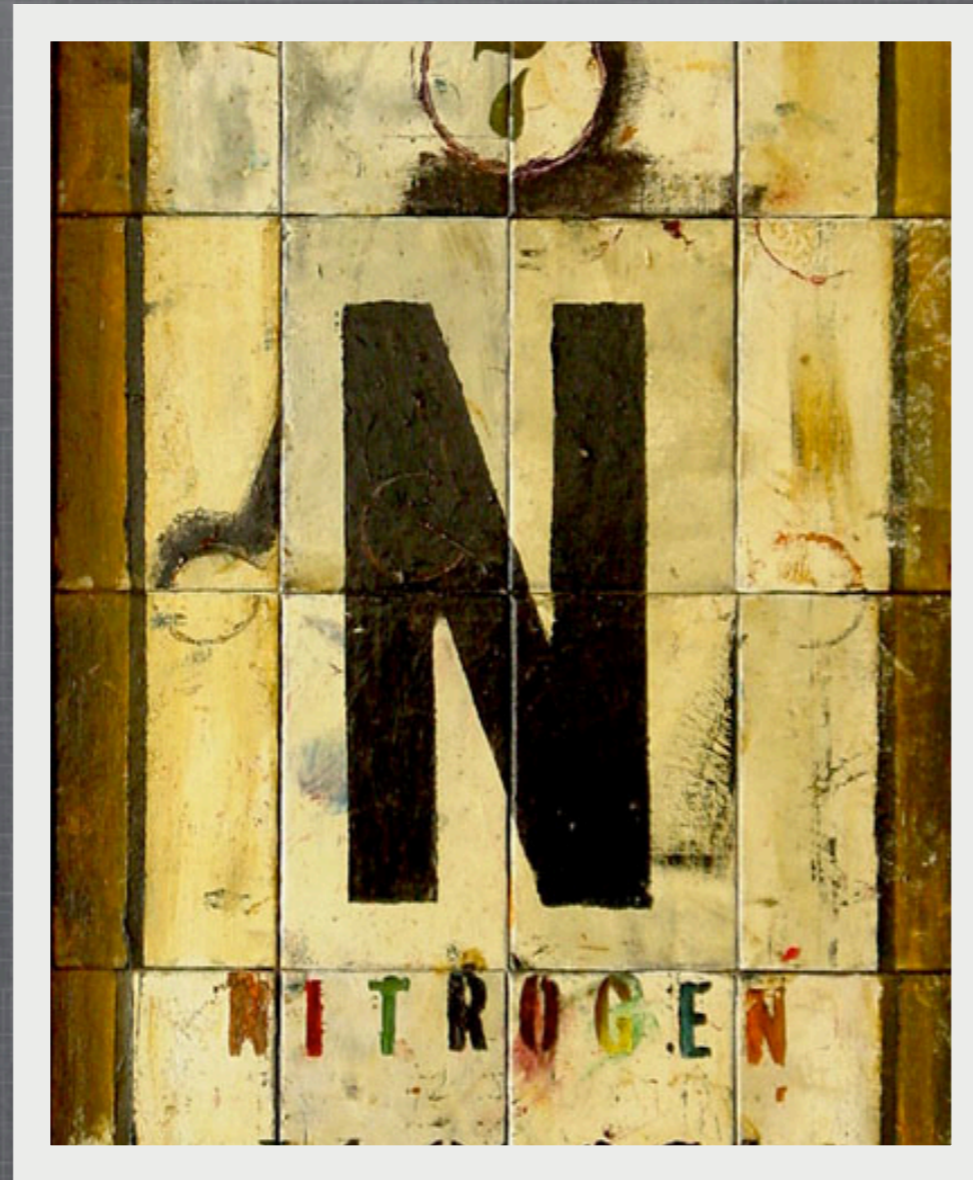


Nitrogen fixation

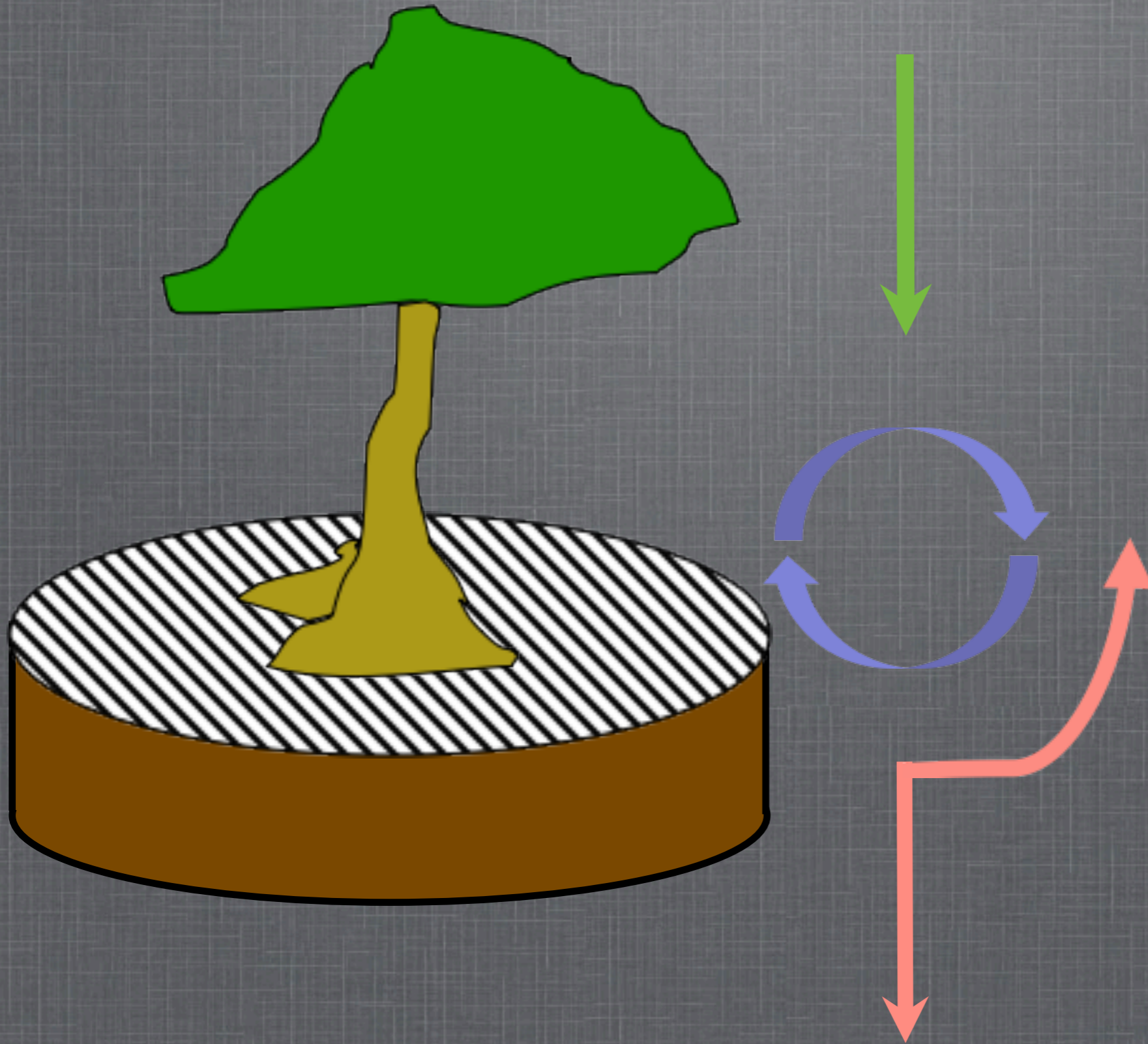
what do we know and what do we need to know?



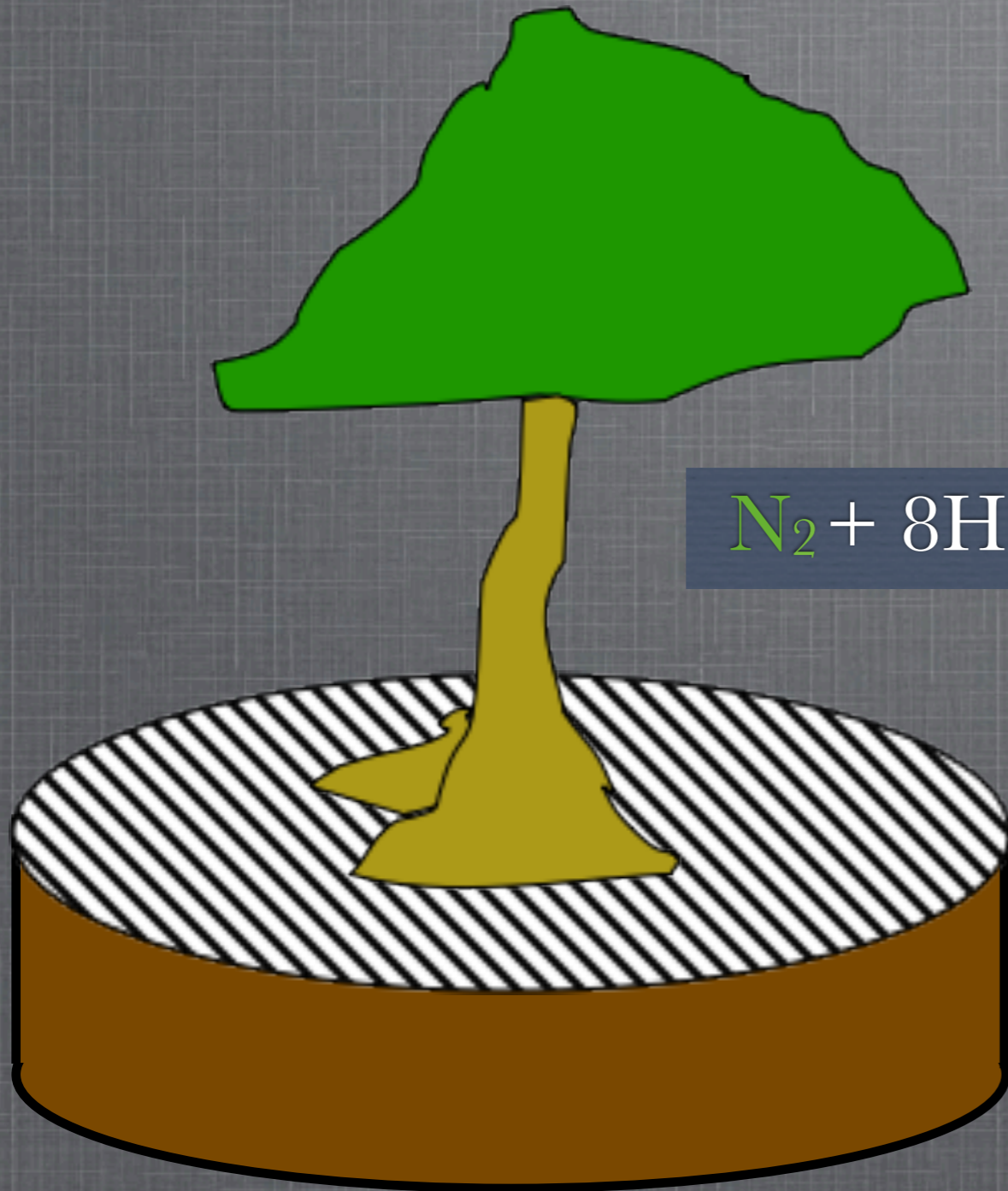
The Plan

1. Agree that understanding N fixation is critical to considerations of global change
2. Think explicitly about different N fixation pathways: symbiotic vs. free-living
3. Discuss N fixation environmental controls within the context of global change
4. Where do we go from here?

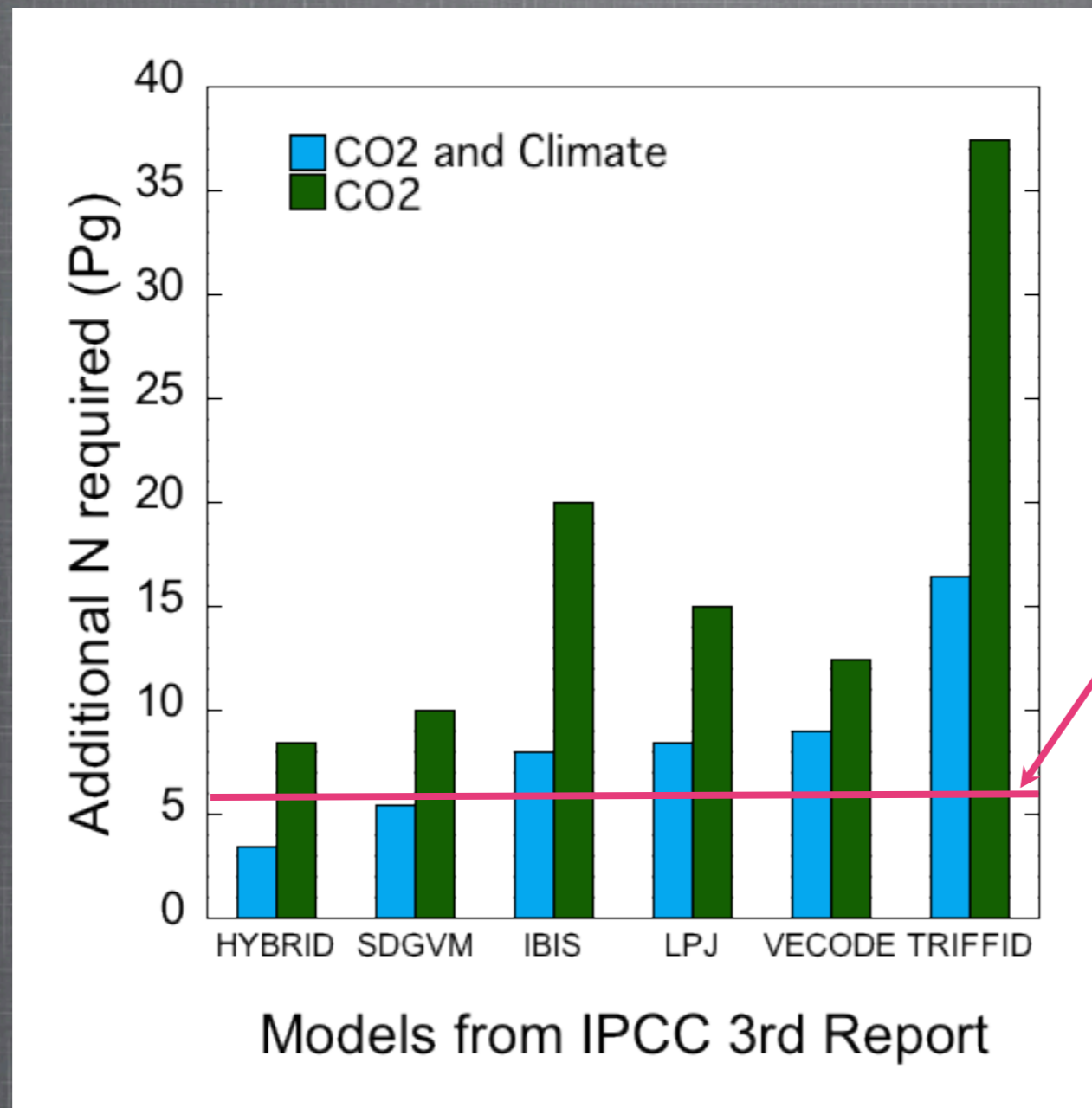
The nitrogen cycle



Nitrogen fixation



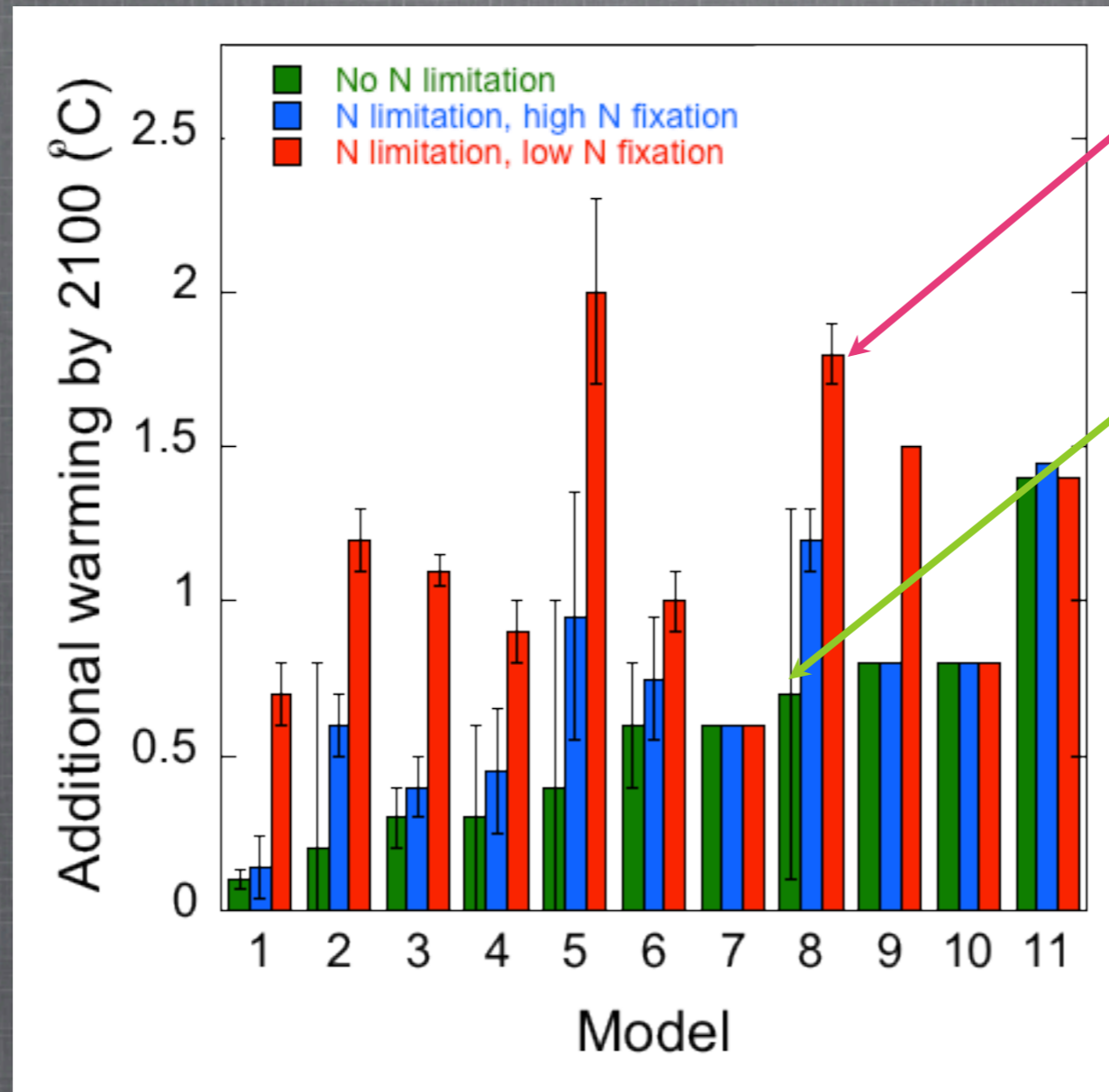
Nitrogen demand and global change



Higher estimate of increased N inputs

Modified from Hungate et al. (2003) Science

A role for nitrogen fixation

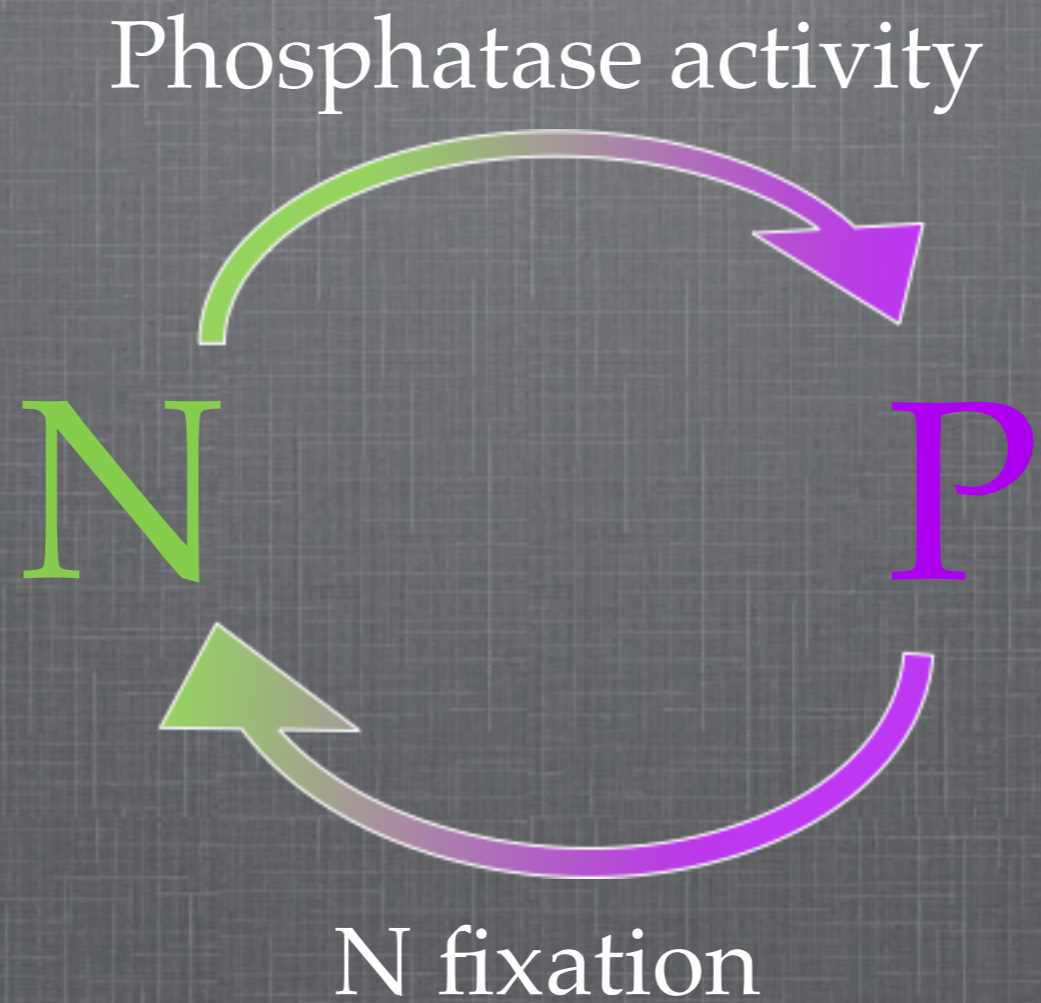


High N limitation and low N fixation

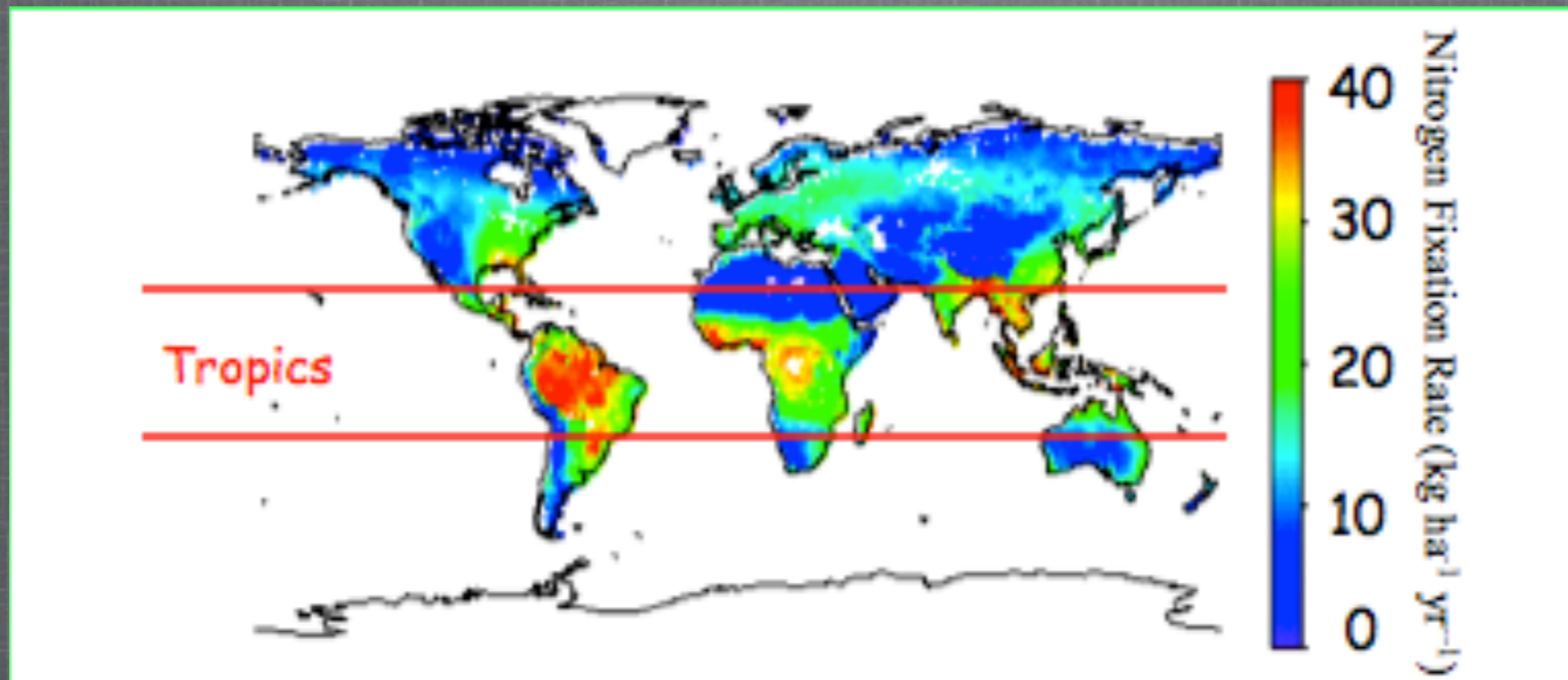
No N limitation

Modified from Wang & Houlton (2009) *Geophysical Research Letters*

Linkages between N and P



Nitrogen fixation by biome

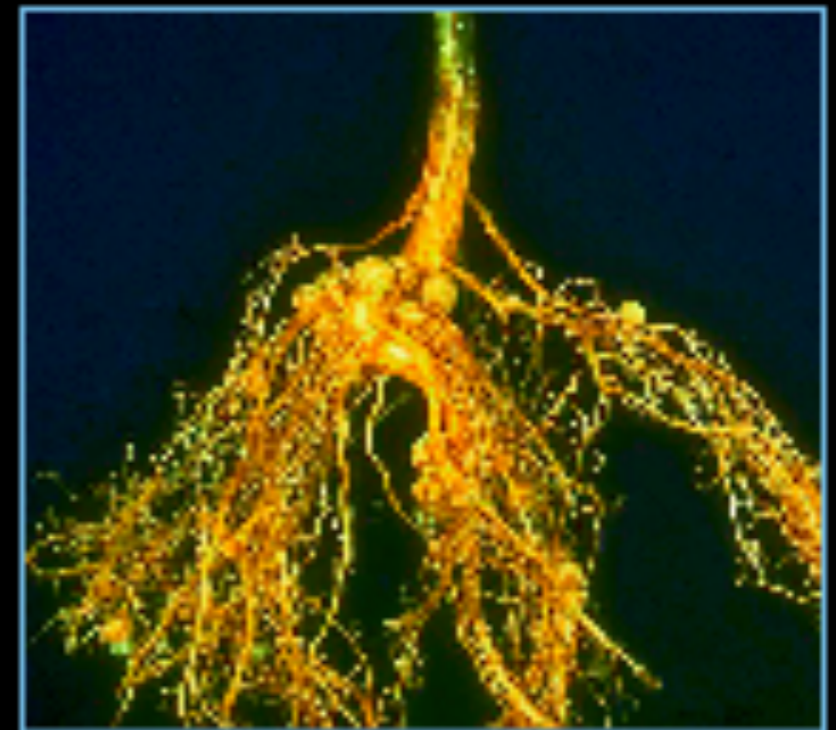


Modified from Cleveland et al. (1999) *Global Biogeochemical Cycles*

Free-Living N Fixation



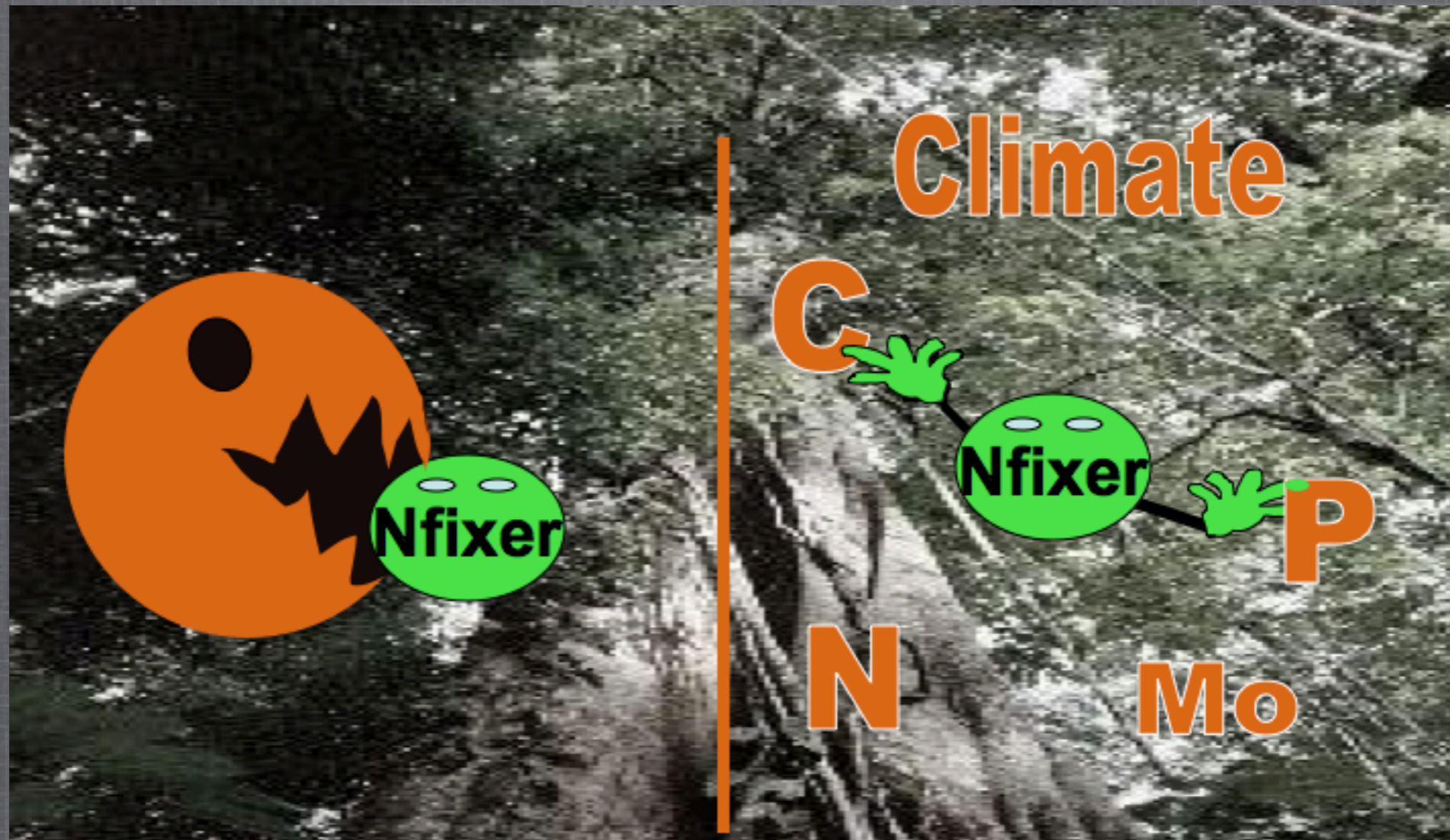
Symbiotic N Fixation



The Plan

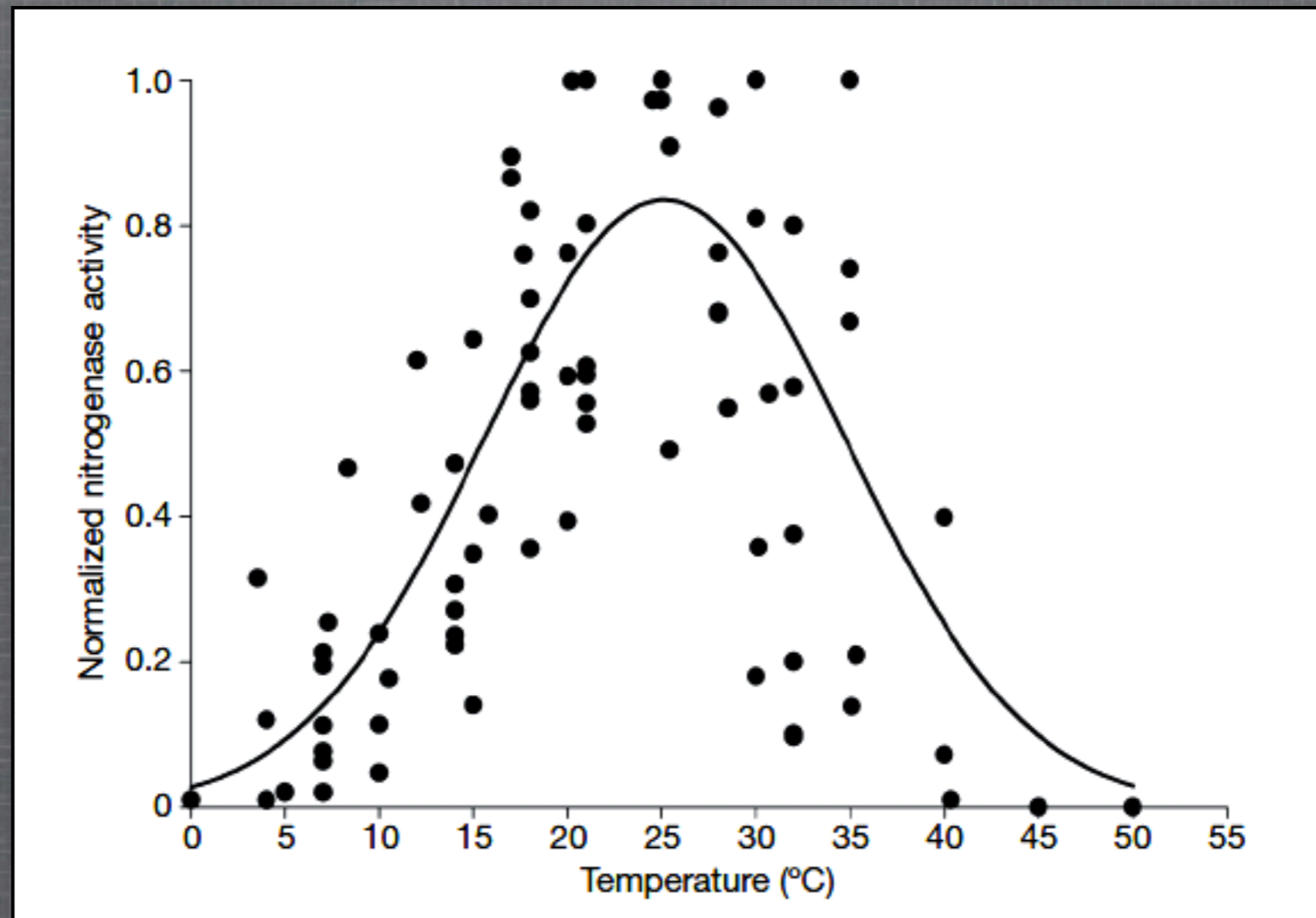
- ✓ 1. Agree that understanding N fixation is critical to considerations of global change
- ✓ 2. Think explicitly about different N fixation pathways: free-living and symbiotic
3. Discuss the ways in which environmental change is likely to affect N fixation rates
4. Where do we go from here?

Controls over N fixation rates



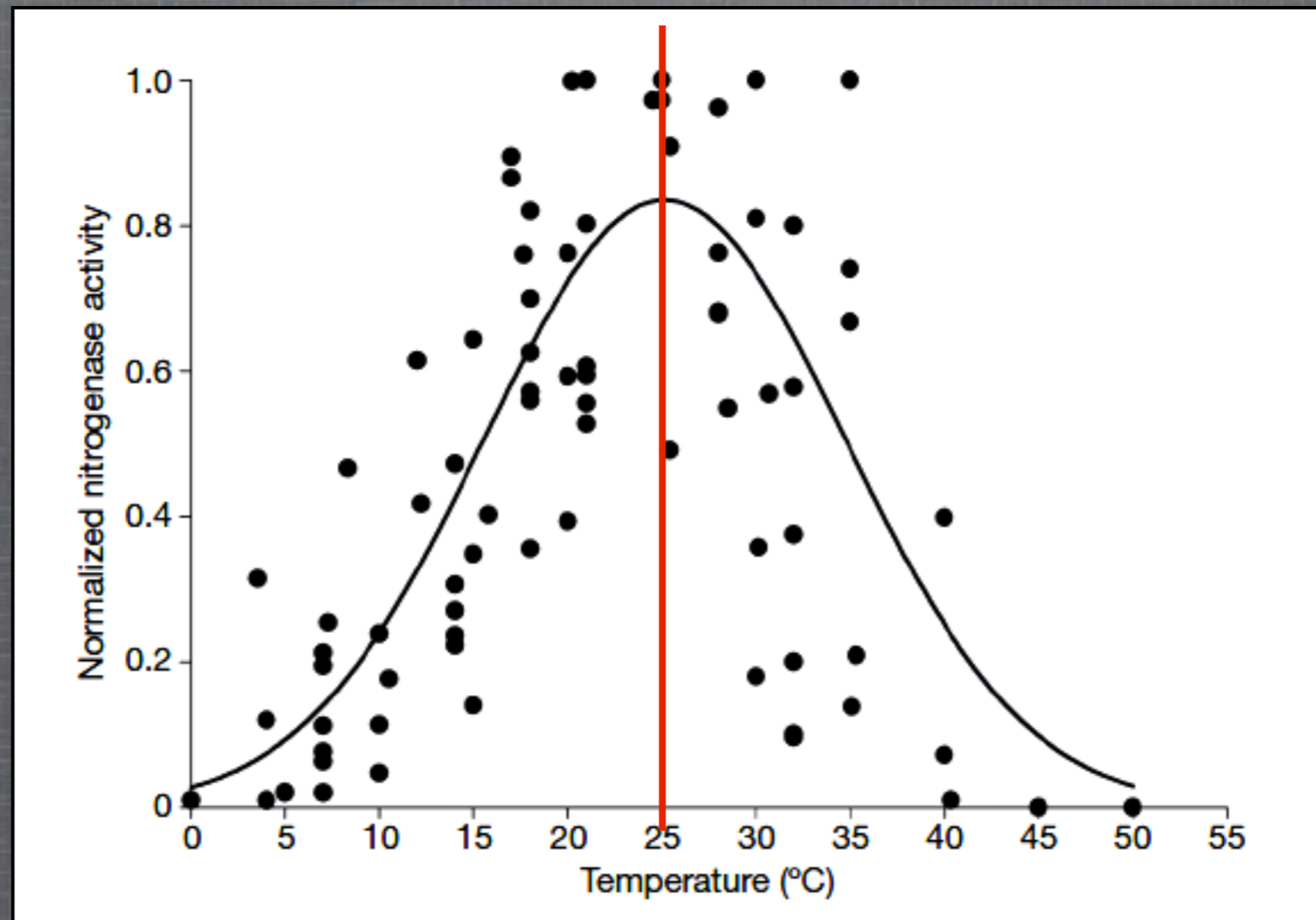
Modified from Vitousek & Howarth (1991) Biogeochemistry

Controls over N fixation rates: Climate



Houlton et al. (2008) Nature

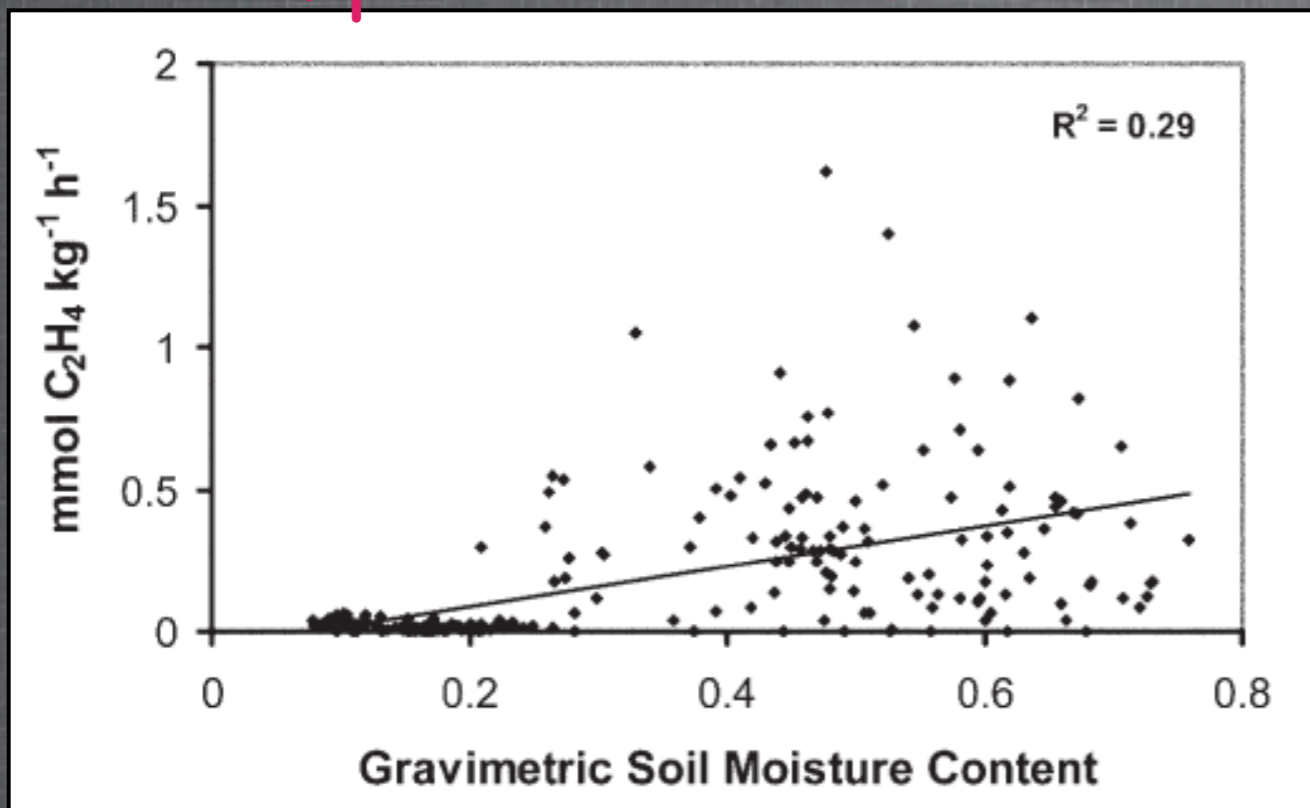
Controls over N fixation rates: Climate



Houlton et al. (2008) Nature

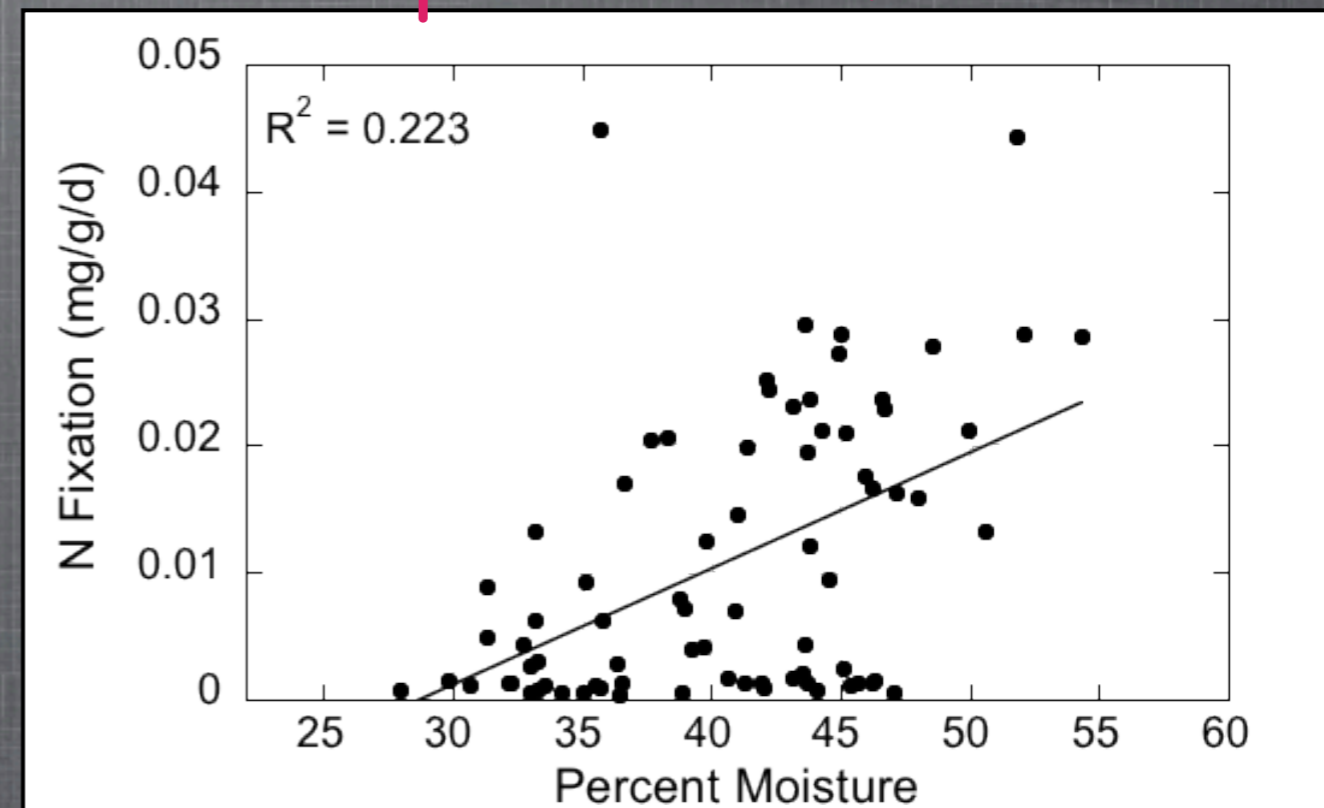
Controls over N fixation rates: Climate

Temperate Pine Forest



Hofmockel & Schlesinger (2007) Soil Sci. Soc. Am.

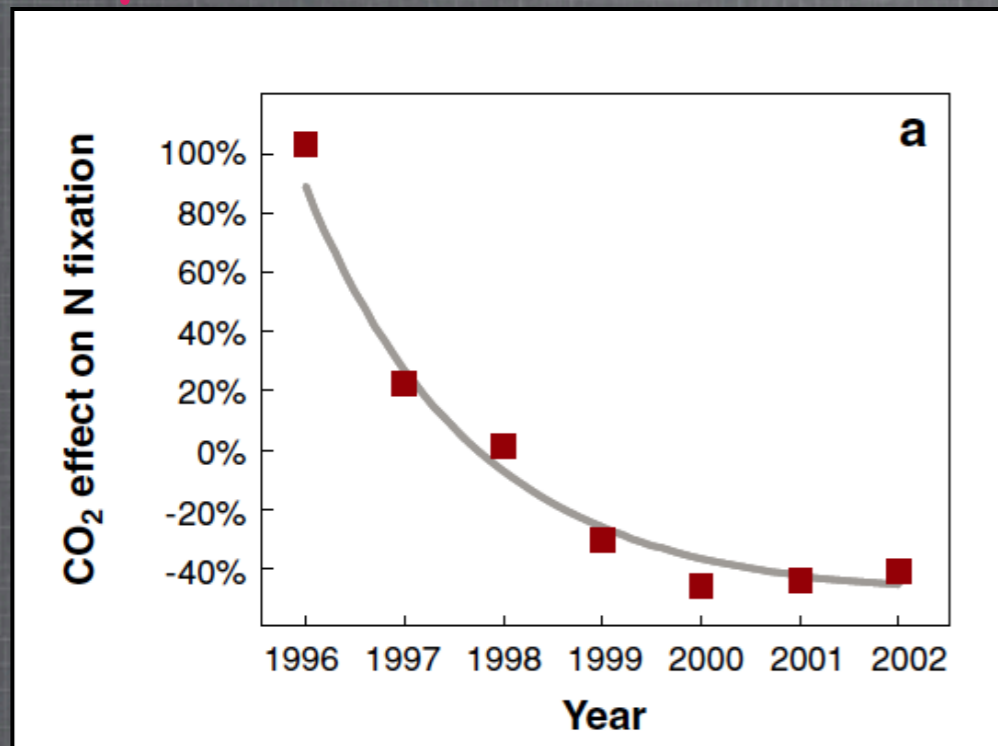
Tropical Rain Forest



Modified from Reed et al. (2007) Biotropica

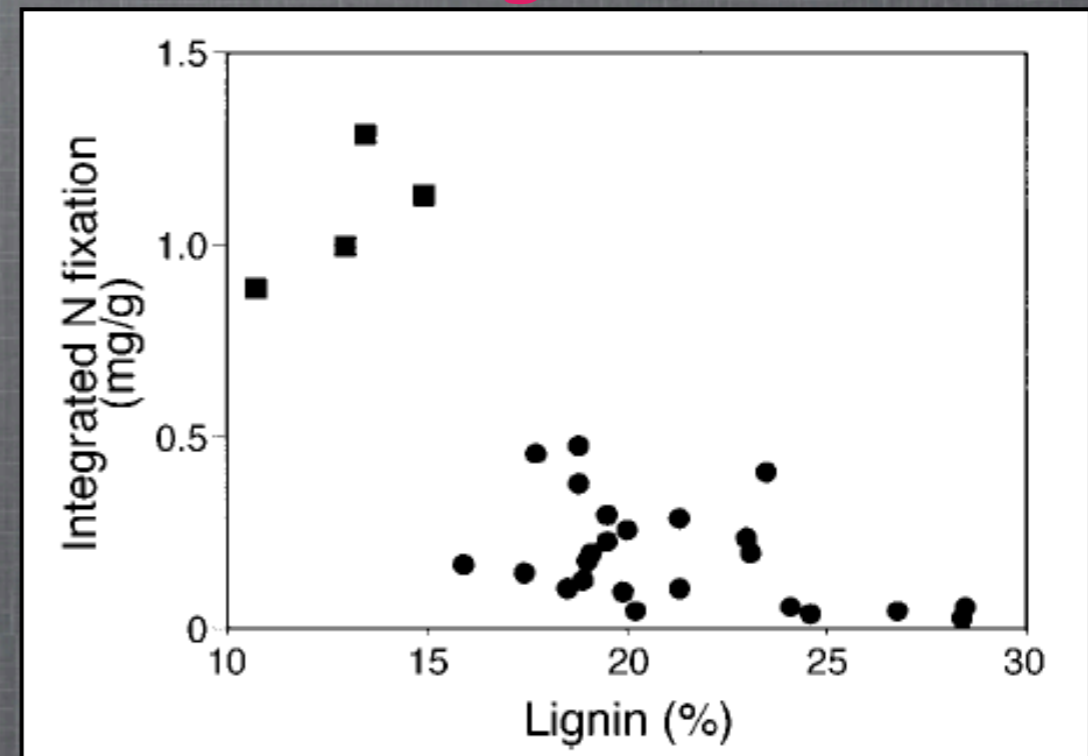
Controls over N fixation rates: Carbon

Symbiotic N fixation



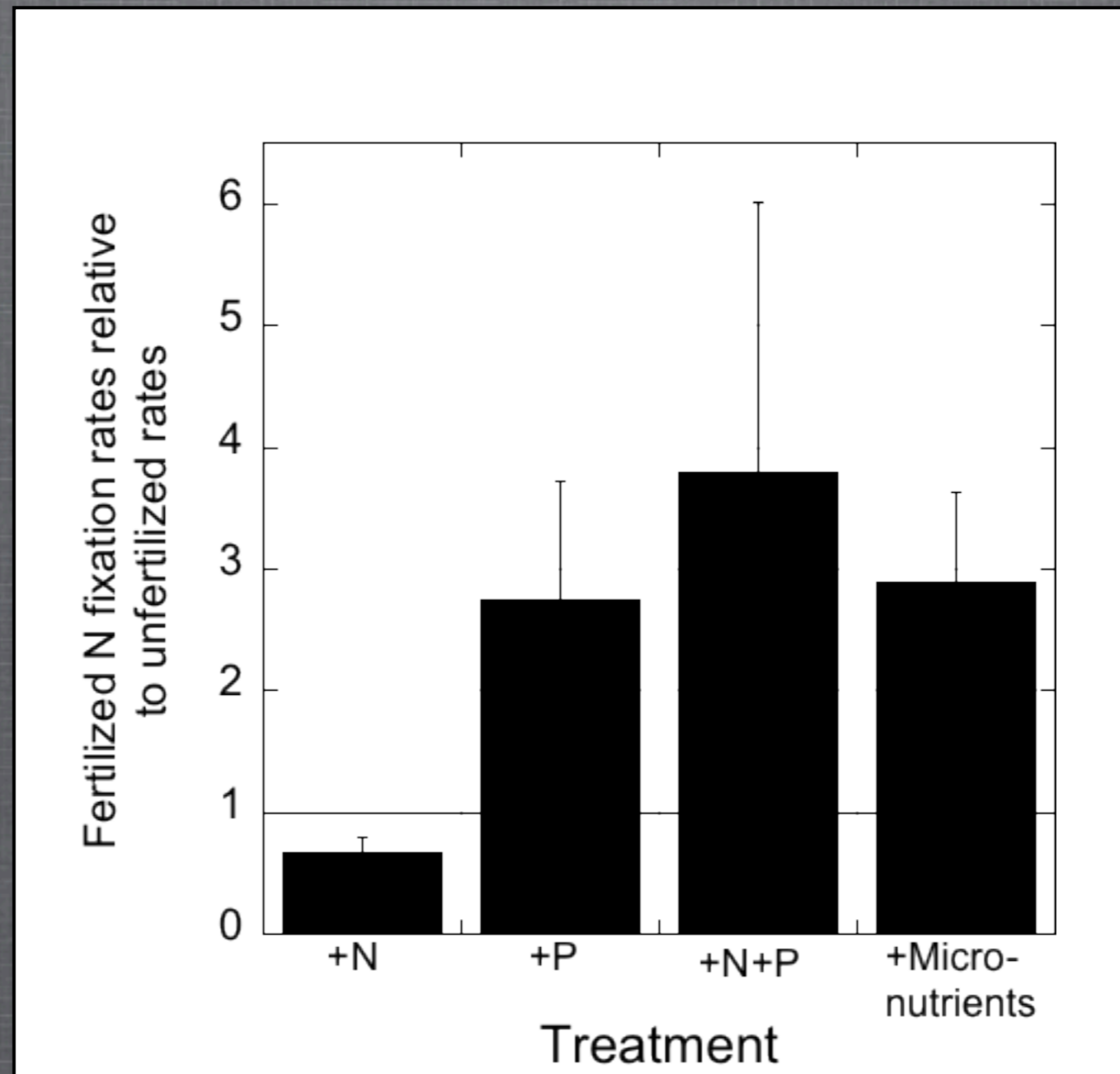
Hungate et al. (2004) Science

Free-living N fixation



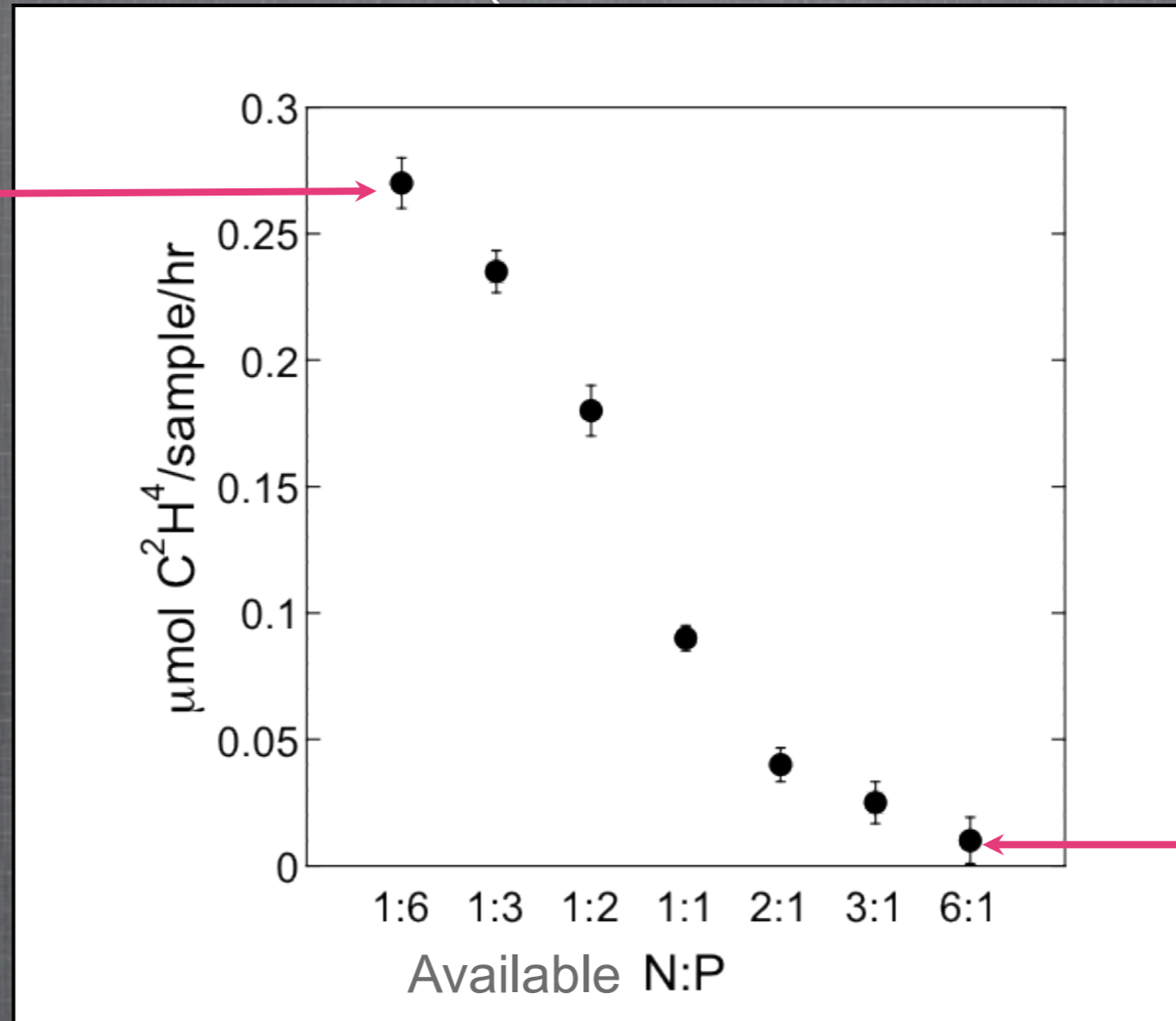
Vitousek & Hobbie (2000) Ecology

Controls over N fixation rates: Nutrients



Controls over N fixation rates: Nutrients (stoichiometry)

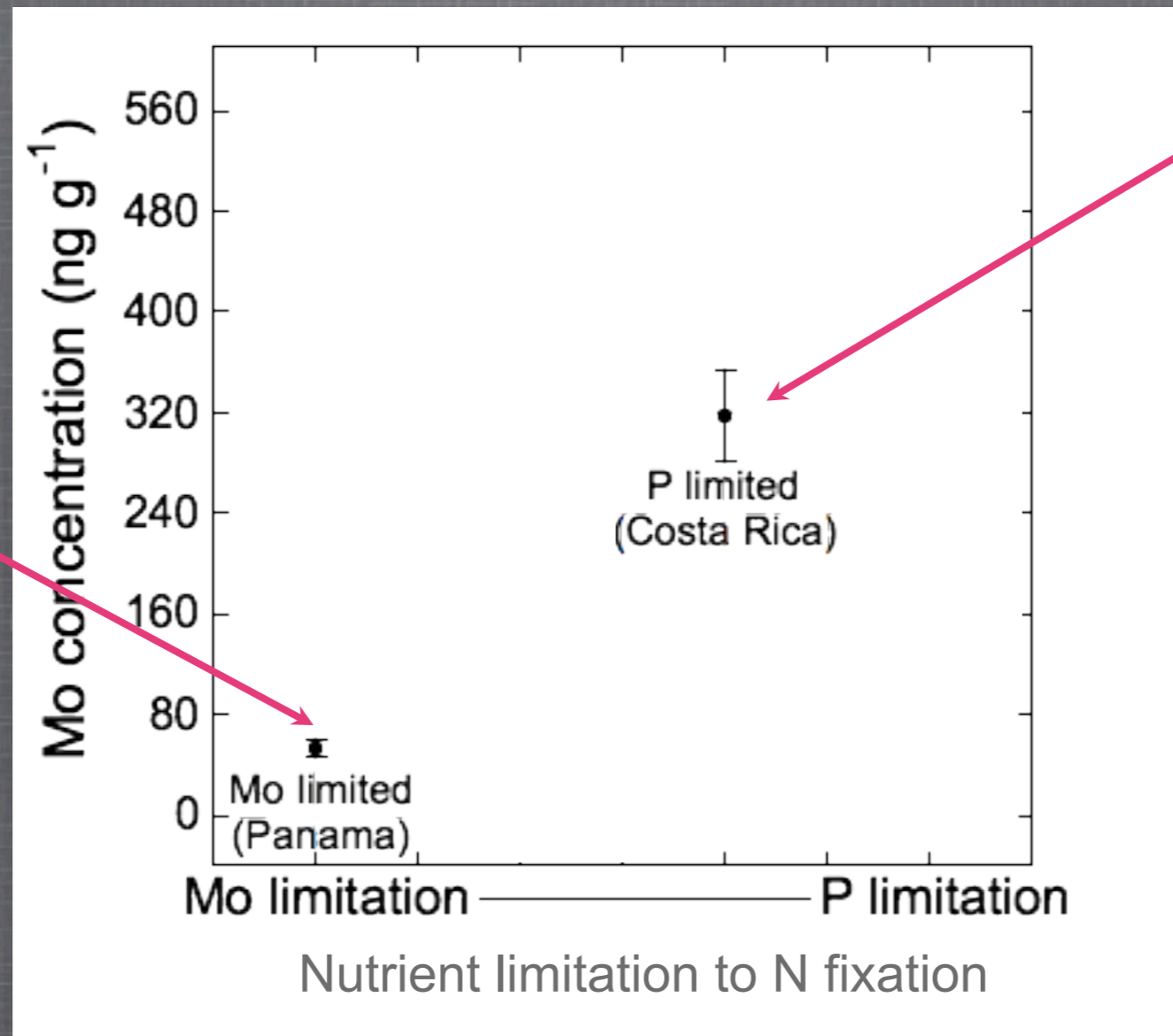
Low N:P
High Nfix



High N:P
Low Nfix

Modified from Eisele et al. (1989) *Oecologia*

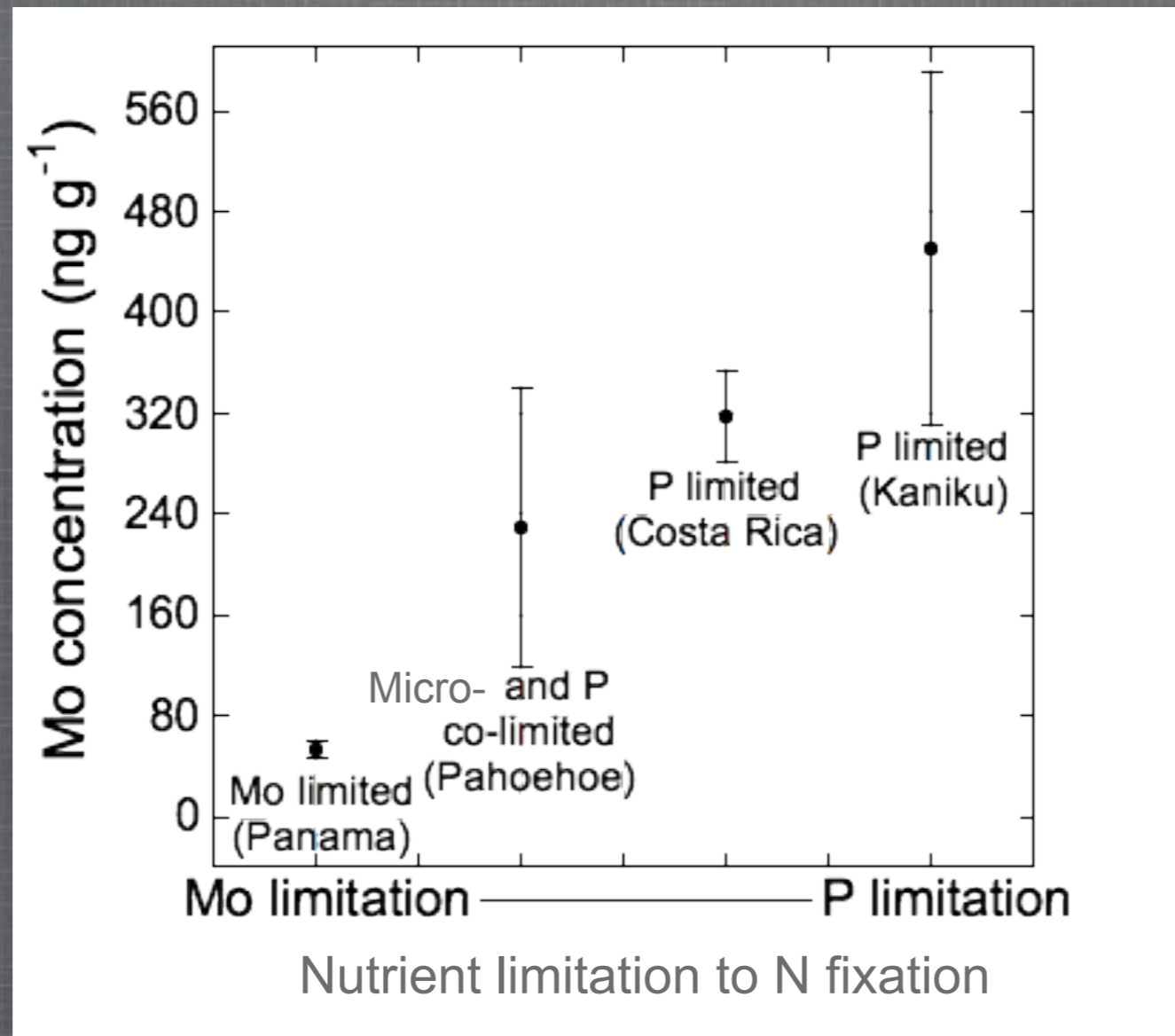
Controls over N fixation rates: Nutrients



Reed et al. (In review)
high Mo relative to P

Barron et al. (2008)
Nature-Geoscience
low Mo relative to P

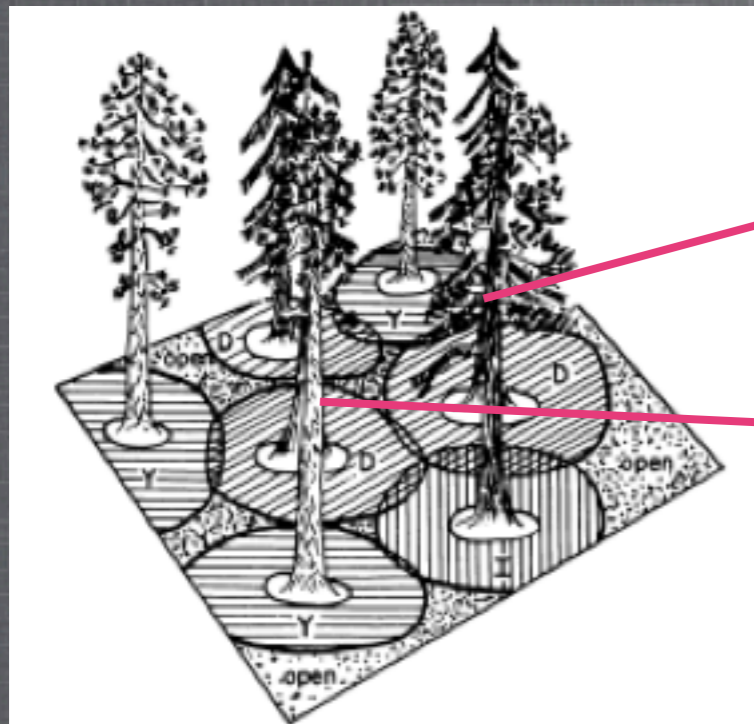
Controls over N fixation rates: Nutrients



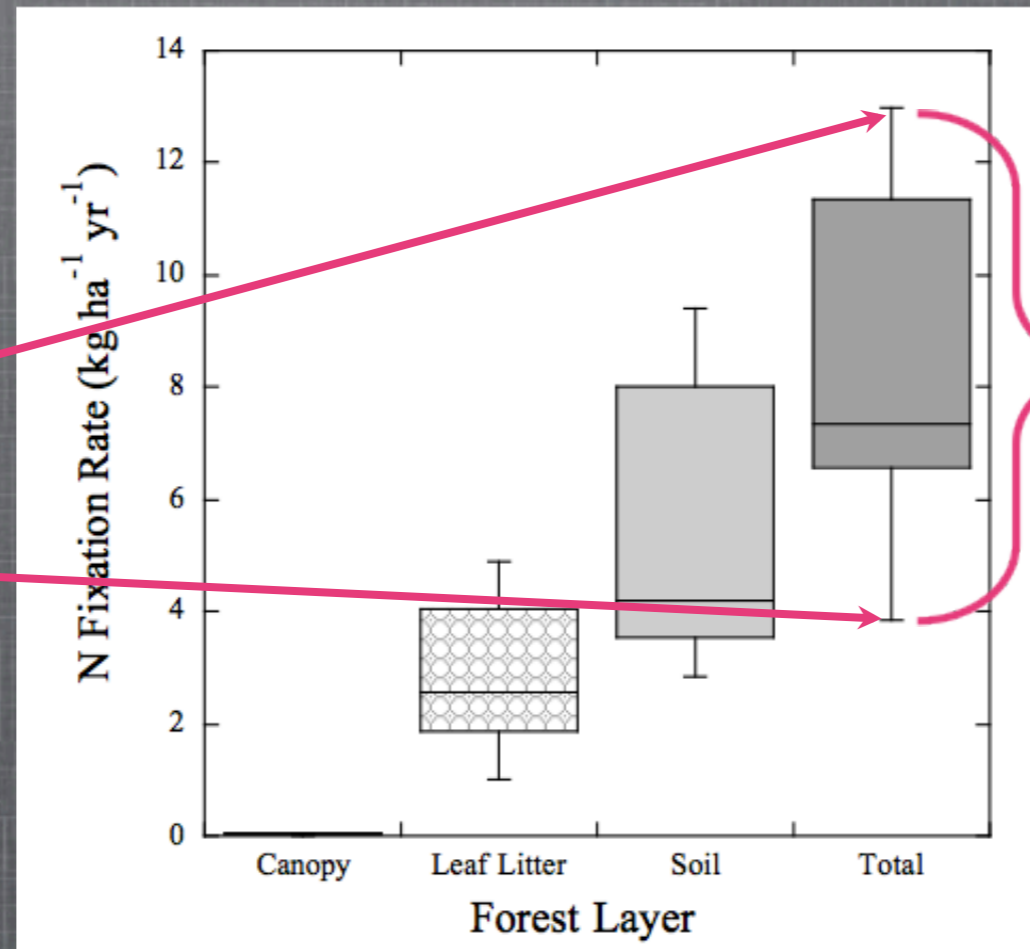
Controls over N fixation rates: Community composition



Controls over N fixation rates: Community composition



Zinke (1962) Ecology

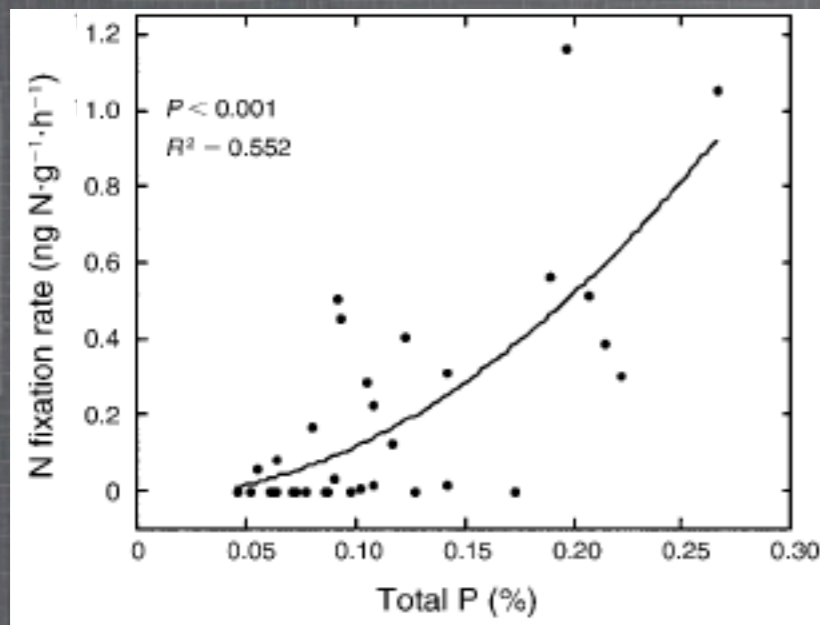


Modified from Reed et al. (2008) Ecology

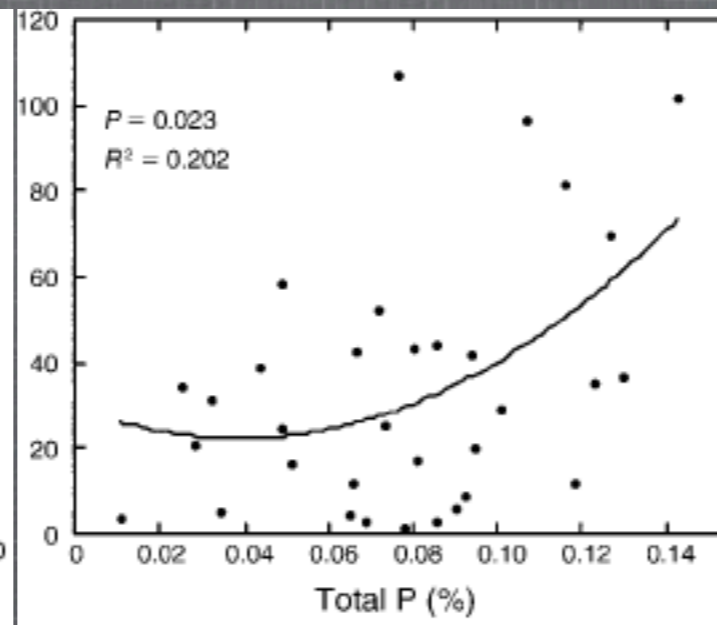
> 9 kg N/ha/y

Controls over N fixation rates: Community composition

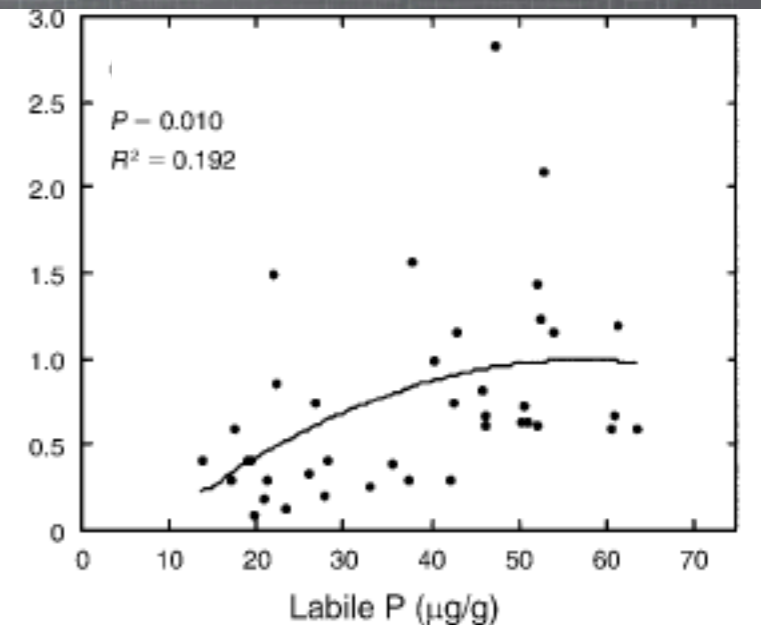
Canopy leaves



Leaf litter

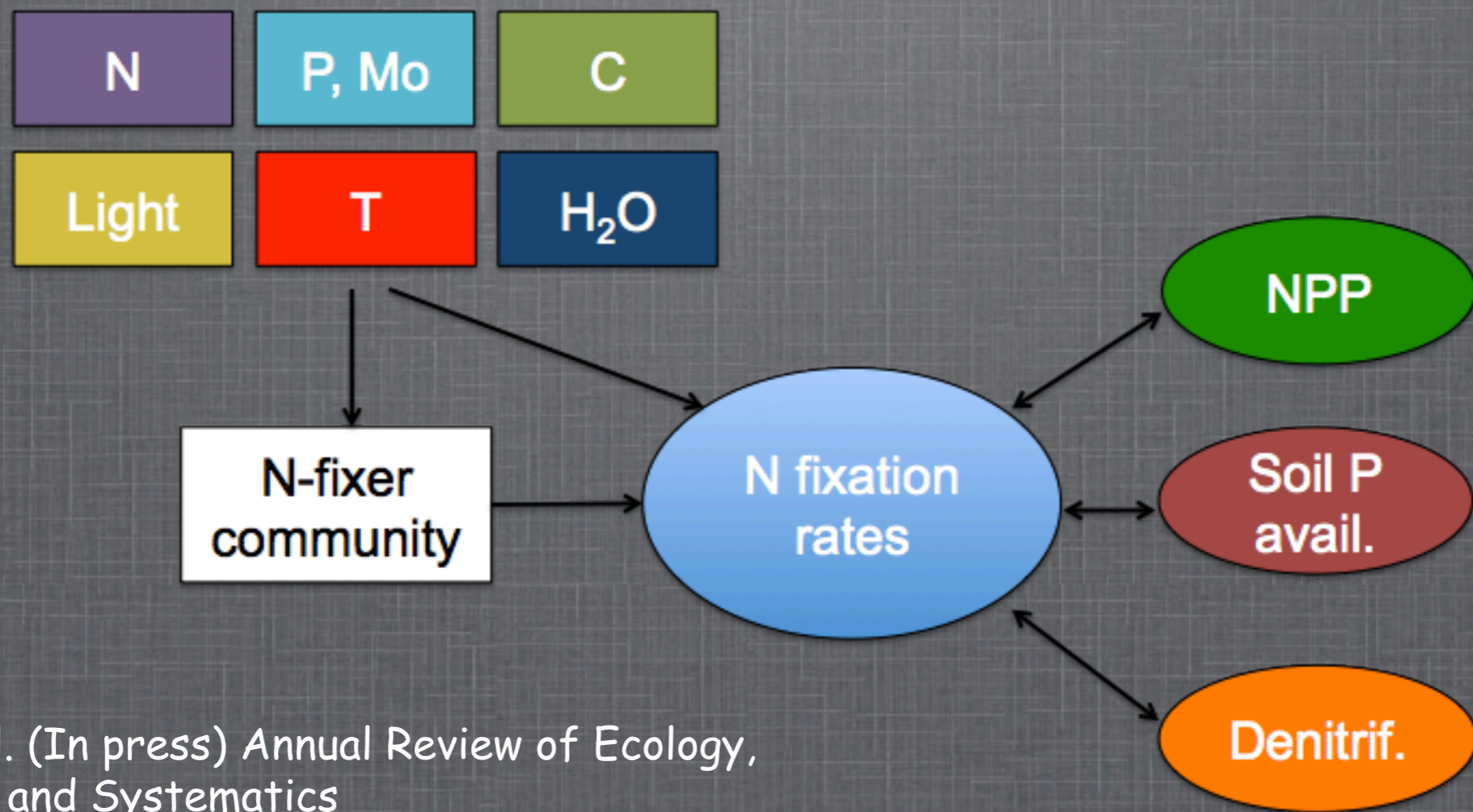


Soil



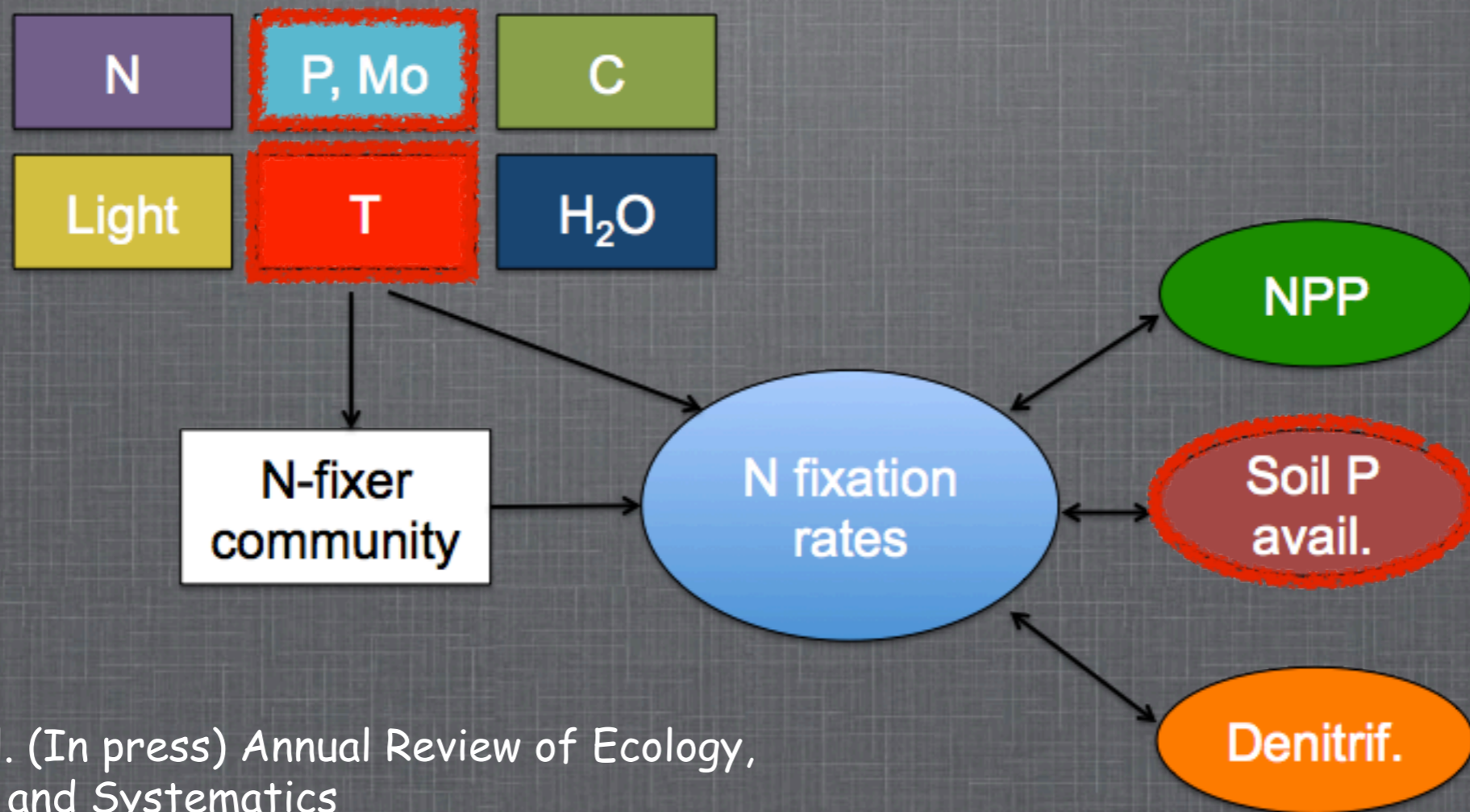
Reed et al. (2008) Ecology

Controls over N fixation rates: Putting it all together



Reed et al. (In press) Annual Review of Ecology, Evolution, and Systematics

Controls over N fixation rates: Putting it all together



Reed et al. (In press) Annual Review of Ecology, Evolution, and Systematics

Next steps

There's lots of things we still need to know about N fixation...

Next steps

There's lots of things we still need to know about N fixation, but there are lots of things we know already too. We know climate, nutrients, light etc. matter to N fixation rates.

The challenge now is to include these relationships in a mechanistic, synthetic way numerically.

screed@usgs.gov