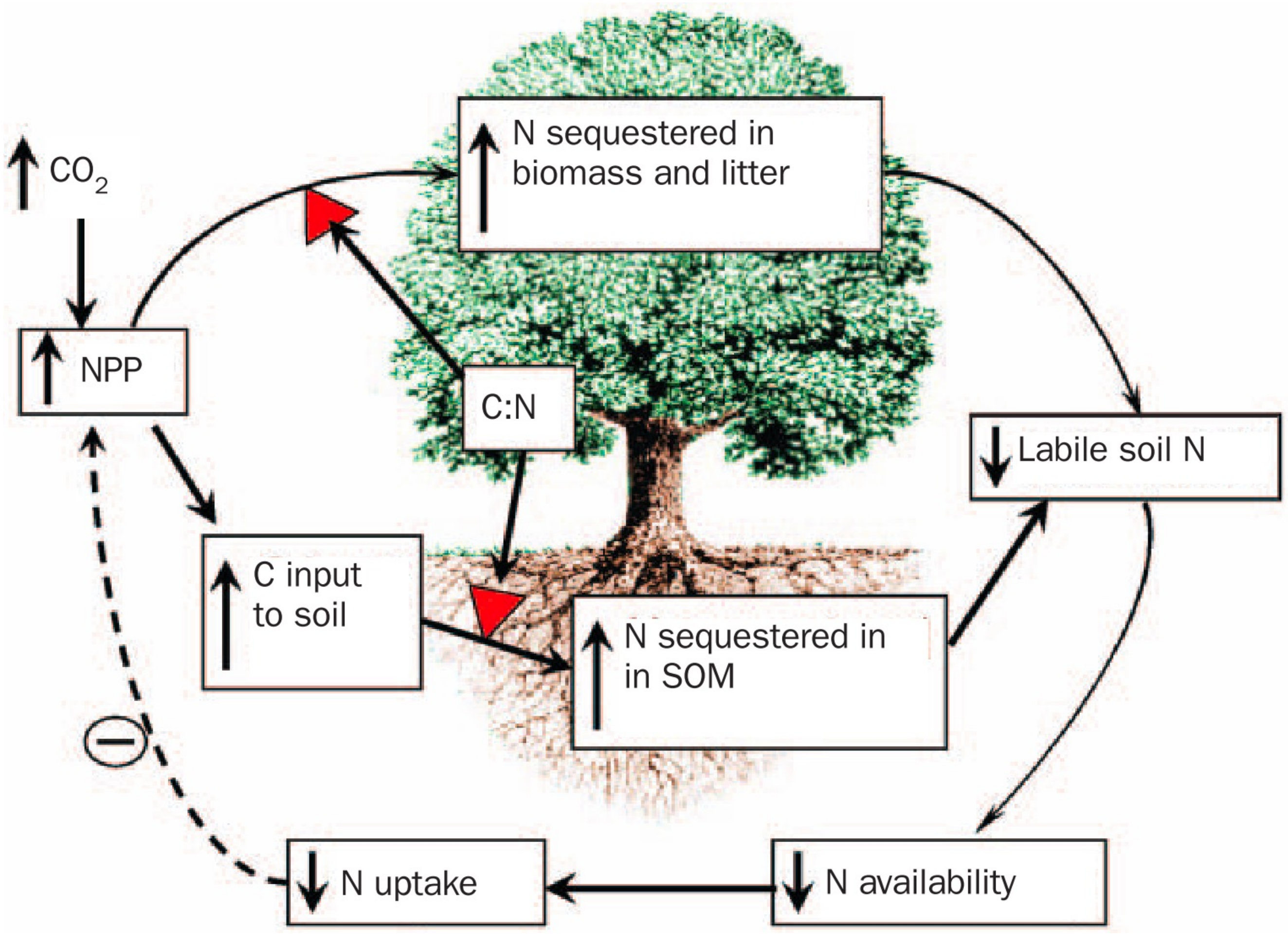
Grassland productivity limited by multiple nutrients

Philip A. Fay, Suzanne M. Prober, W. Stanley Harpole, Johannes M. H. Knops, Jonathan D. Bakker, Elizabeth T. Borer, Eric M. Lind, Andrew S. MacDougall, Eric W. Seabloom, Peter D. Wragg, Peter B. Adler, Dana M. Blumenthal, Yvonne M. Buckley, Chengjin Chu, Elsa E. Cleland, Scott L. Collins, Kendi F. Davies, Guozhen Du, Xiaohui Feng, Jennifer Firn, Daniel S. Gruner, Nicole Hagenah, Yann Hautier, Robert W. Heckman, ... Louie H. Yang + Show authors

Nature Plants **1**, Article number: 15080 (2015) | Cite this article

LeBauer & Treseder (2008) *Ecology*; Fay et al. (2015) *Nature Plants*

Nutrient limitation has been hypothesized to be the primary mechanism driving plant responses to CO_2



Luo et al. (2004) *BioScience*

However, an alternative hypothesis suggests that plant demand to build and maintain photosynthetic enzymes drives the leaf response to CO_2

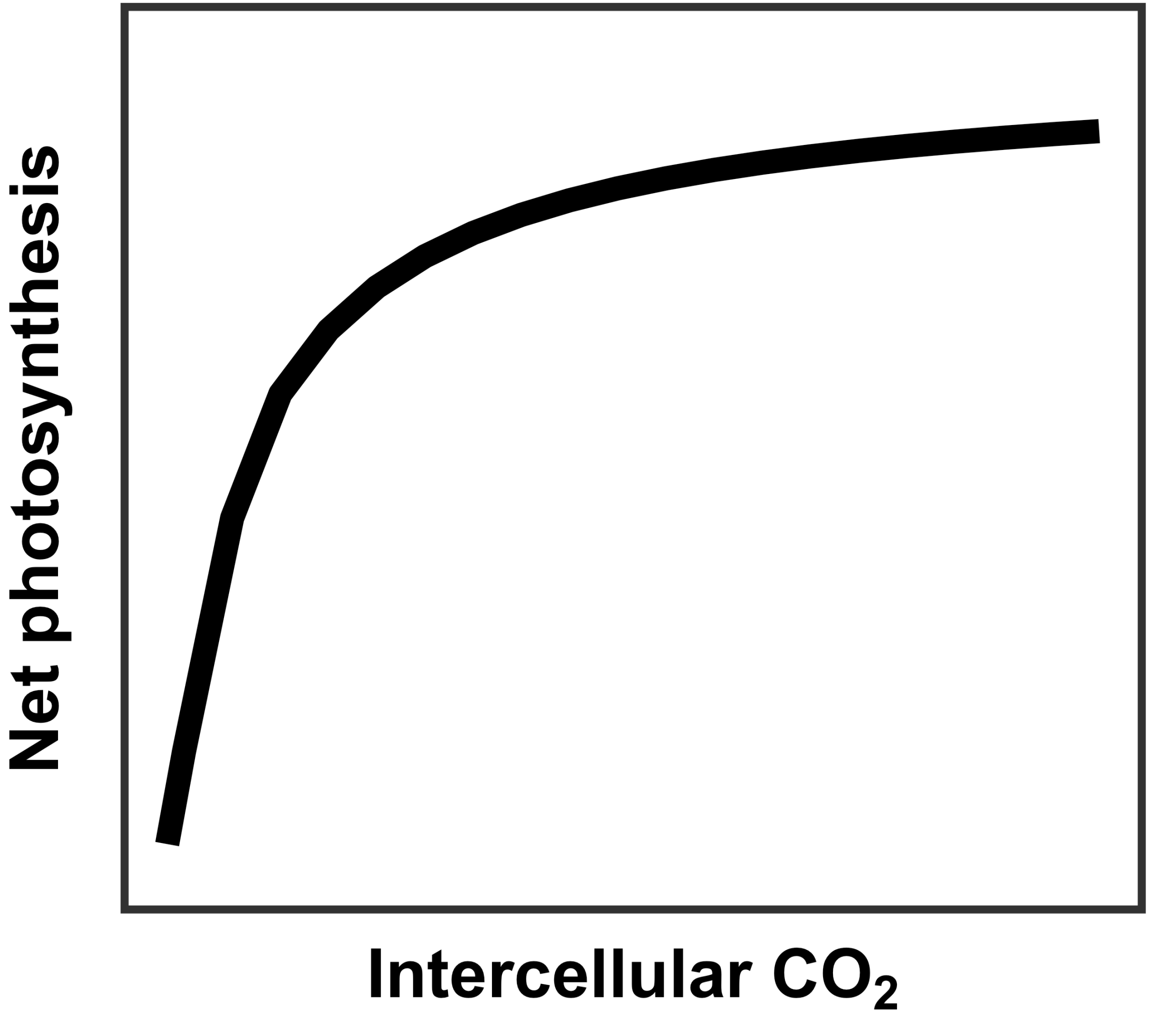


Figure adapted from Moore et al. (1999) *PC&E*

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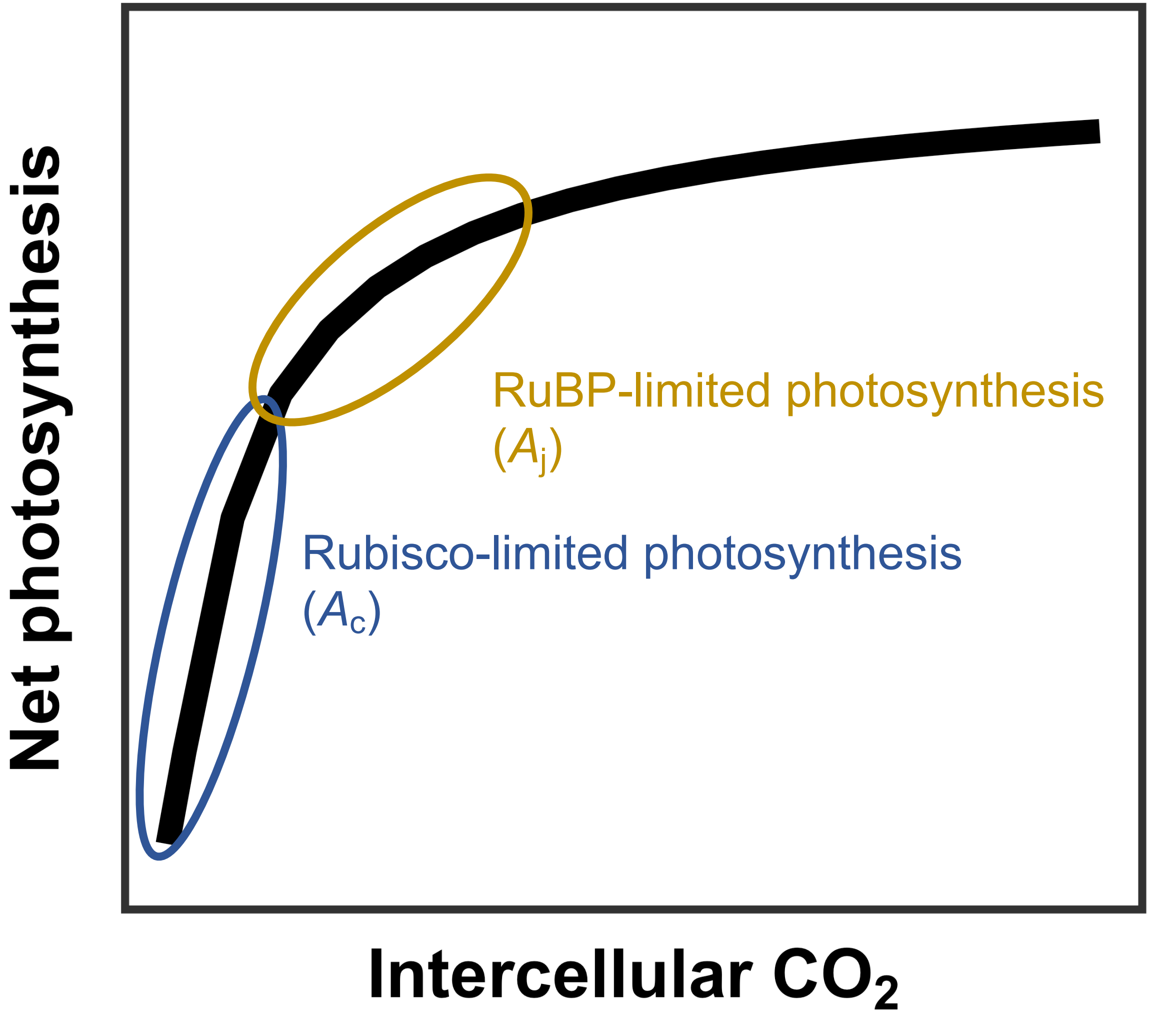

Figure adapted from Moore et al. (1999) *PC&E*

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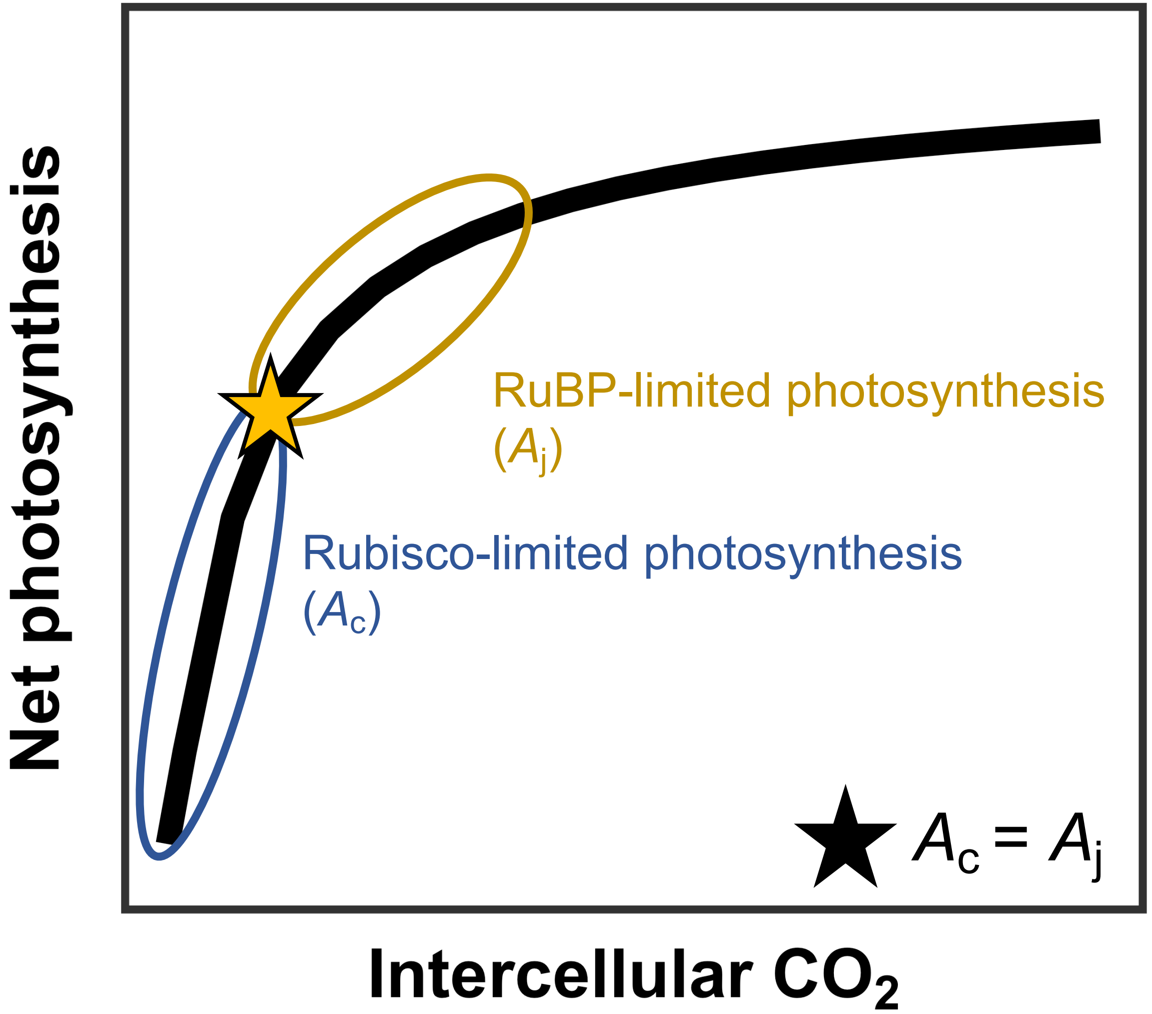

Figure adapted from Moore et al. (1999) *PC&E*

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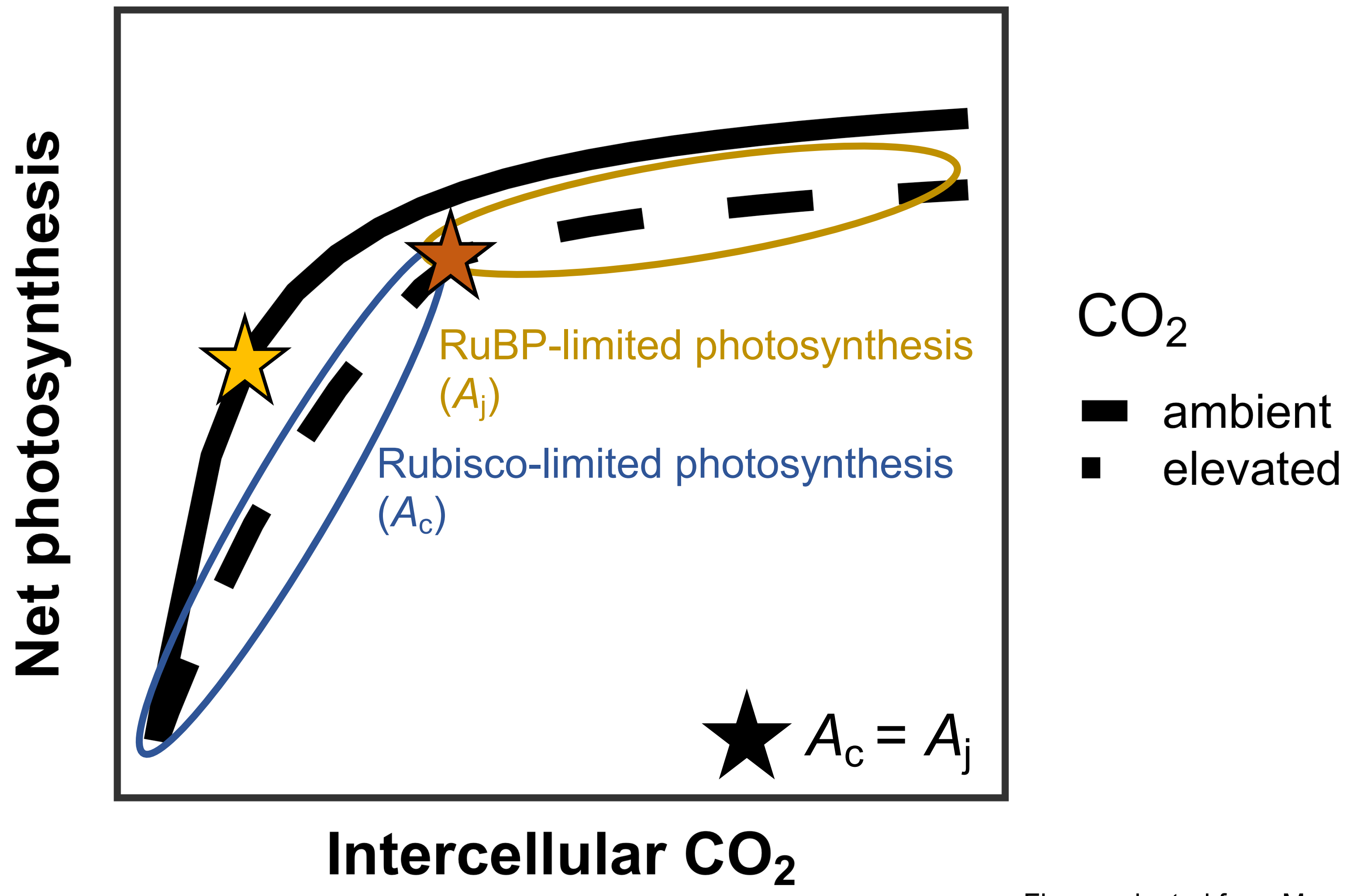
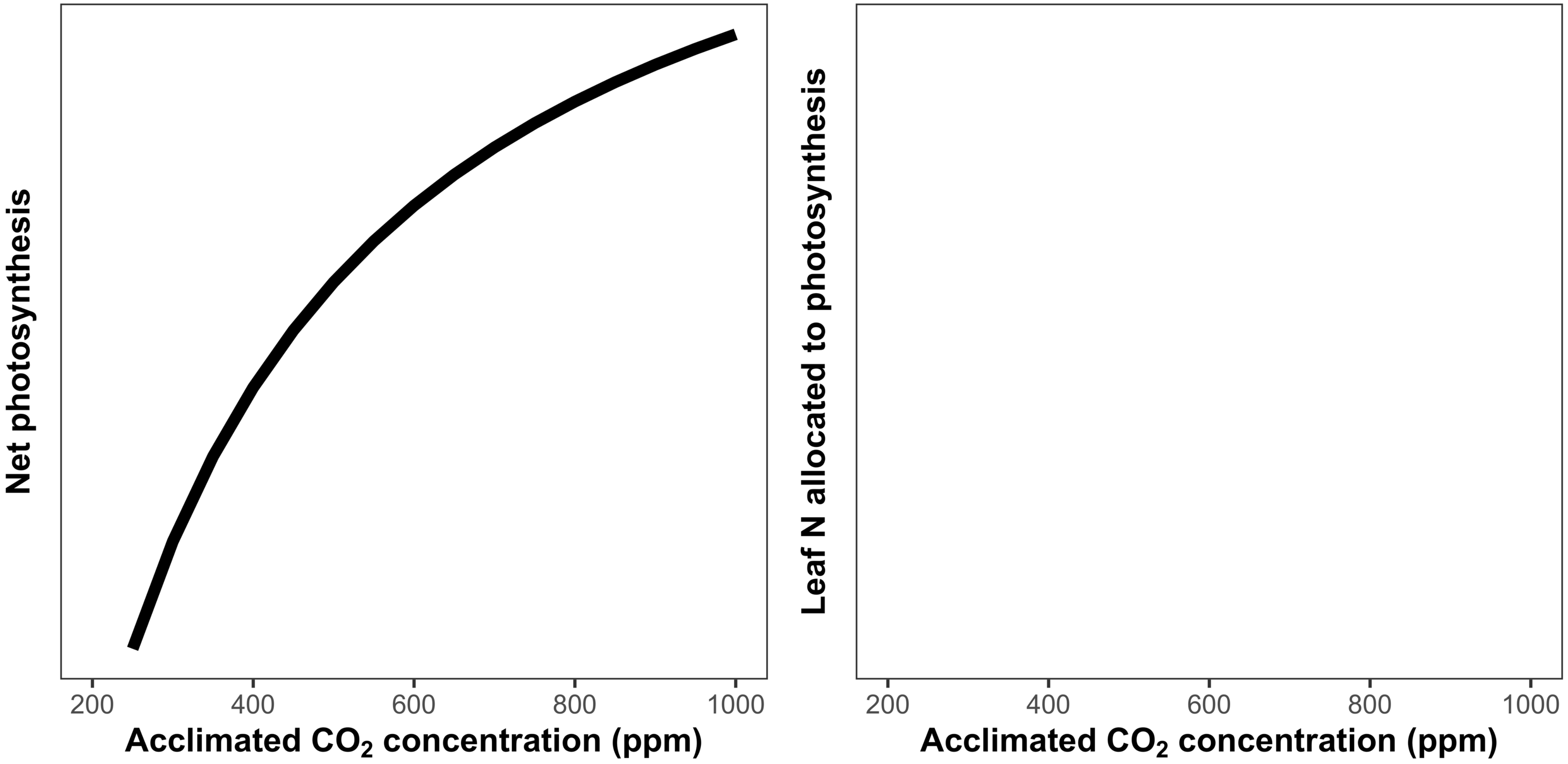


Figure adapted from Moore et al. (1999) *PC&E*

Optimal resource investment to photosynthetic enzymes increases leaf photosynthesis at lower nutrient use



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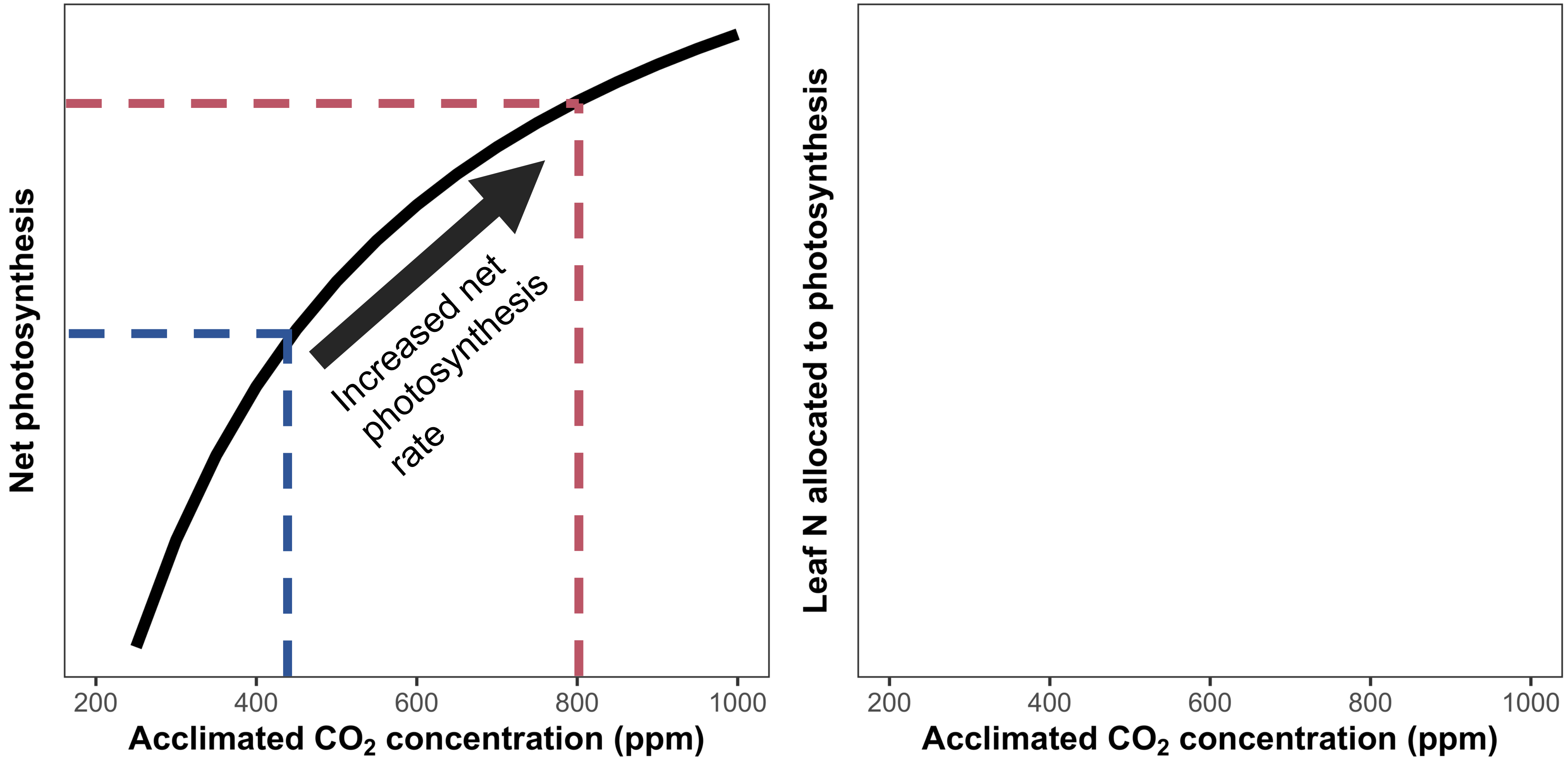

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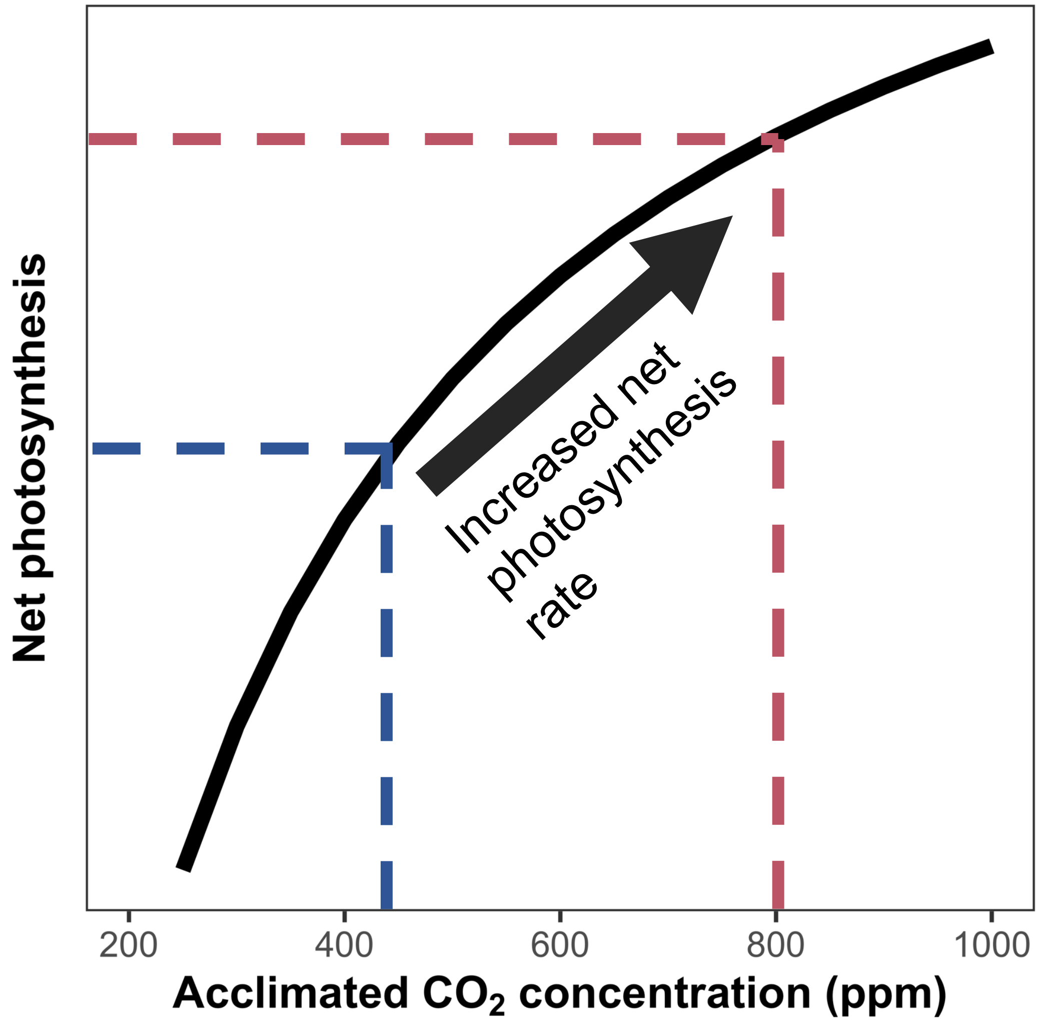
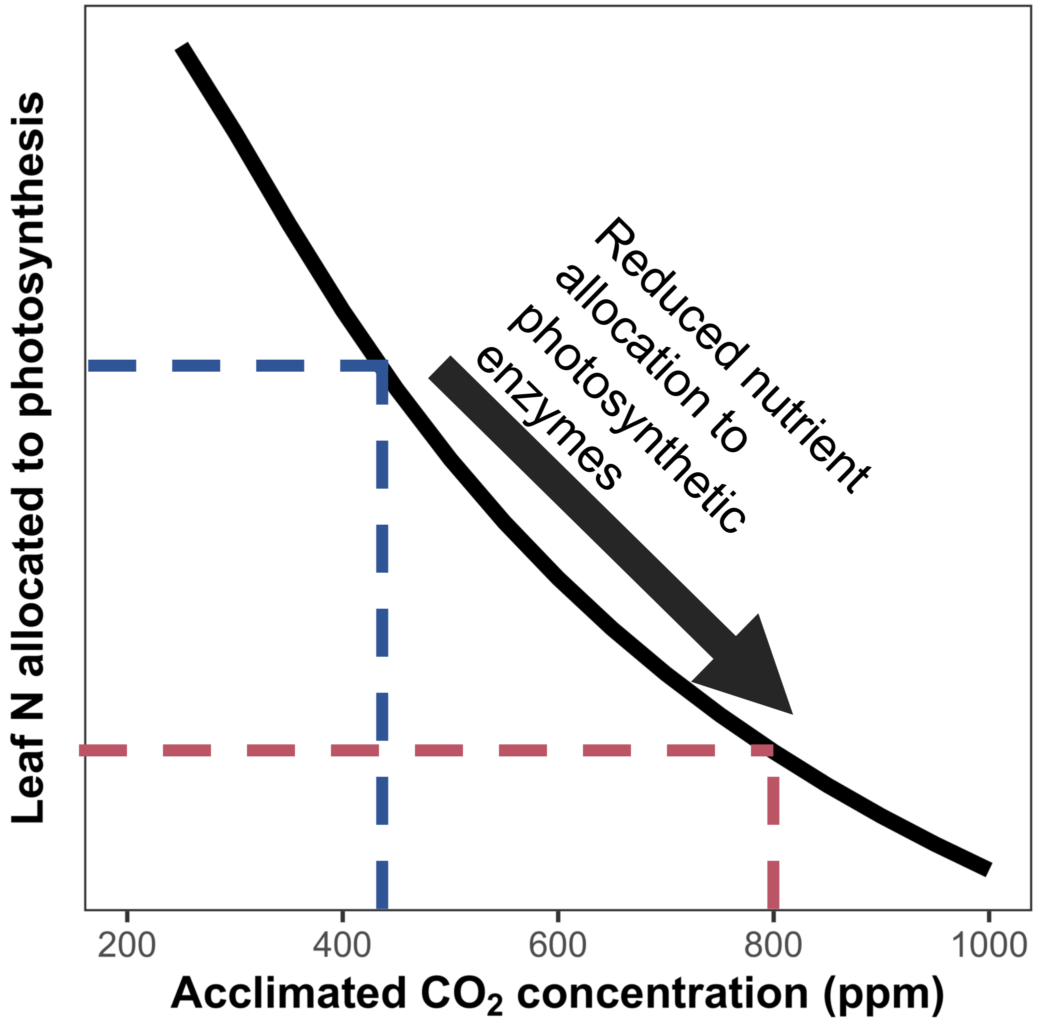
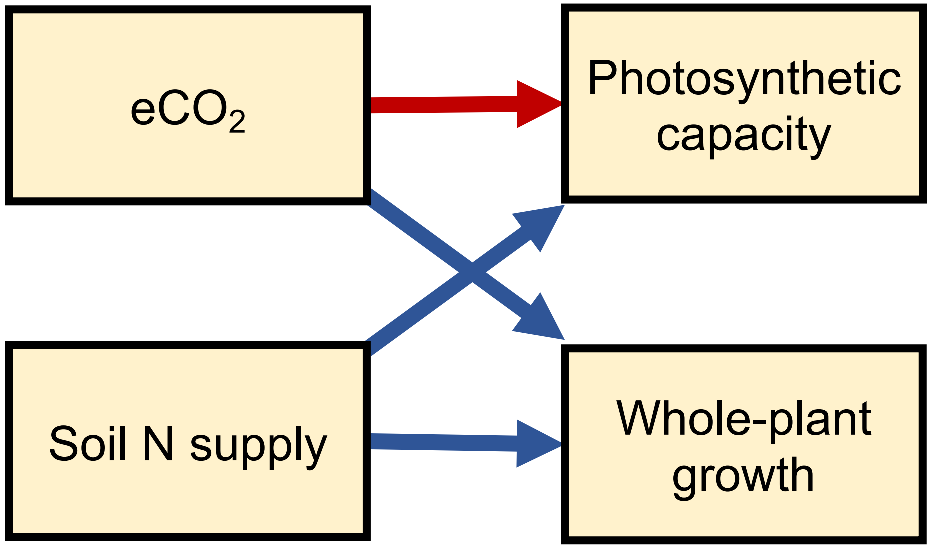




Study Question

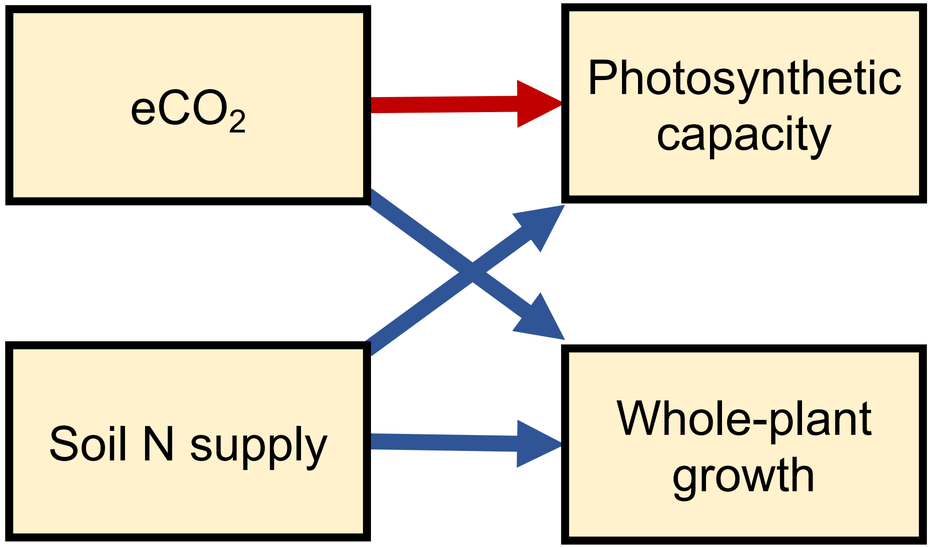
How does soil nitrogen availability modify leaf and whole plant responses to CO_2?

Nitrogen limitation hypothesis

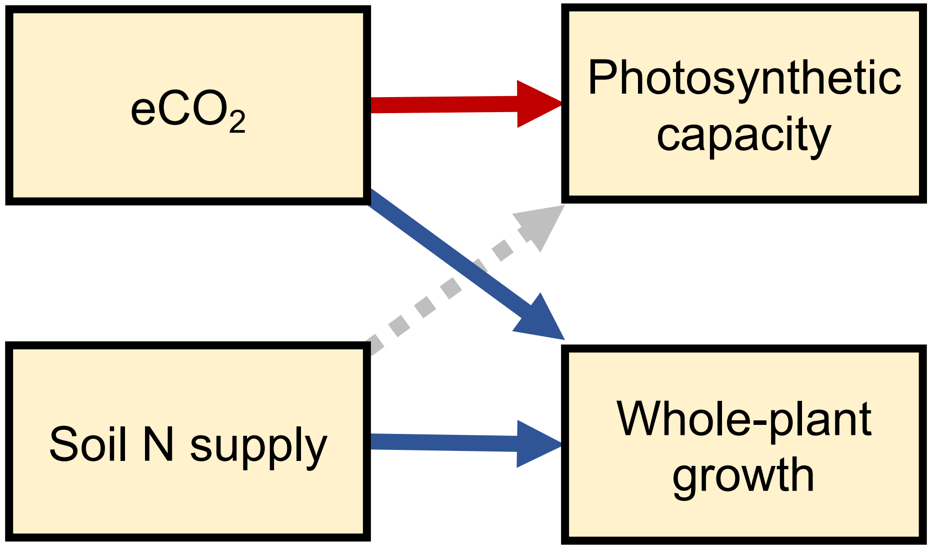


= net positive effect
= net negative effect
= null effect

Nitrogen limitation hypothesis



Optimality hypothesis



= net positive effect
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Experiment setup

Acquisition strategy

+ BNF

- BNF

CO_2 treatments

ambient (420 ppm)

elevated (1000 ppm)

Soil N treatments

0 ppm N

35 ppm N

70 ppm N

105 ppm N

140 ppm N

210 ppm N

280 ppm N

350 ppm N

630 ppm N

Perkowski et al. (in prep)

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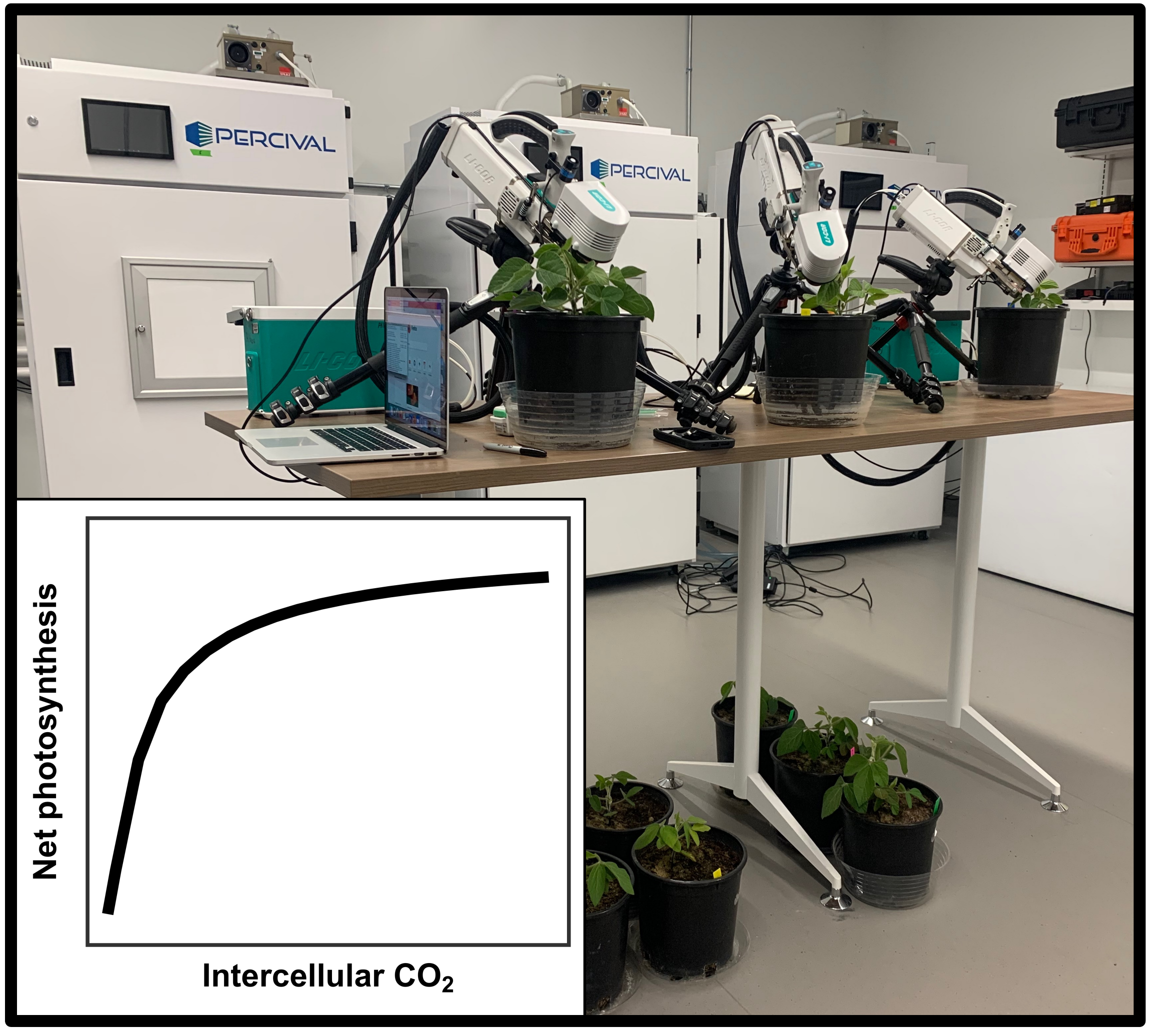
Measurements

1. Leaf biochemistry (V_{cmax25}, J_{max25}, J_{max25}:V_{cmax25})



Perkowski et al. (in prep)

Leaf trait

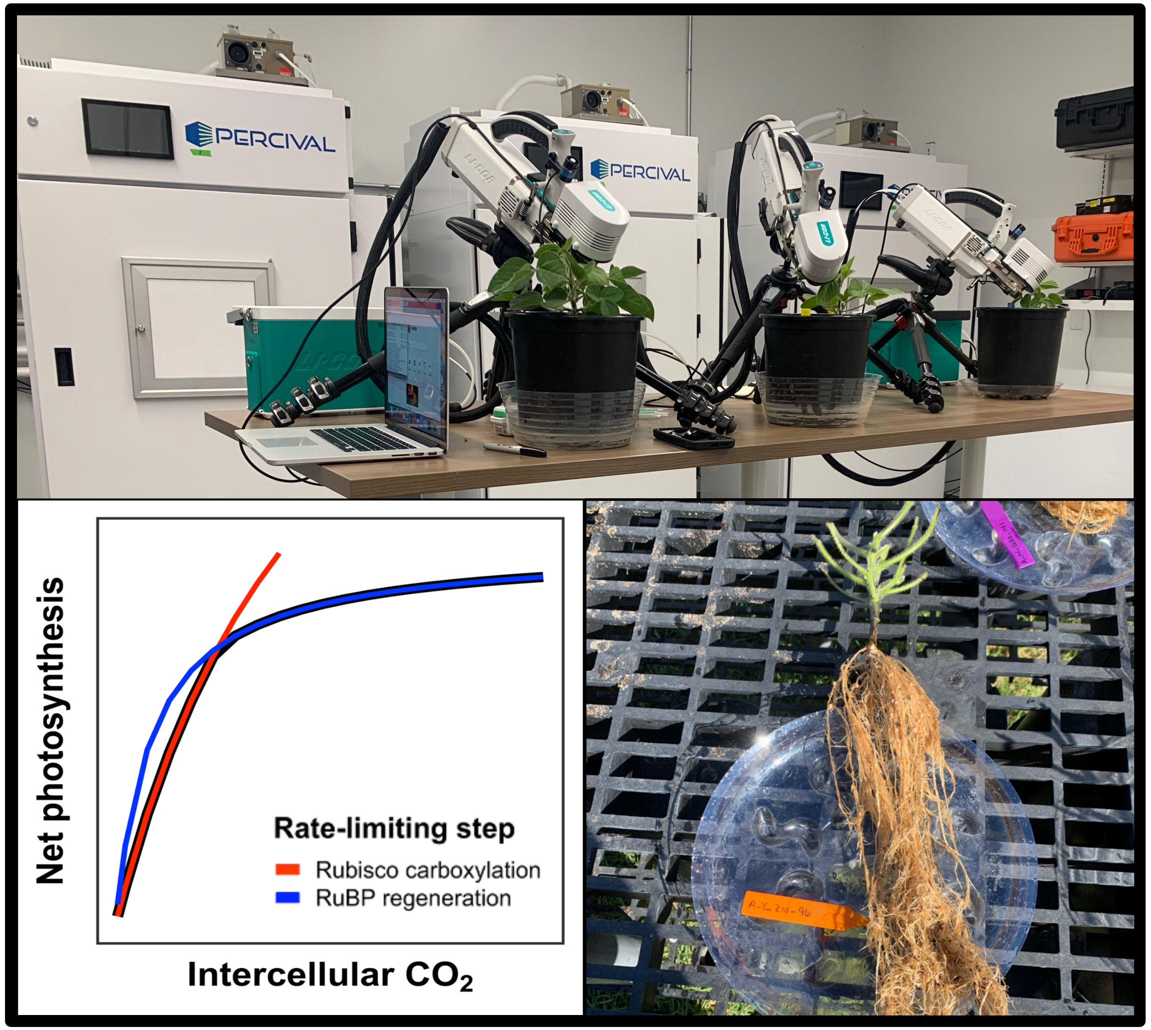
Whole plant trait

Measurements

1. Leaf biochemistry (V_{cmax25}, J_{max25}, J_{max25}:V_{cmax25})

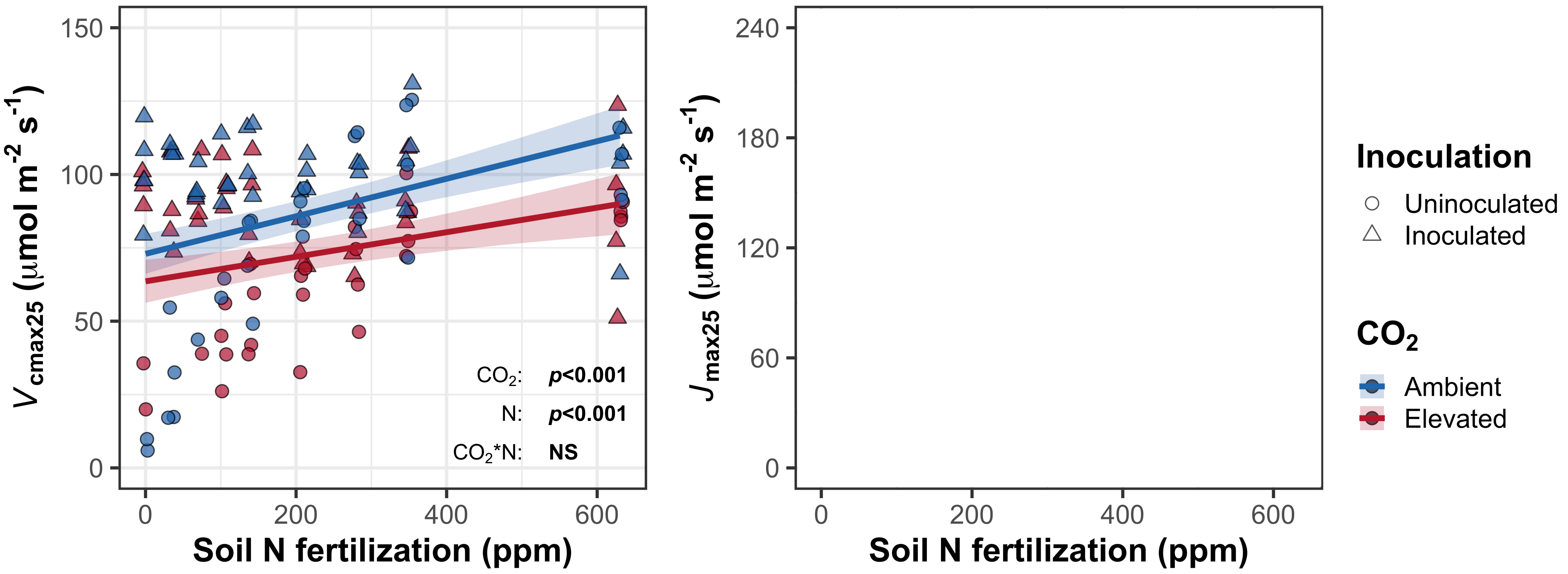
2. Total leaf area, total biomass

3. Carbon cost to acquire nitrogen



Perkowski et al. (in prep)

Elevated CO_2 **decreased** photosynthetic capacity **independent** of fertilization



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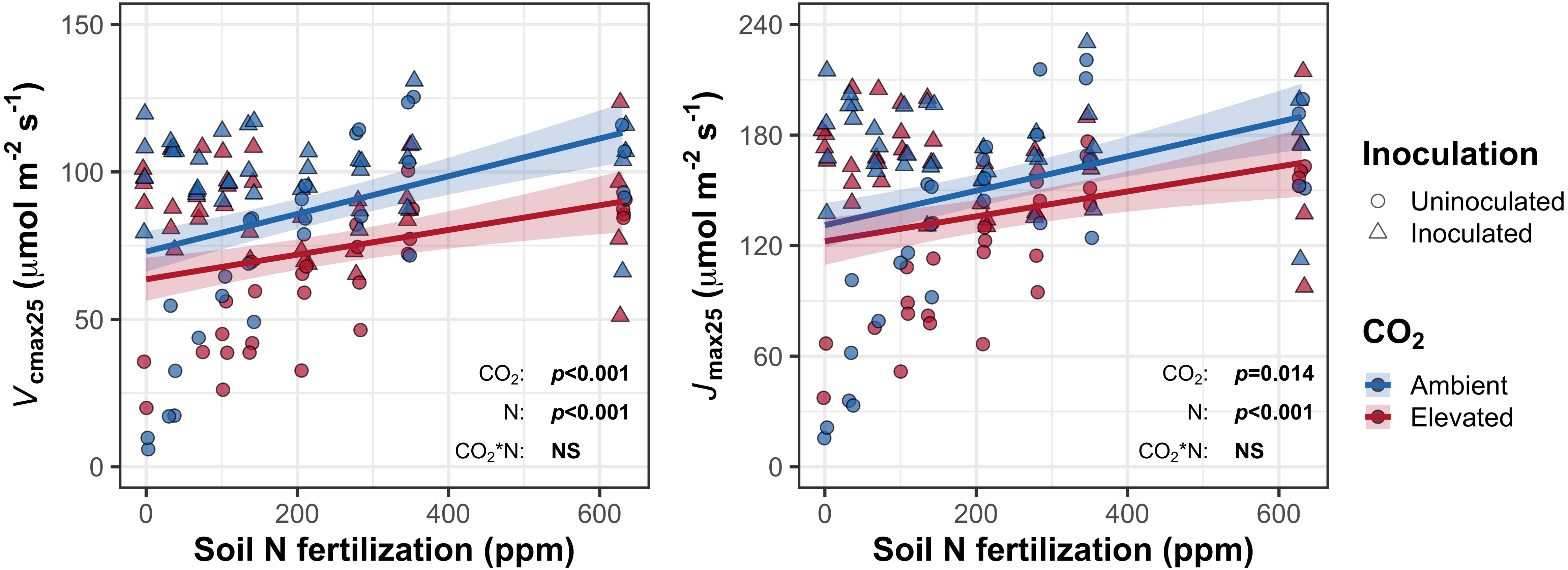
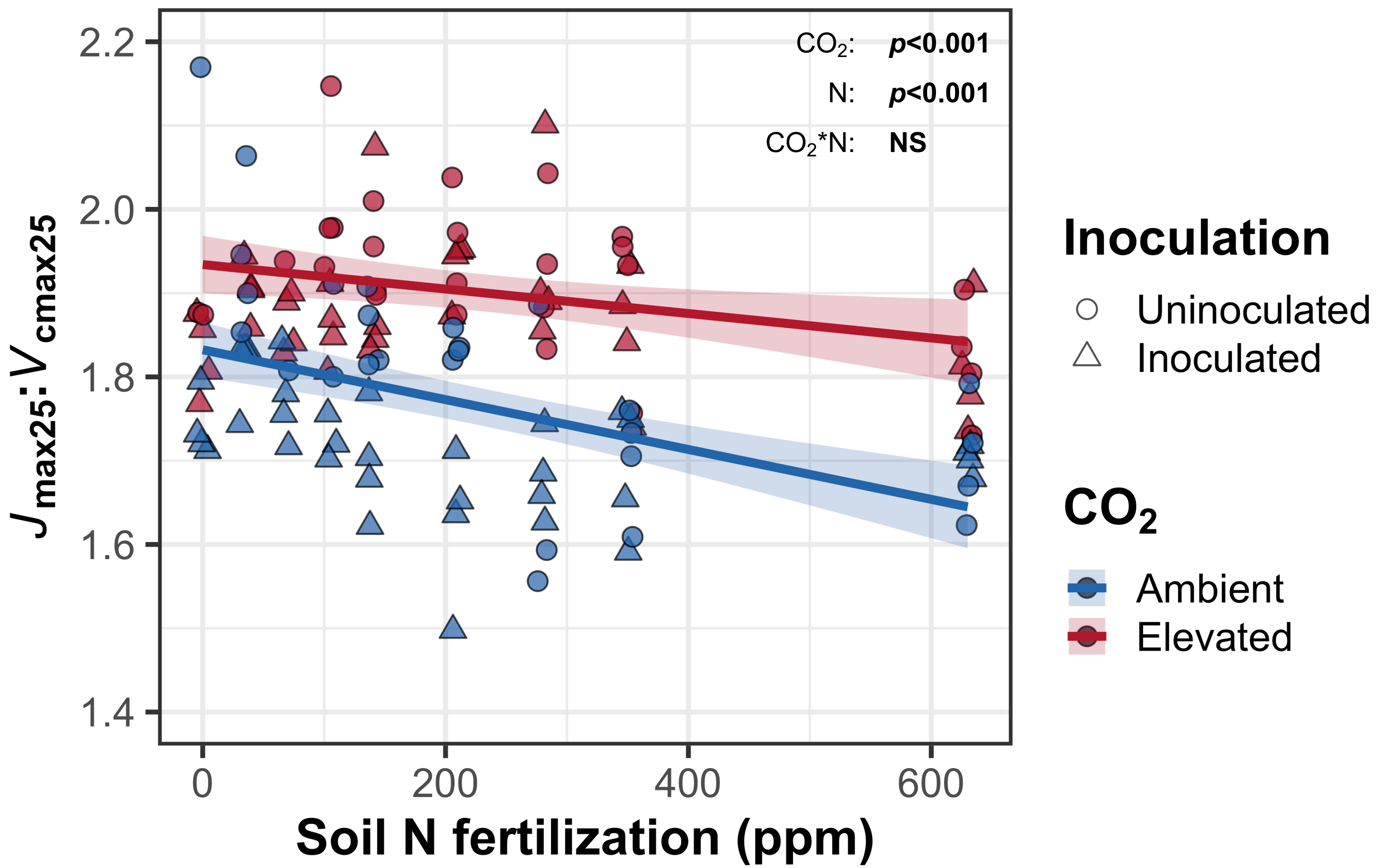
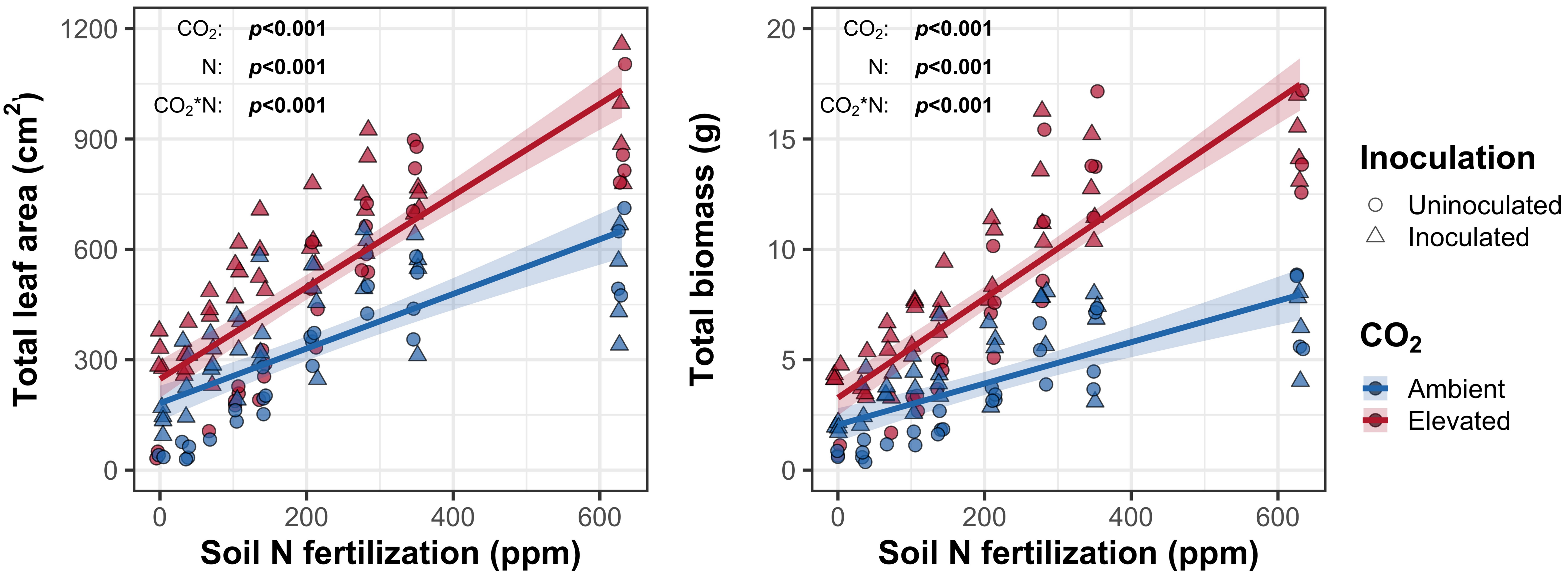


Elevated CO_2 **decreased** V_{cmax25} **more strongly** than J_{max25}, again **independent** of fertilization

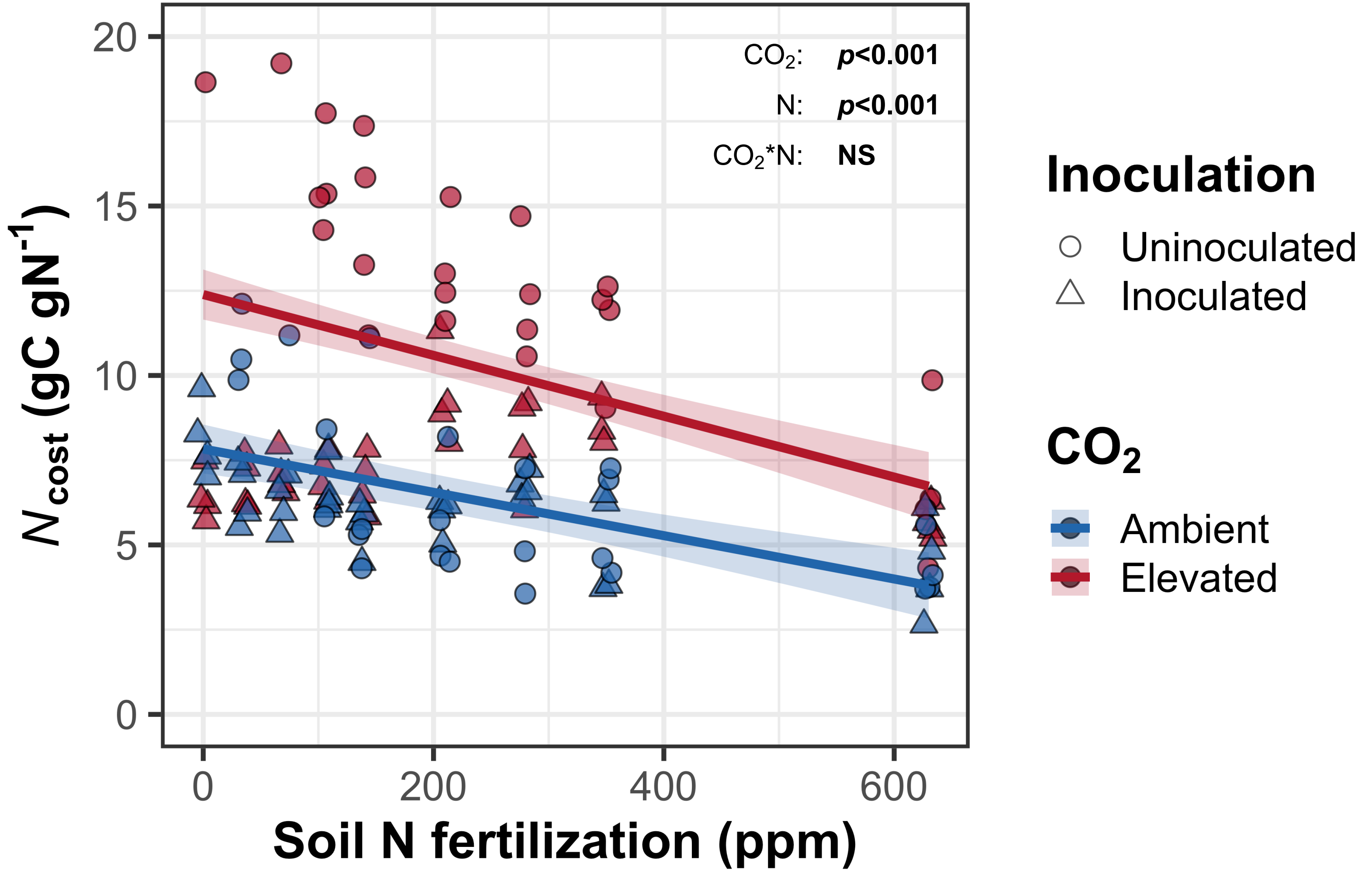


Increasing fertilization **increased** the **positive** effect of elevated CO_2 on whole-plant growth



Perkowski et al. (in prep)

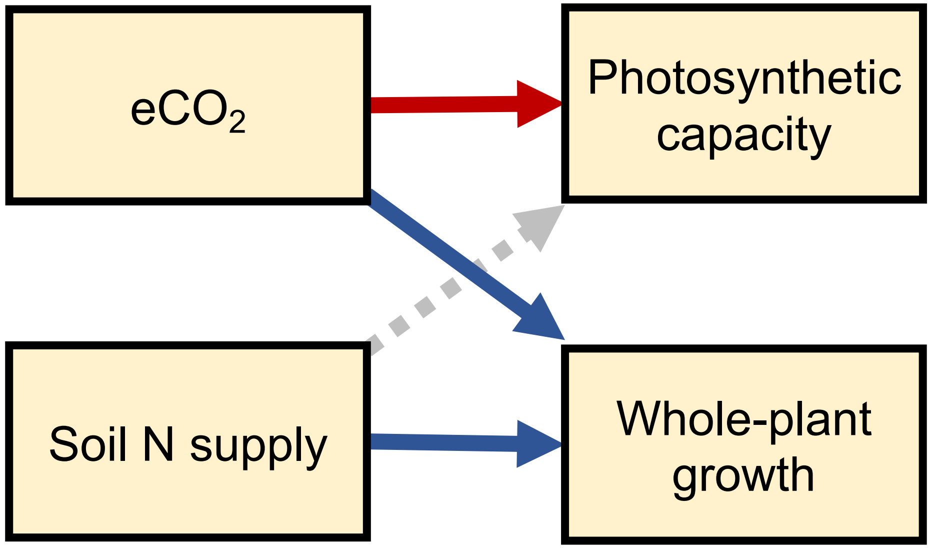
Increasing fertilization **decreased** costs of nitrogen acquisition **similarly** across the two CO_2 treatments



Perkowski et al. (in prep)

Conclusions

- Nitrogen demand and supply control plant responses to eCO_2 at different scales
  - N supply → whole-plant response to eCO_2
  - N demand → leaf responses to eCO_2



Acknowledgements

- Mylea Lovell (TTU IGCAST Phytotron manager)
- University of California-Davis Stable Isotope Facility
- EcoHealth Lab at Texas Tech University
    - Brad Posch
    - Alissar Cheaib
    - Eve Gray
    - Monika Kelley
    - Isa Beltran
    - Snehanjana Chatterjee

LEMONTREE
Land Ecosystem Models based On New Theory, obseRvations and ExperimEnts

SCHMIDT FUTURES

BOTANICAL SOCIETY OF AMERICA

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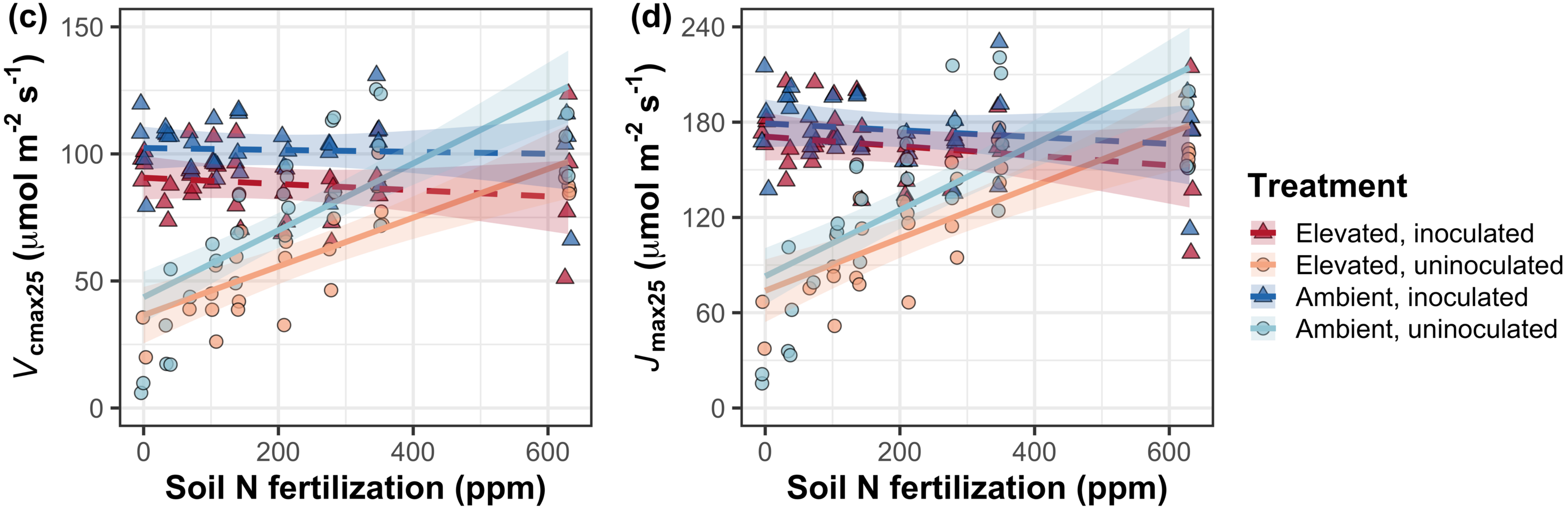
Thank you!

Extra slides

Soil N fertilization only influences leaf biochemical process rates in <u>uninoculated pots</u>



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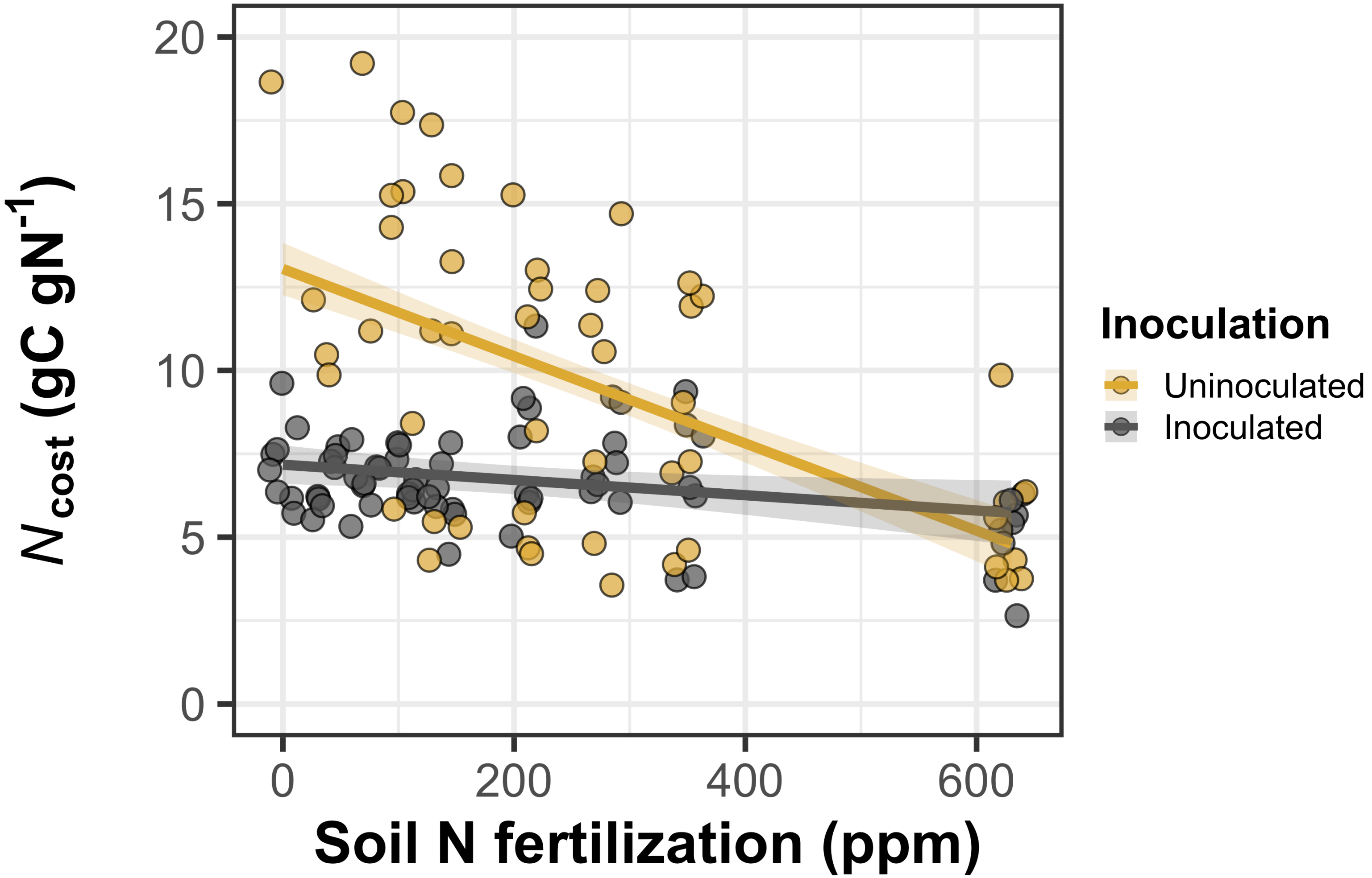
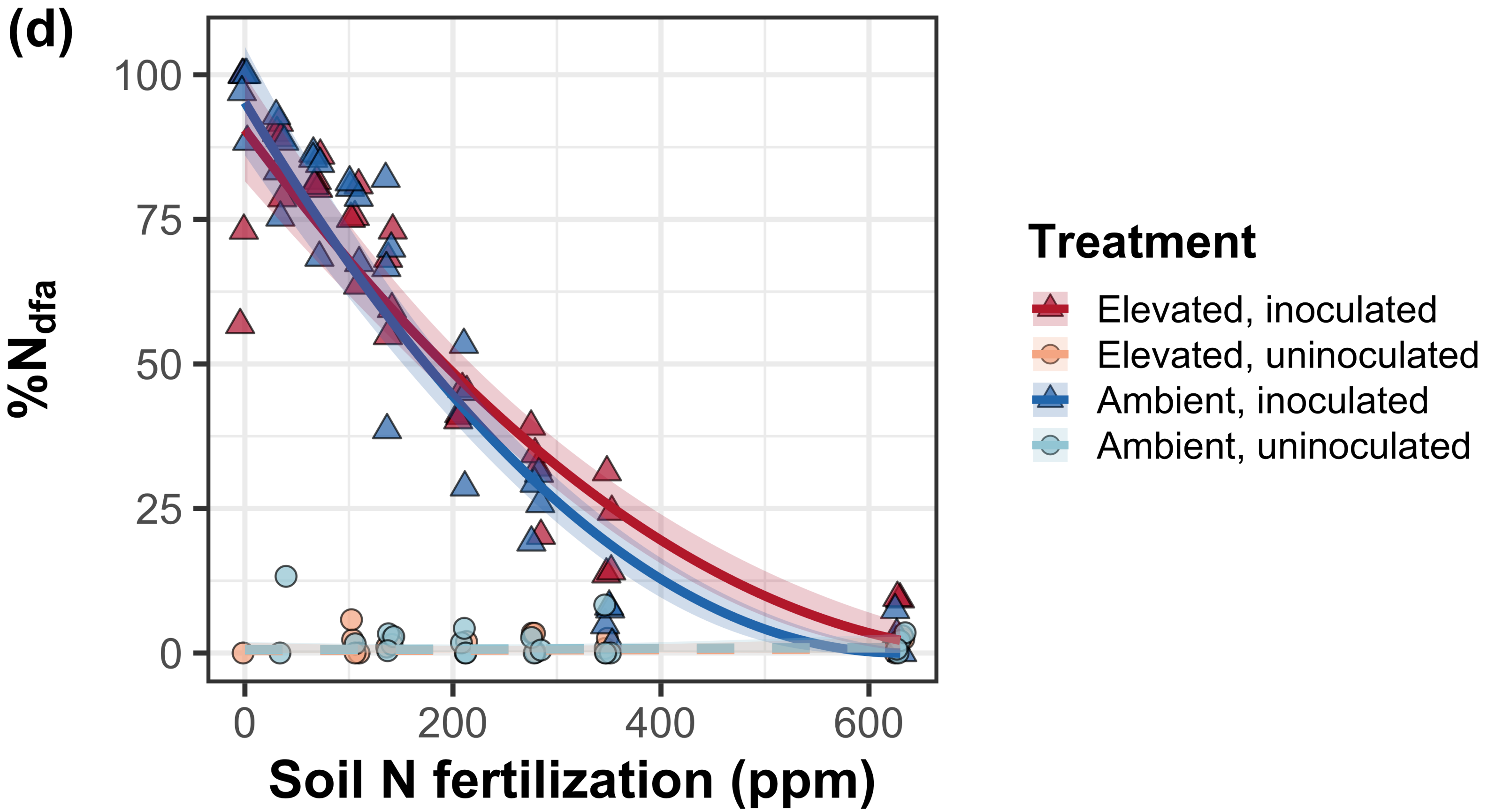
Inoculation **reduced** the **negative** effect of increasing fertilization on costs to acquire nitrogen



Perkowski et al. (in prep)

Plants **reduce** investment in nitrogen fixation with increasing fertilization



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