The Role of Biological Nitrogen Fixation in Balancing the N-Budget in ESMs and Implications for Predicting Anthropogenic Carbon Uptake

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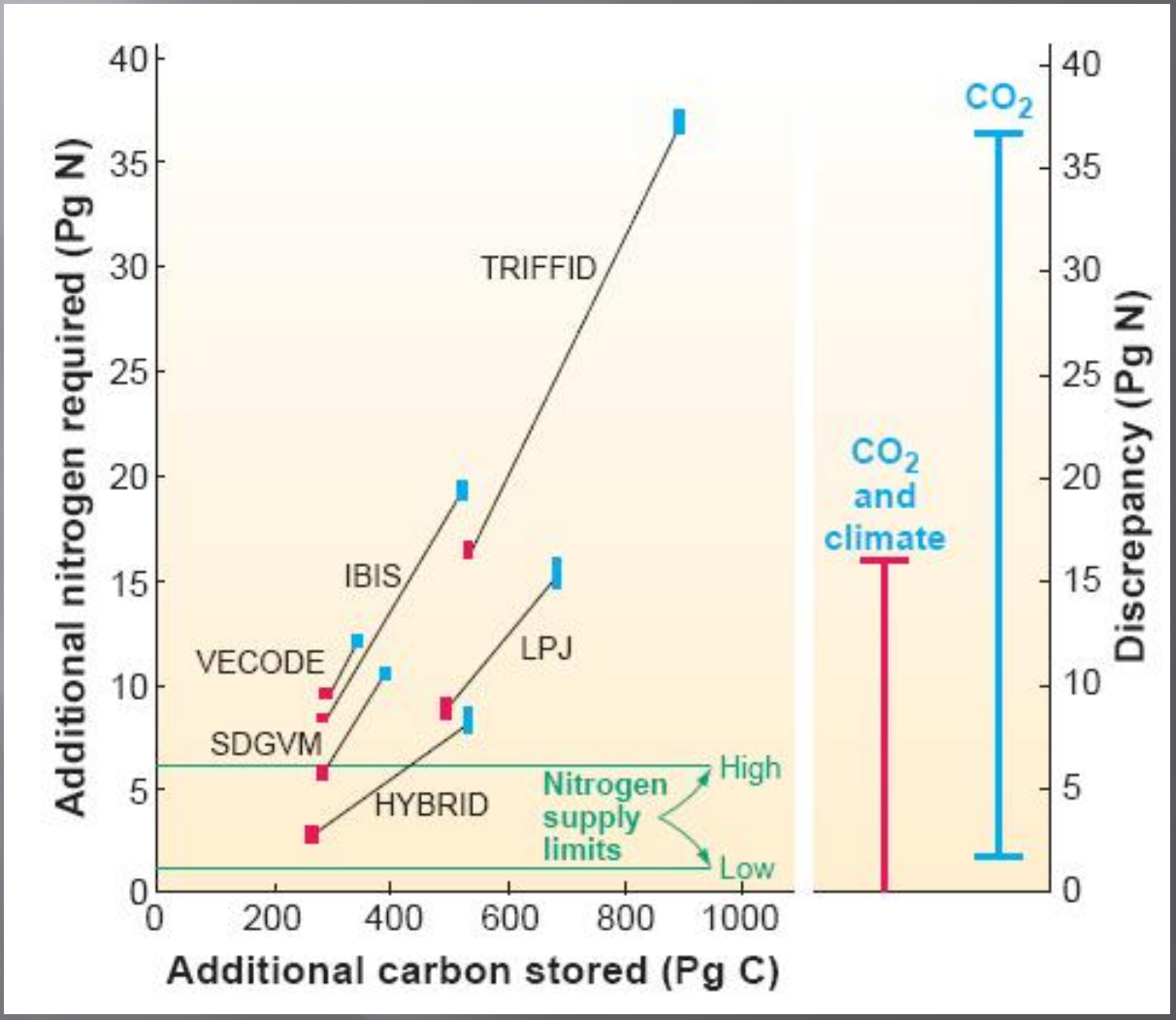
Nutrient Constraint on CO_2 fertilization



Hungate et al., 2003

Hungate et al., 2003

- Stoichiometry remains fixed in vegetation and soils
- N fixation and N deposition are primary input pathways
- 5 to 10 % of N deposited contributes to C storage
- N fixation increases between 10 and 45 % per doubling of CO_2
- Leaching losses decline between 0 and 10 % per doubling of CO_2

LM3V

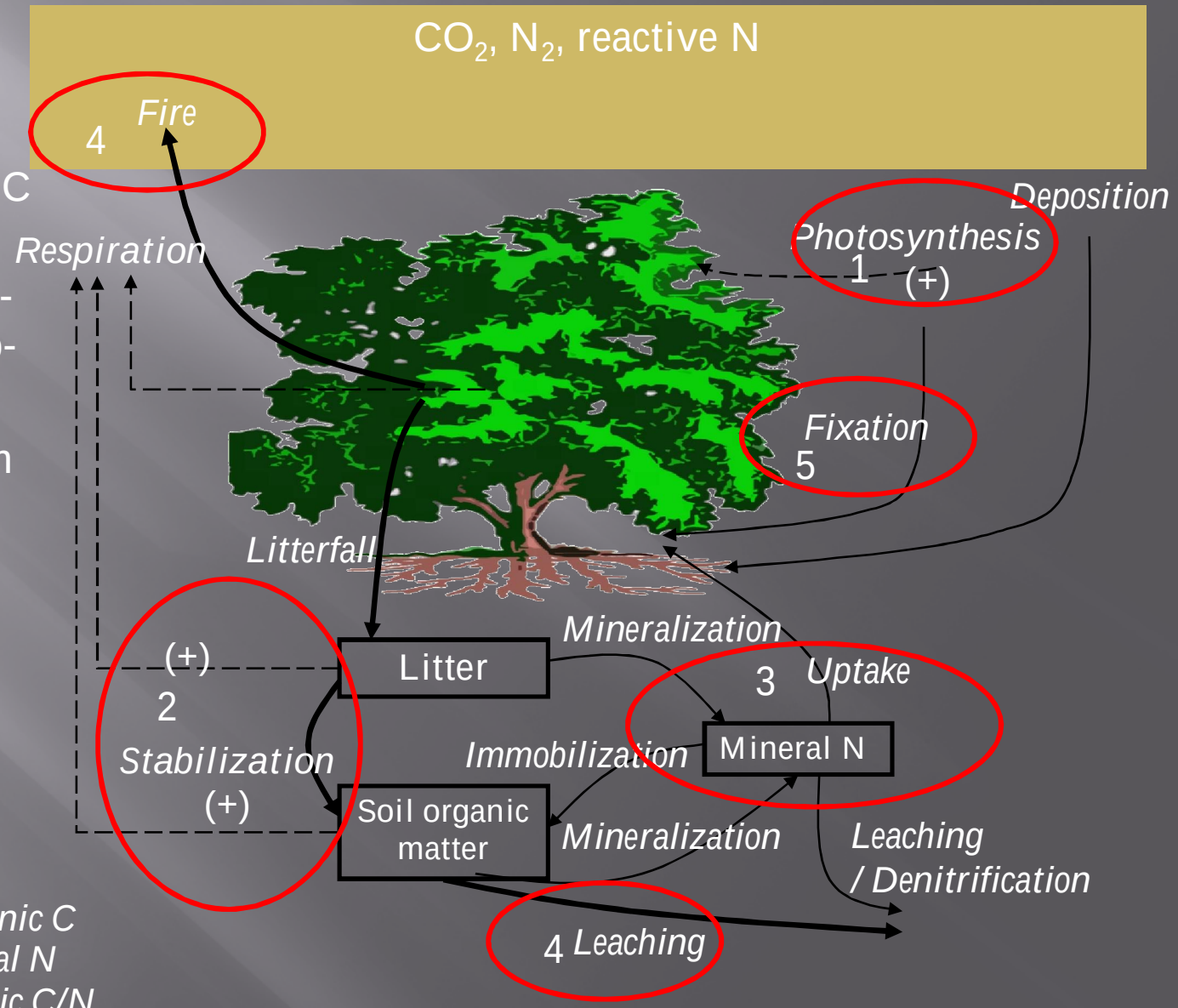
1) Plant regulation of C and N intake

2) N dependent humification and decomposition

3) Hierarchical system for N sink

4) N losses from organic pool

5) Biological N fixation: Response to ecosystem N demand

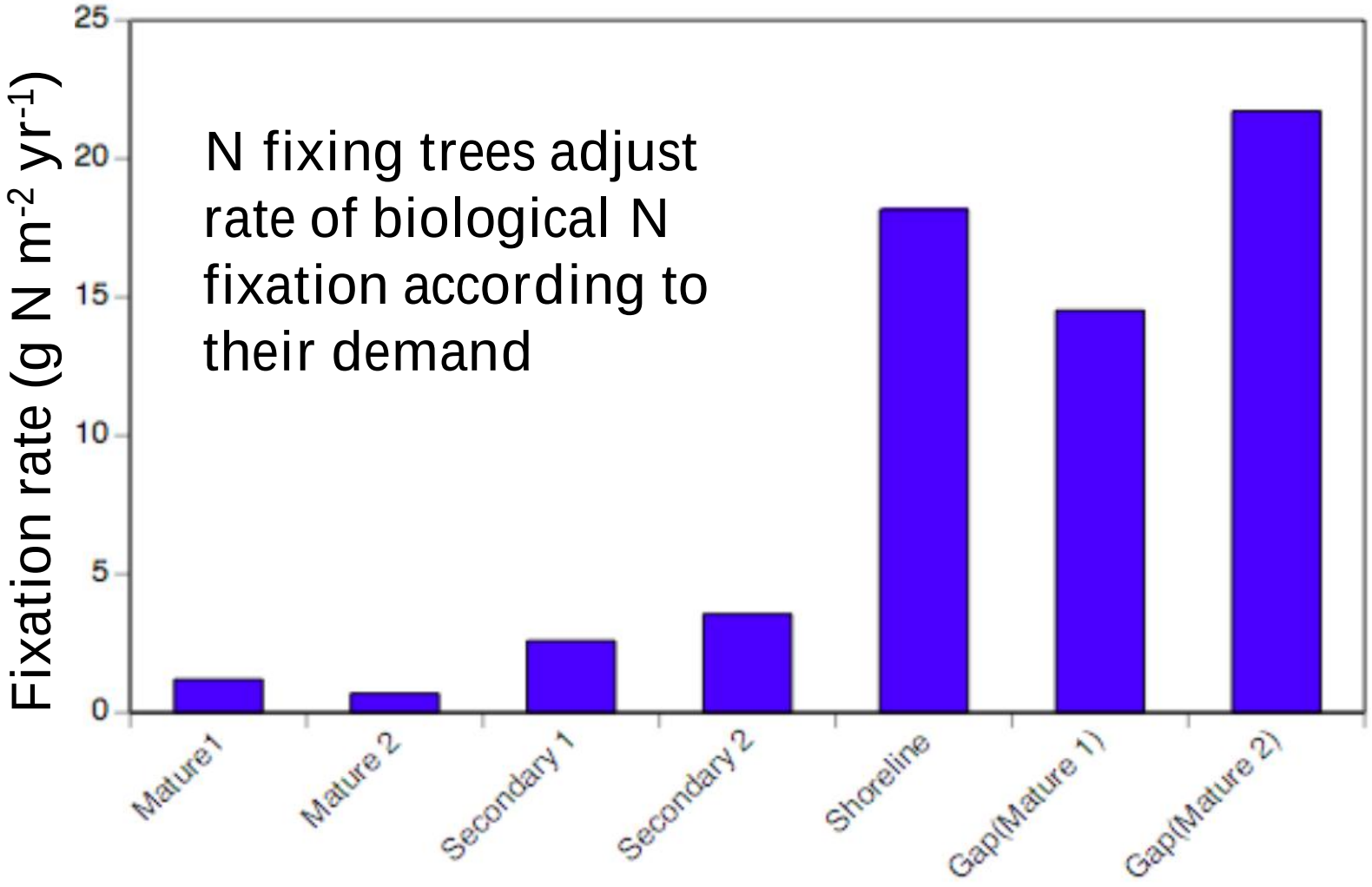


Characteristics of N fixation in LM3V

- Costly Process
- Opportune, if other N sources are exhausted
- Possibly limited by light, particularly in extra-tropics
- Dynamics of regulation likely varies, fast adjustment in tropics, slow adjustment (succession) in temperate

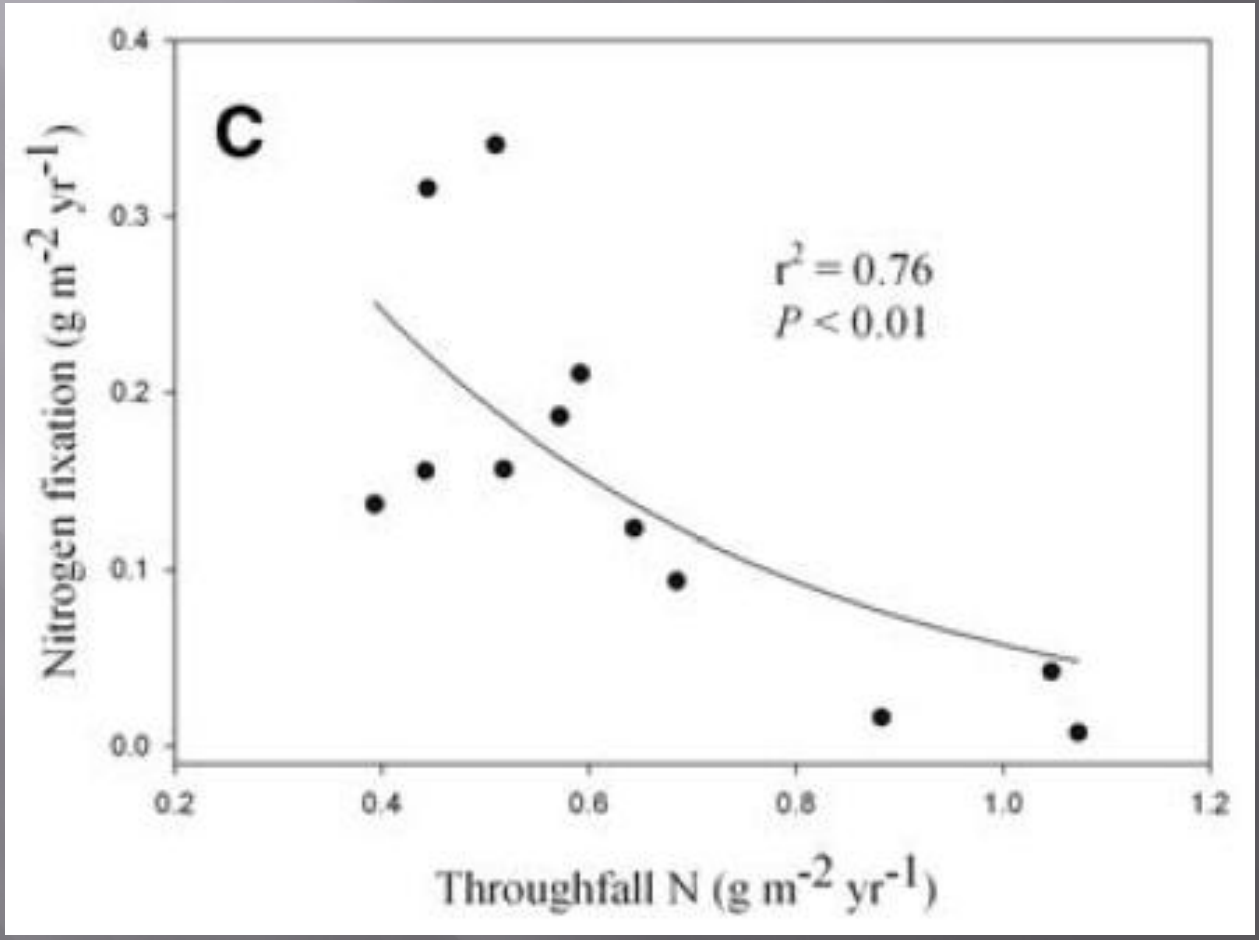
Tropical Forests: Facultative N fixation

Barron, 2007



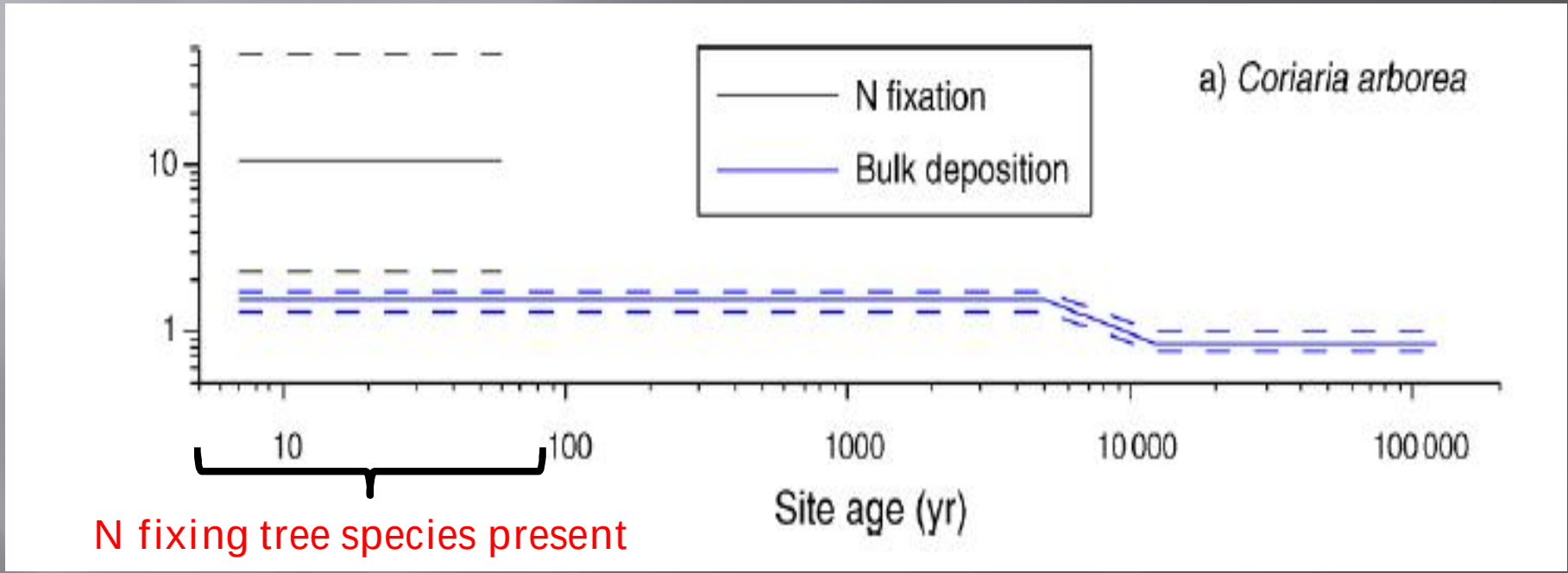
Demand-driven N fixation in boreal feather moss

DeLuca et al., 2008



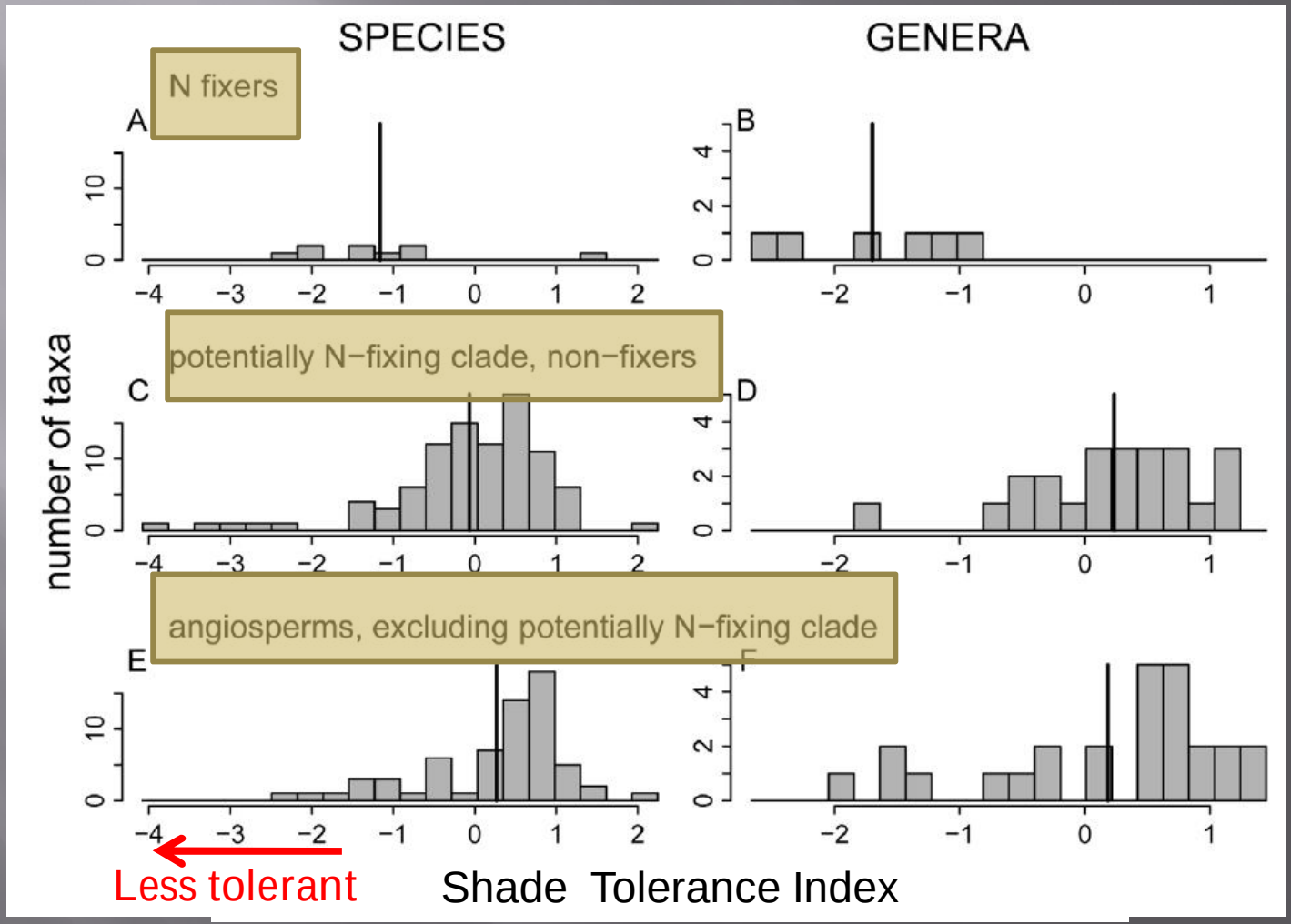
New Zealand Chronosequence of N fixation

(Menge and Hedin, 2009)

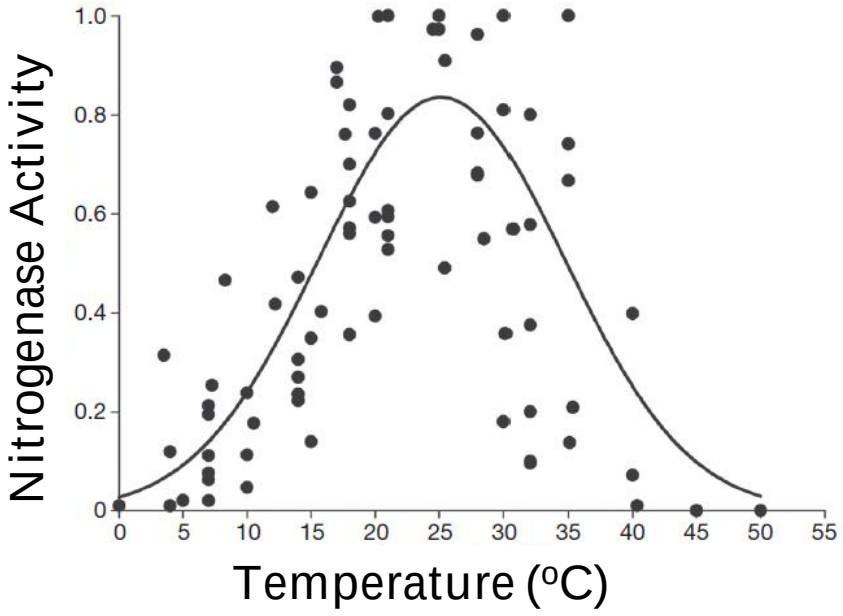


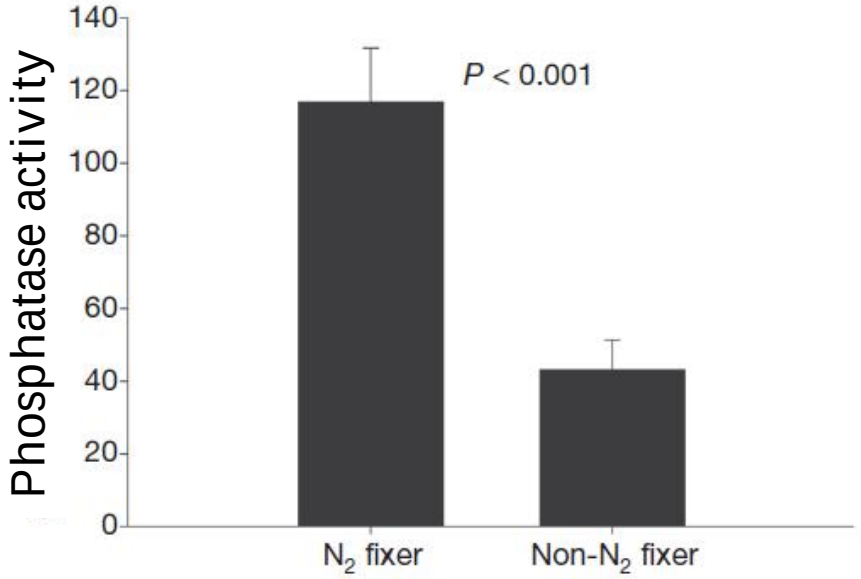
Shade intolerance of N fixing species in US Forest Inventory Data

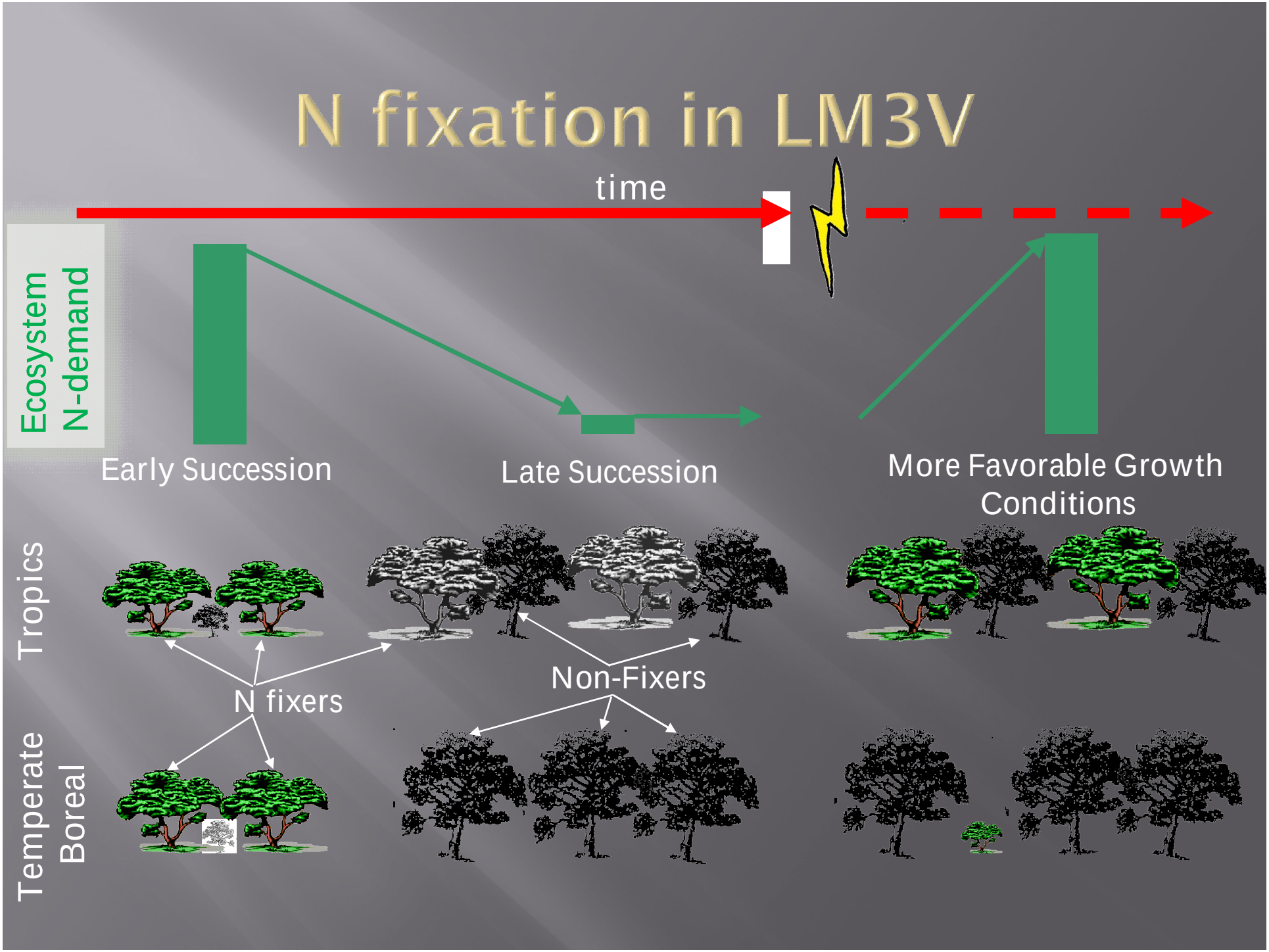
Menge et al., 2010



P acquisition purpose
T – dependence
Houlton et al., 2008





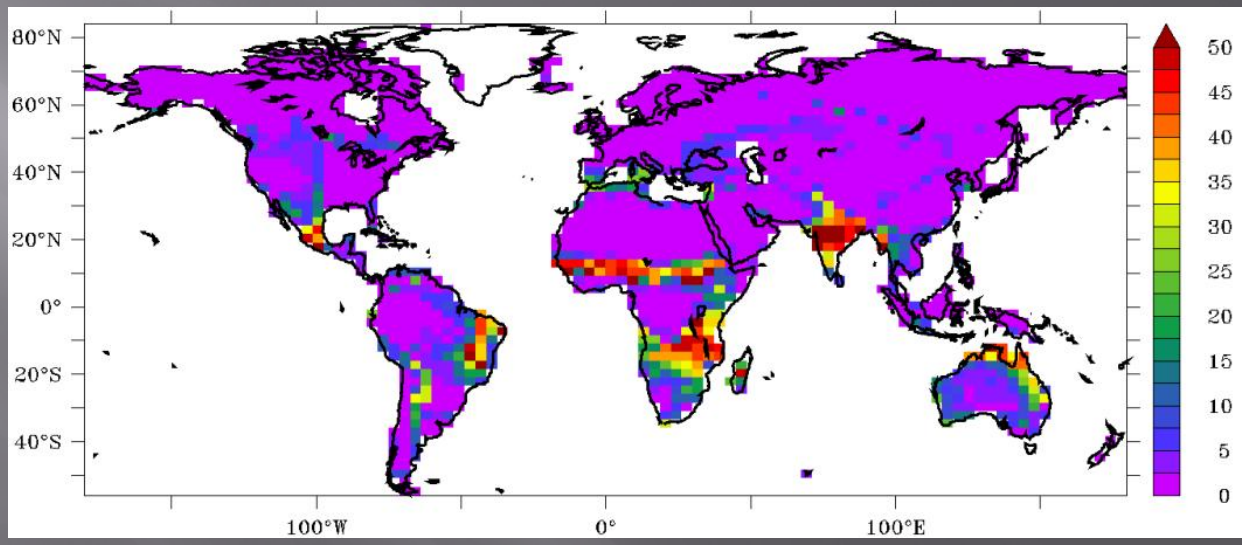

N fixation in LM3V
time
Ecosystem N-demand
Early Succession
Late Succession
More Favorable Growth Conditions
Tropics
Temperate Boreal
N fixers
Non-Fixers

N fixation to maintain biomass == steady state

kg N ha^{-1} yr^{-1}

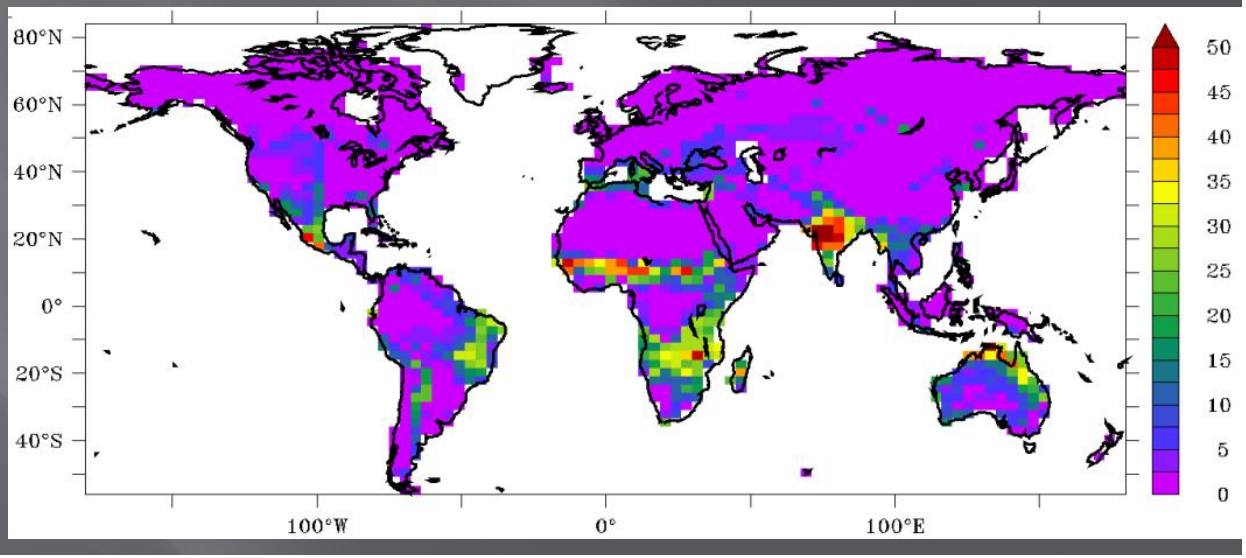
N demand of a unconstrained system

(C-only)

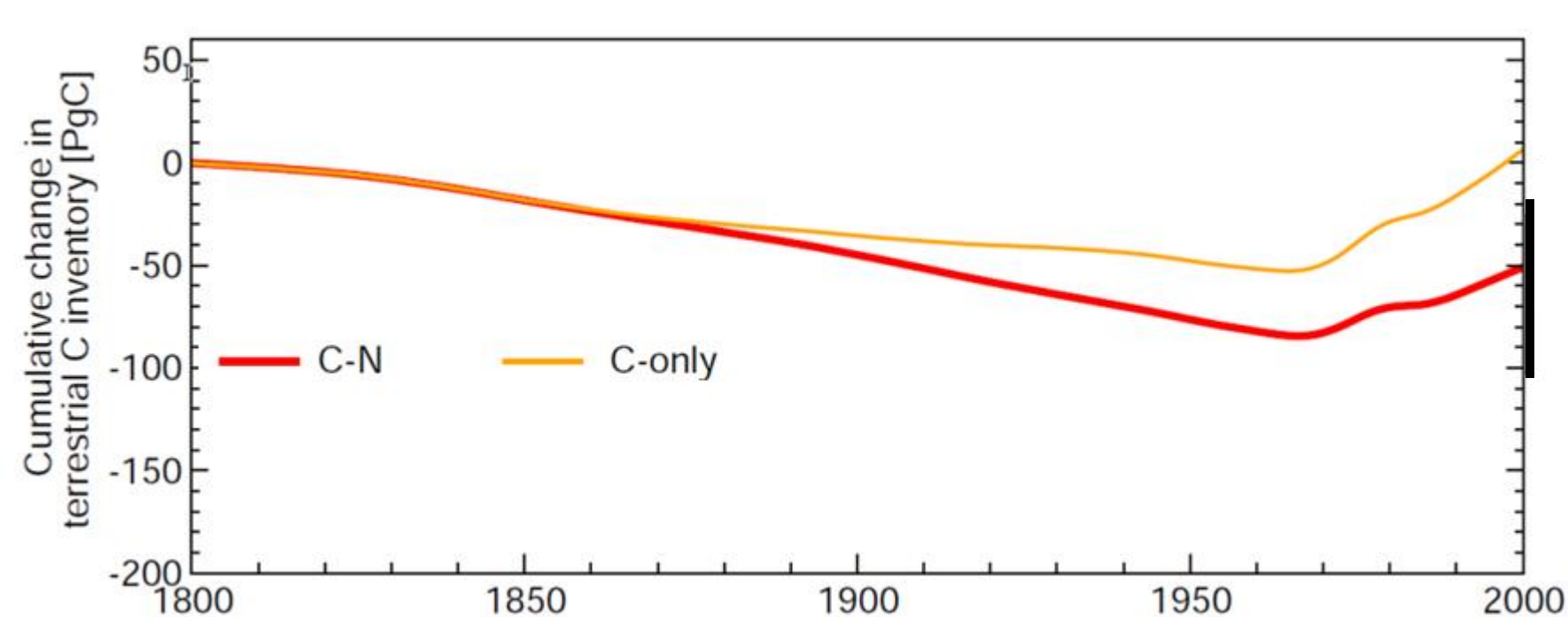


Realized N fixation

C-N

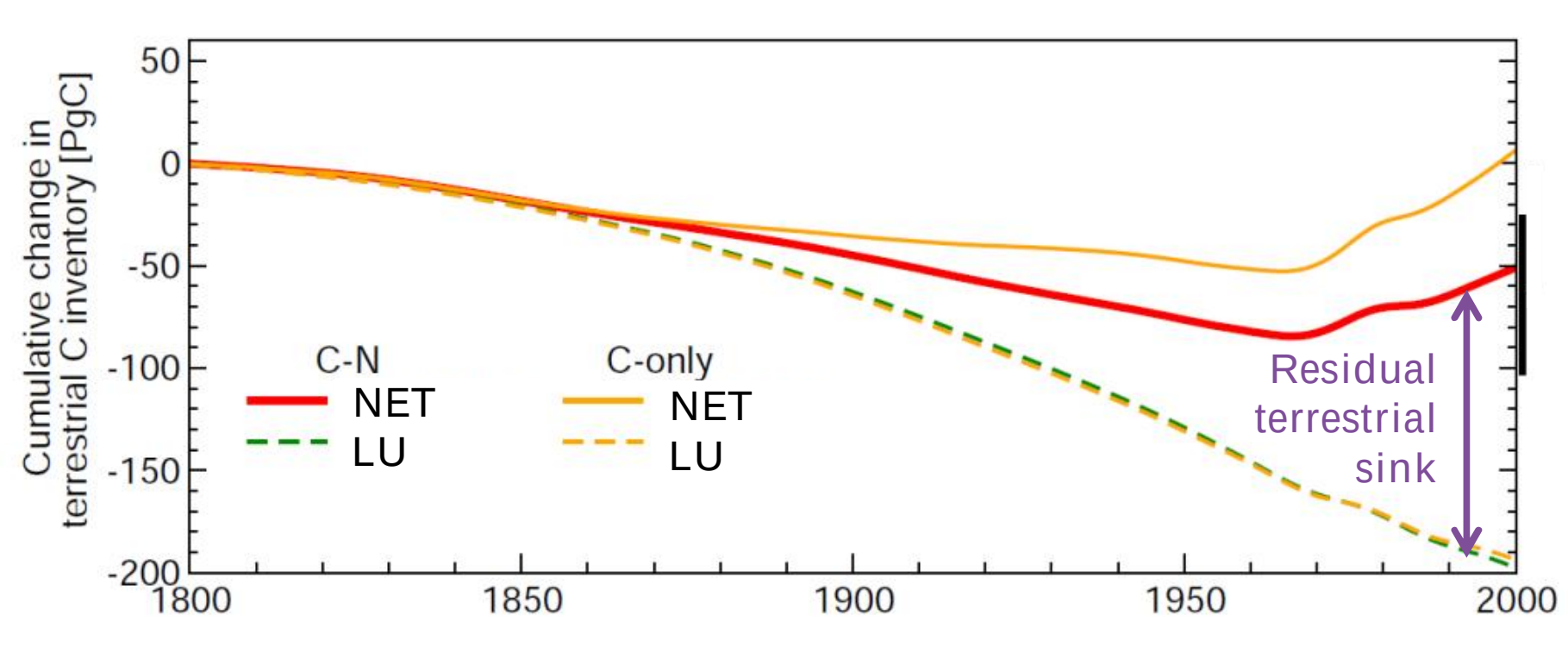


Net change in terrestrial C inventory



Net change in land carbon inventory based on ocean-atmosphere budget[a] (Sabine et al., 2004)

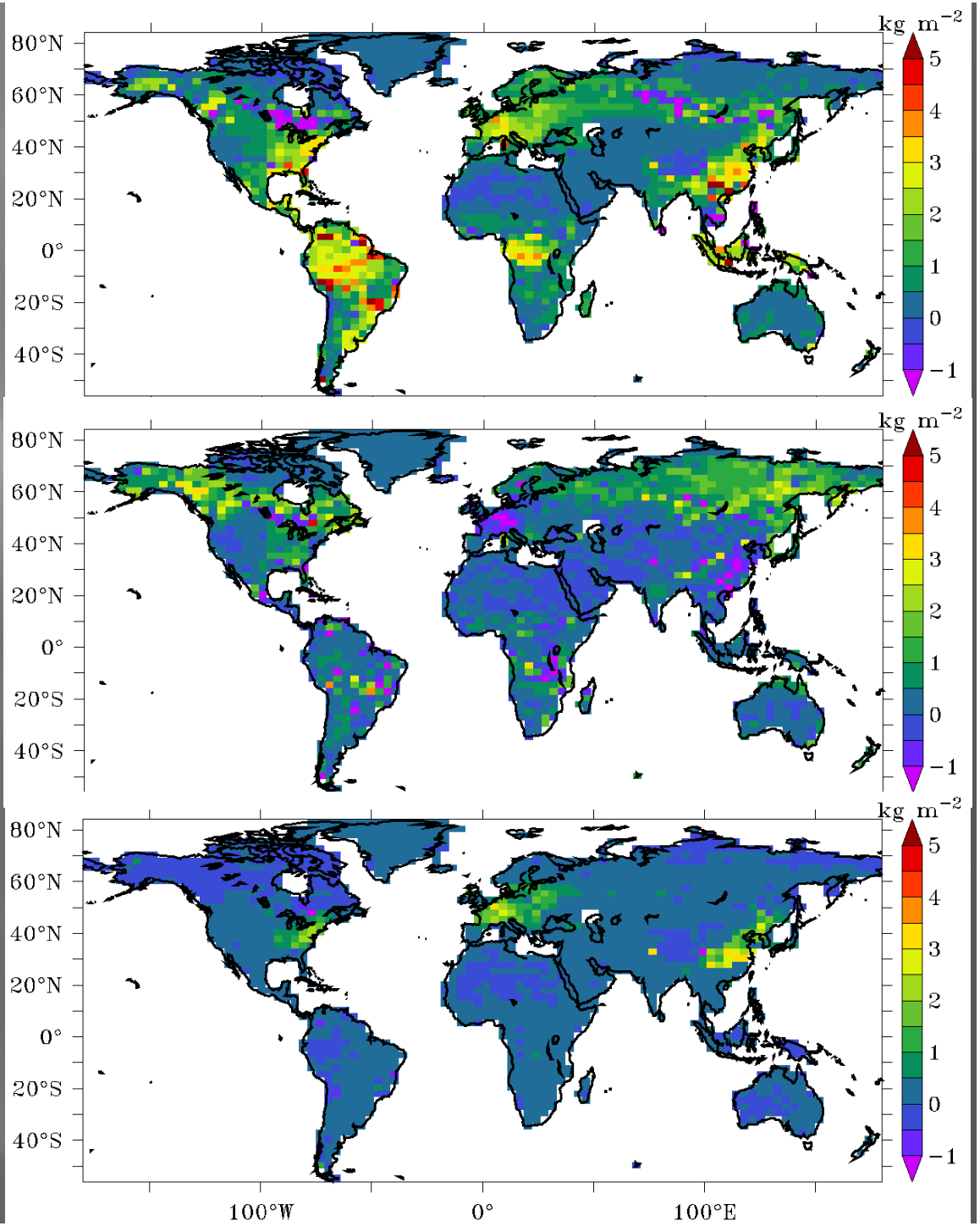
Net land CO2 exchange as calculated with LM3V



Residual terrestrial sink 1800 to 2000

Effects of N cycle on residual sink (C-only minus C-N)

Effects of anthropogenic N deposition cycle on residual sink (C-N minus C-N-Natural Deposition)

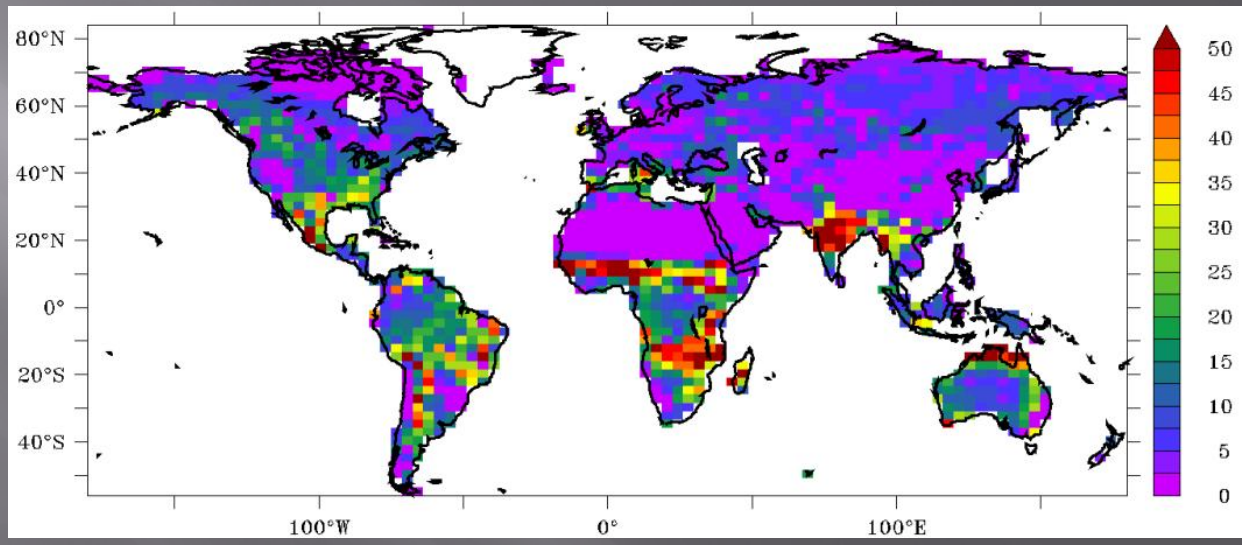


Perturbed System 1980-2000
(Natural and Secondary Vegetation)

kg N ha^{-1} yr^{-1}

N demand of a unconstrained system

(C-only)



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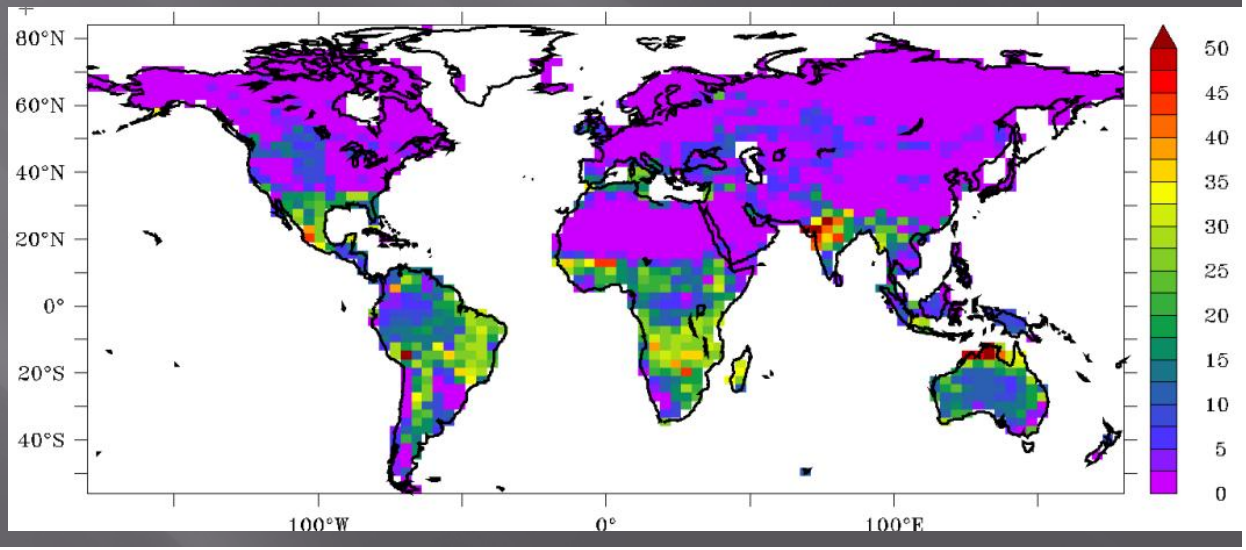

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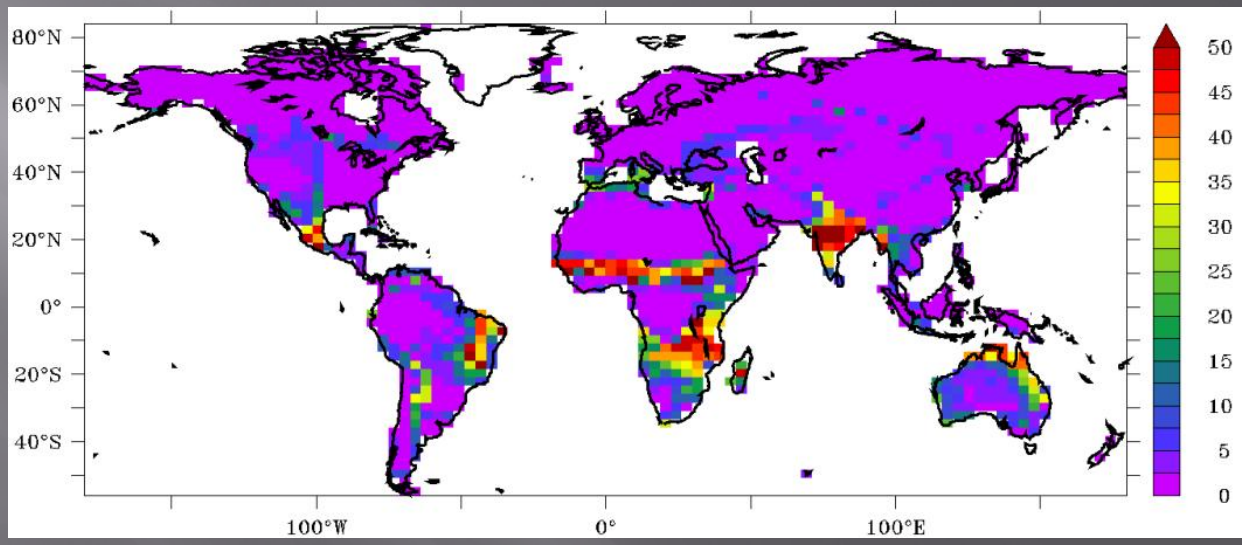

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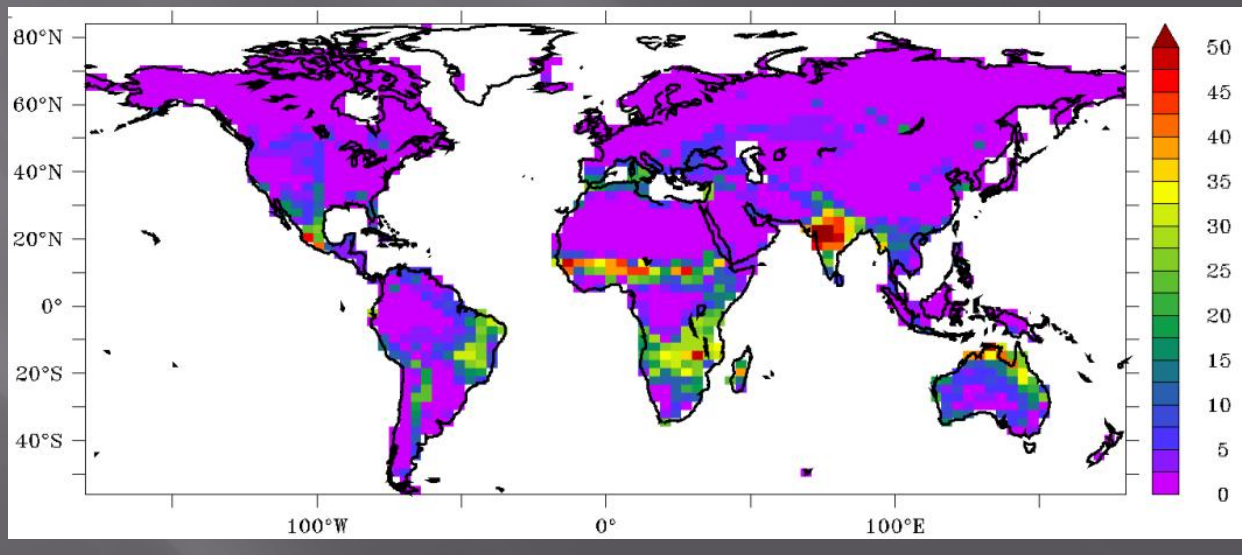
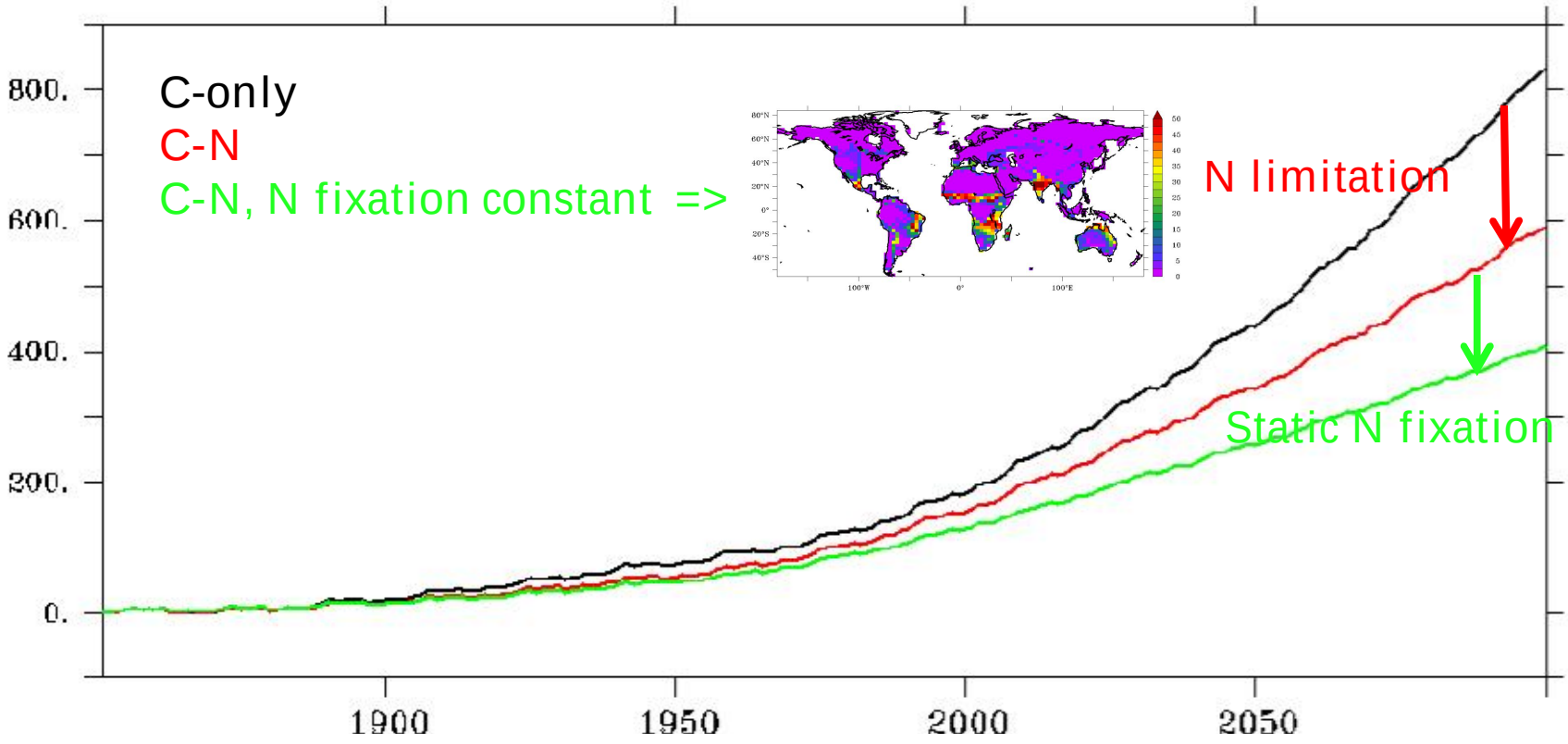
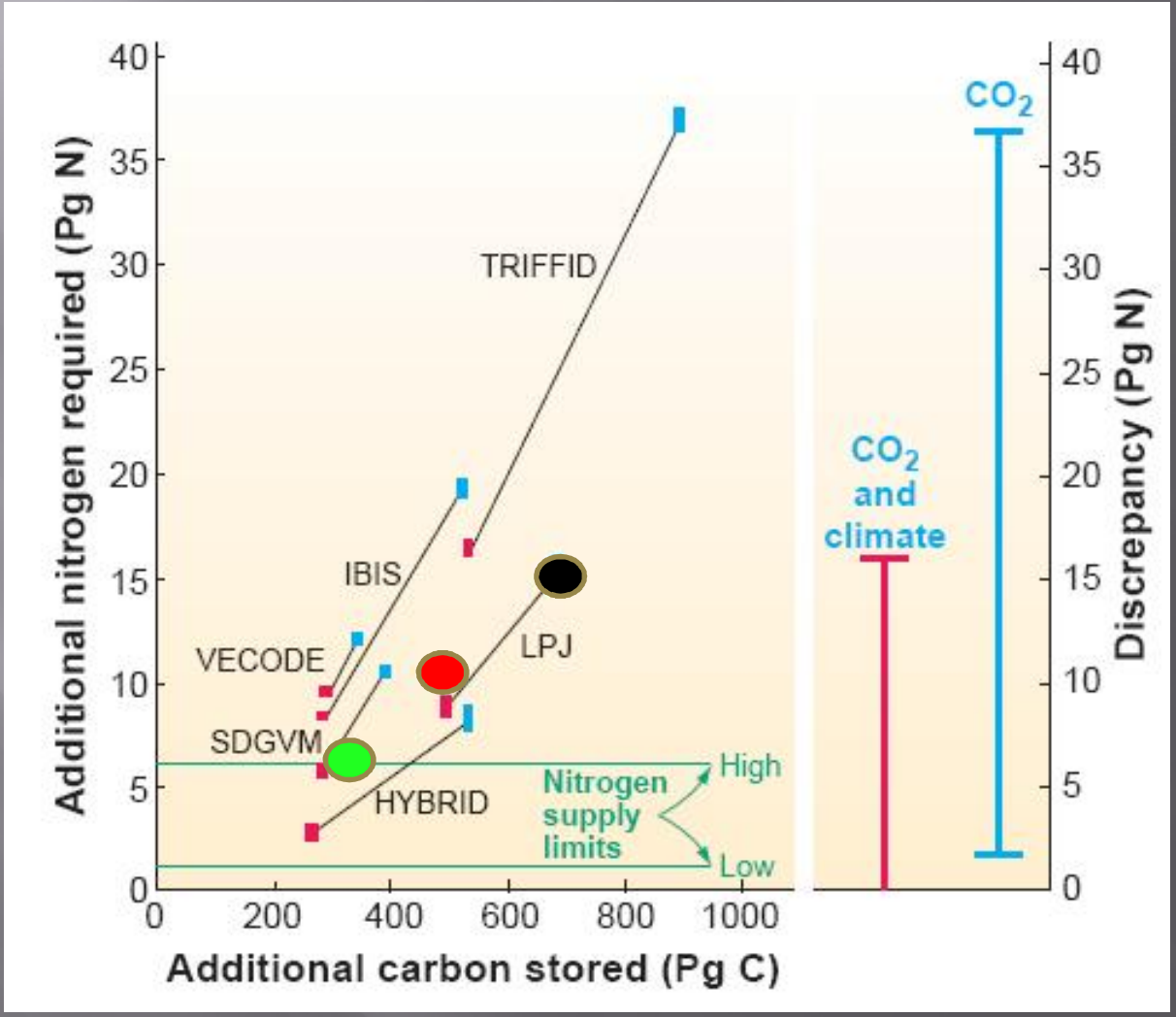


Anthropogenic Carbon Uptake (PgC)



Nutrient Constraint on CO_2 fertilization



Hungate et al., 2003

Conclusions

- Understanding biological N fixation is central to understand the land's response to CO2
- We are only at the beginning of mechanistic treatment of biological N fixation in models

Questions / Future directions

- P cycle
- Decoupled fixation: heterotrophs, lichens, epiphytes
- N fixation responses to demand, can we detect a CO2 response in N fixation?

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