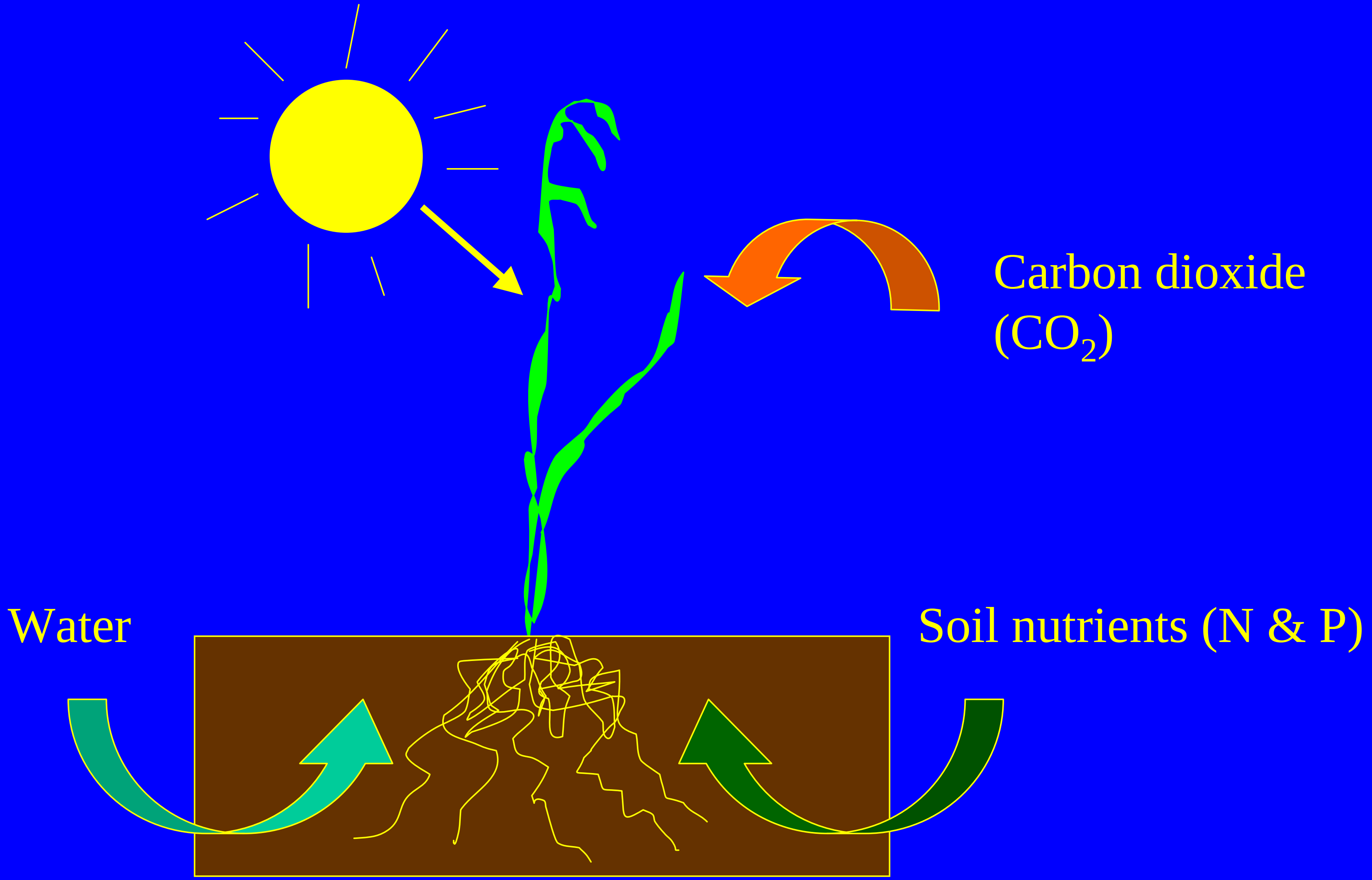
Can microbes limit plant growth under elevated CO_2?

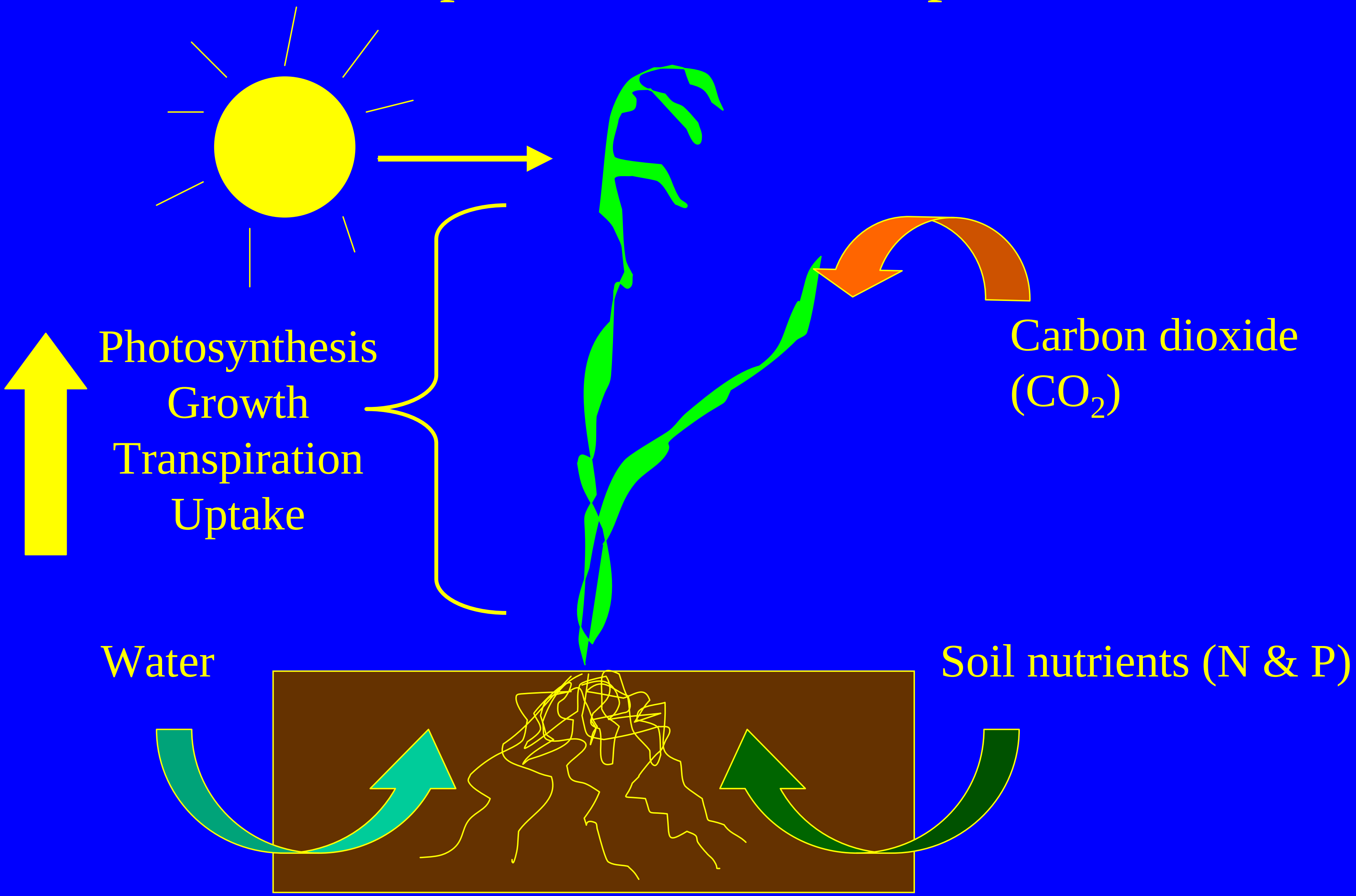
Elsa Cleland – Stanford University

GCEP End of Summer Workshop - 2003

Global changes alter resource availability for plants



Increased temperatures increases process rates

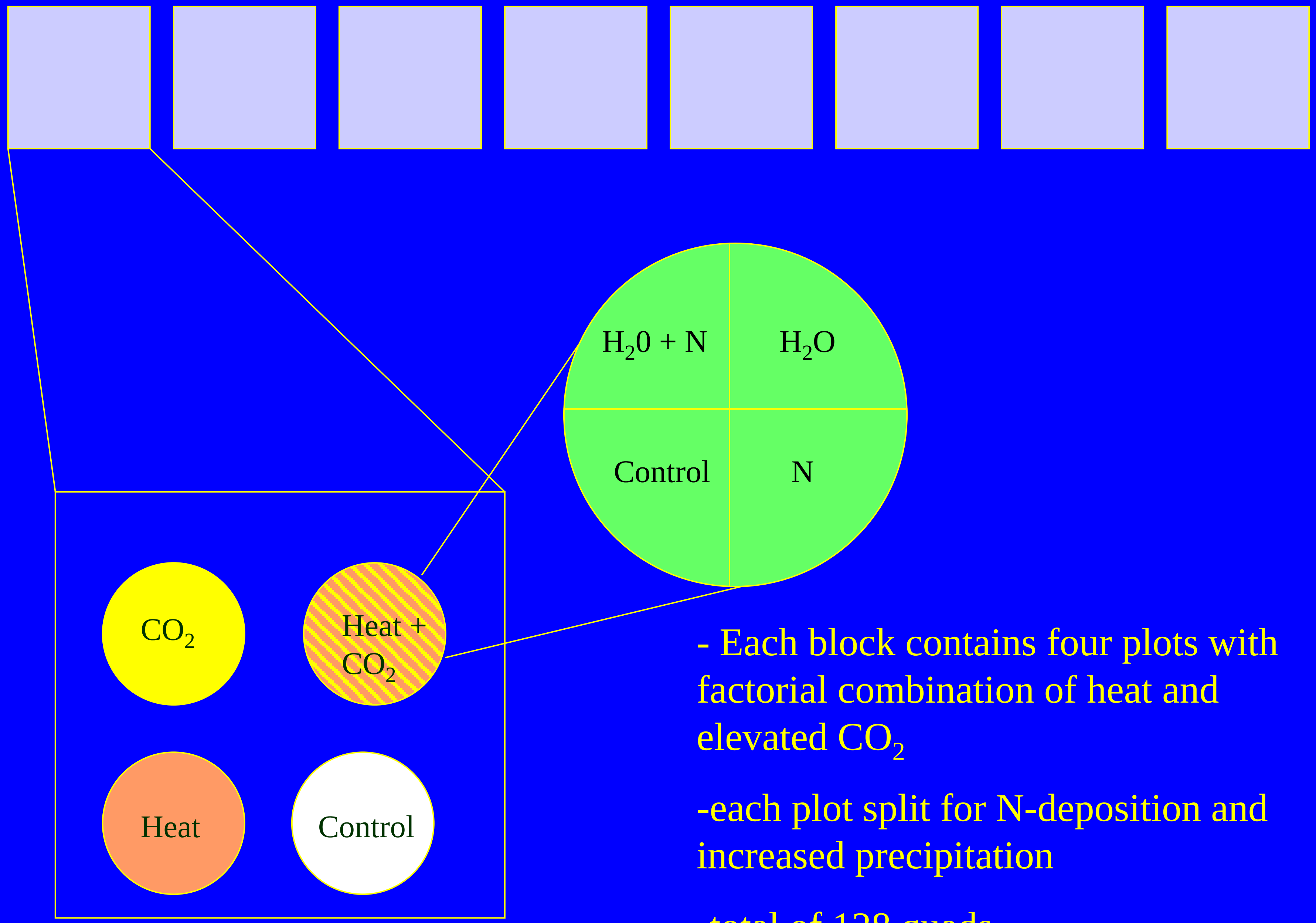


Model system: Jasper Ridge Global Change Experiment

- Warming, elevated CO_2, N-deposition, increased precipitation
- 16 treatments x 8 reps + 8 controls
- N=136
- ANOVA
- Annual grassland
- 5 years of treatments

Jasper Ridge Global Change Experiment

Randomized block design



- Each block contains four plots with factorial combination of heat and elevated CO_2

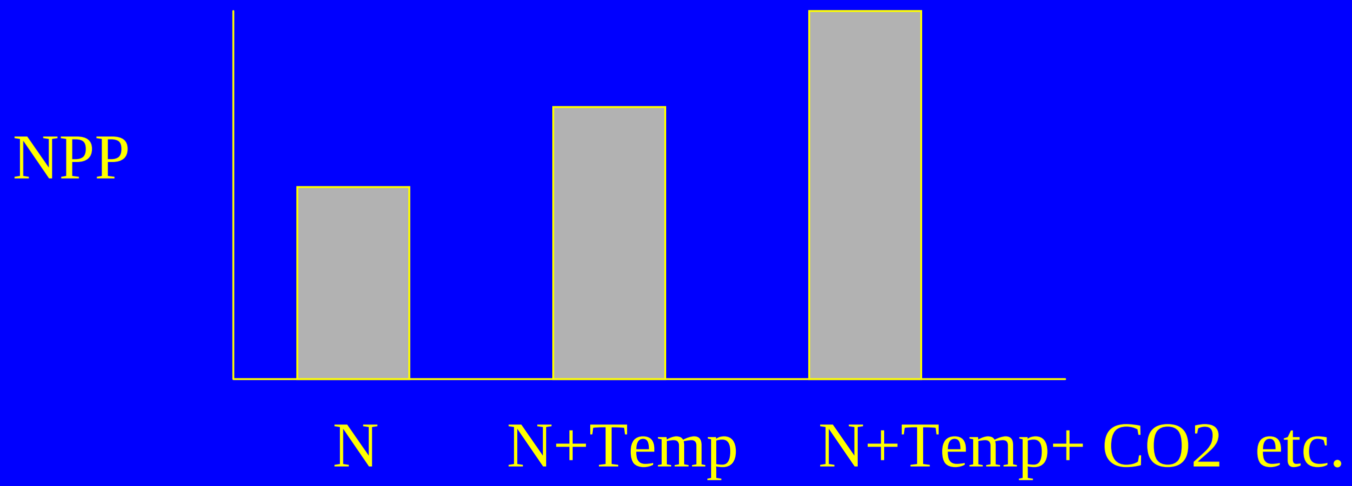
-each plot split for N-deposition and increased precipitation

-total of 128 quads

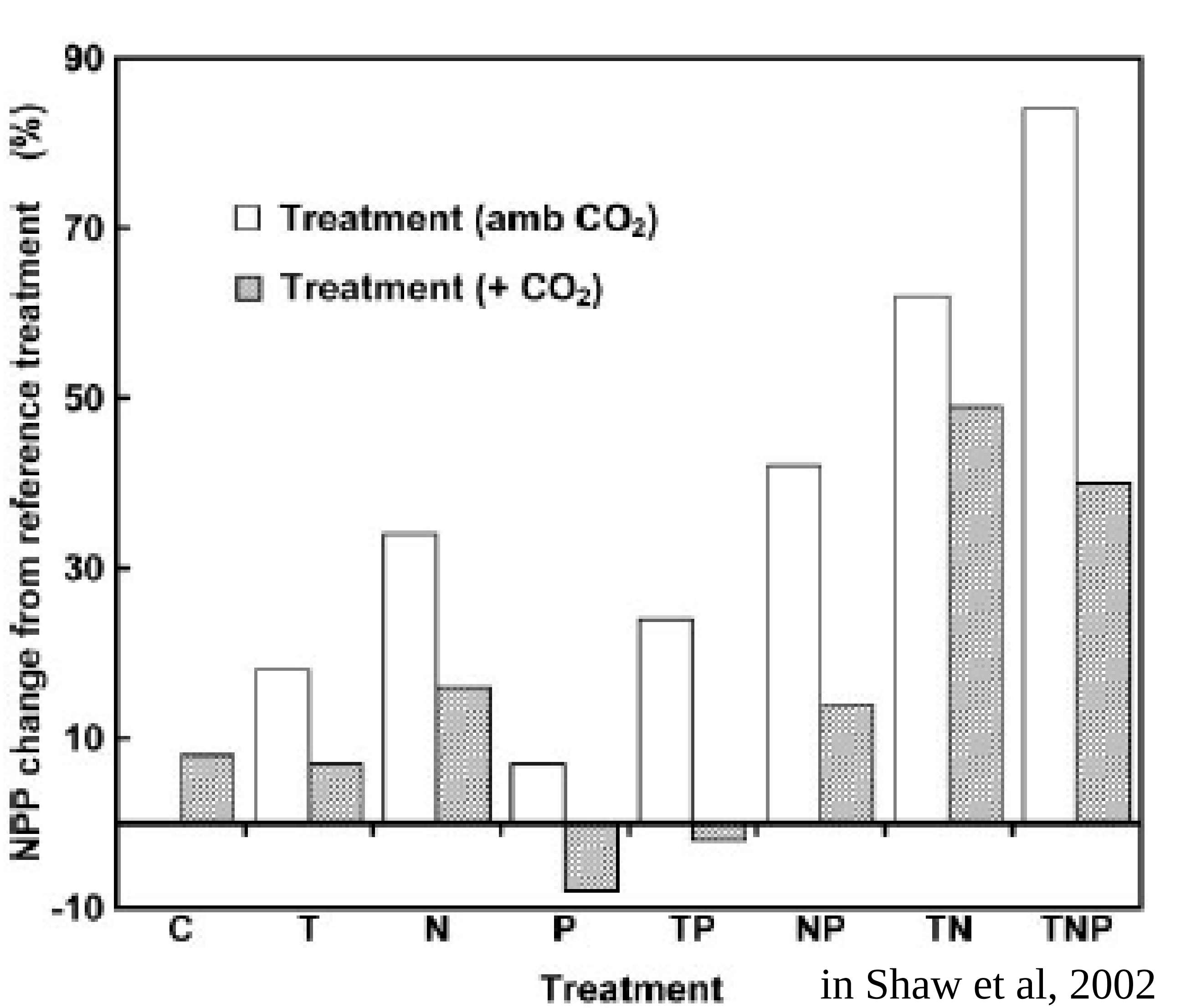
Initial hypotheses:

Hypothesis 1 : Interacting global changes will increase resources required for plant growth, thus increasing Net Primary Productivity

Hypothesis 2: Global changes will interact in an additive manner



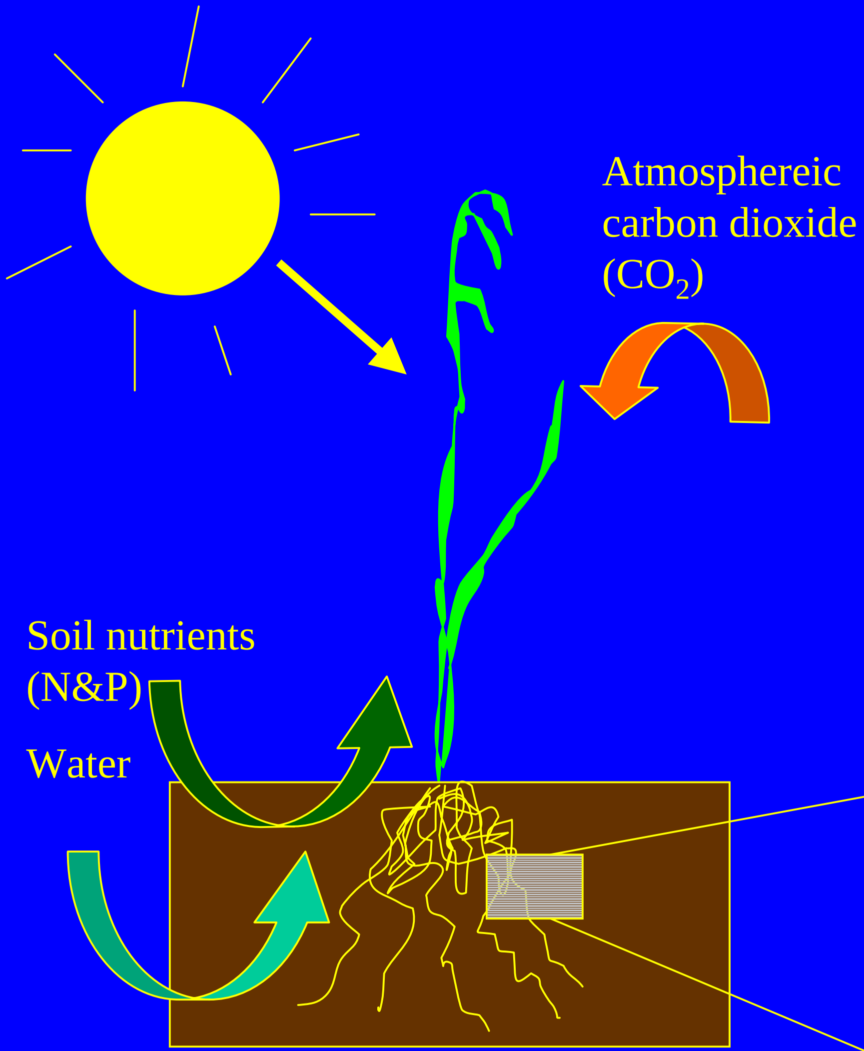
Surprise: Elevated CO_2 suppressed the stimulatory effects that other global changes had on NPP



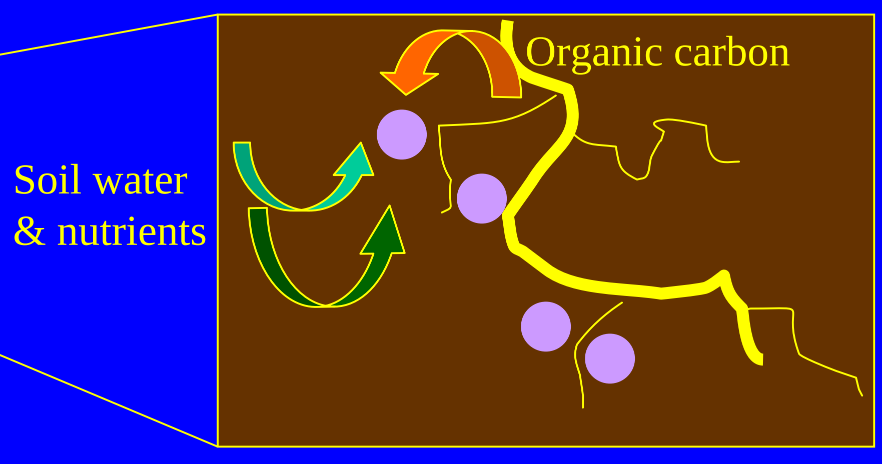
in Shaw et al, 2002

T = increased temperature, N = nitrogen deposition, P = increased precipitation

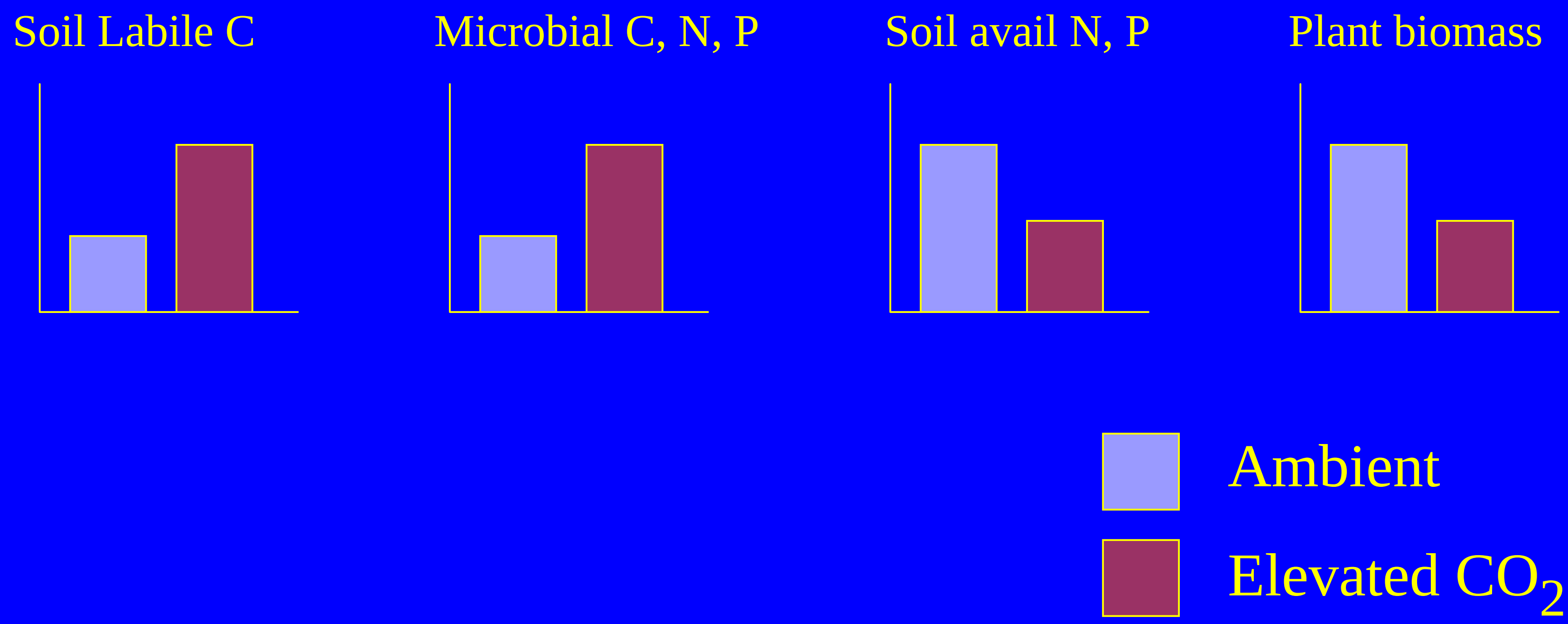
Soil microbes interact with plants, possibly competing for limiting nutrients



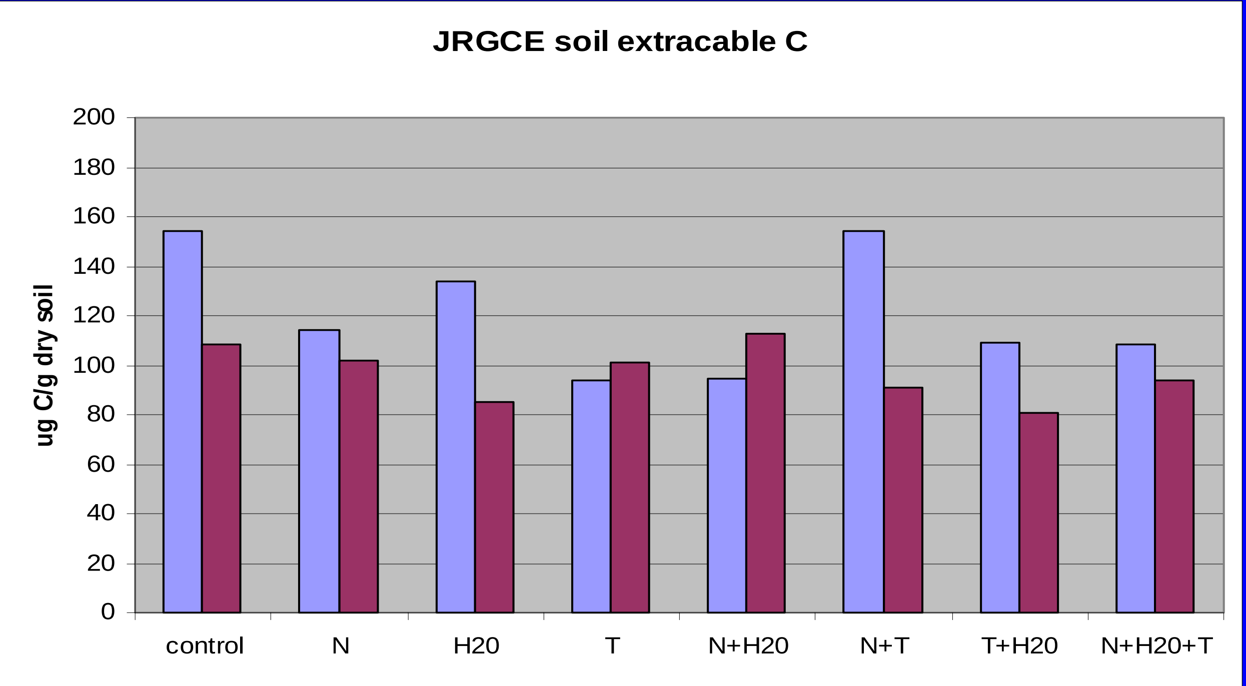
-Microbes are hetertrophic, rely organic carbon sources
-Plants exude carbon-rich compounds from their roots
-Increased exudation with elevated CO_2
-No longer carbon limited, microbes may take up N & P, thus limiting plant growth

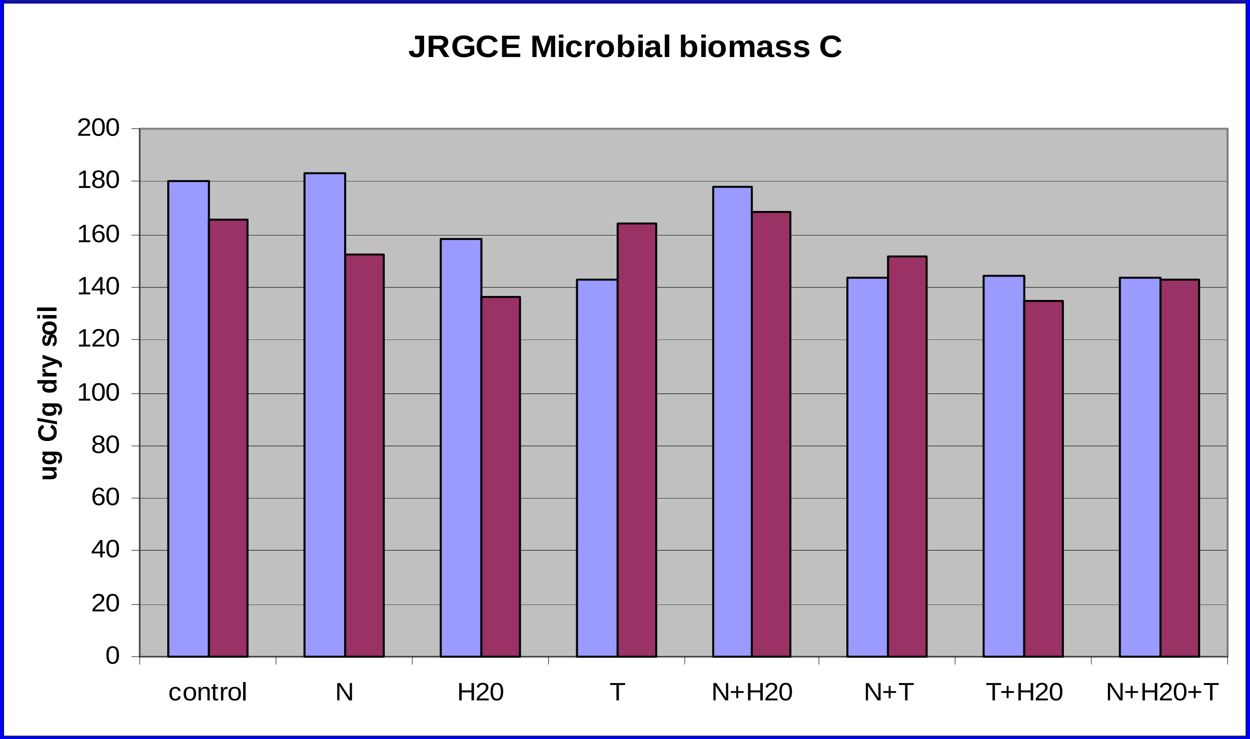


Can microbes limit plant growth responses to elevated CO_2 by immobilizing nutrients?



Elevated CO_2 lowers soil labile C (p=0.07) and microbial biomass (p=0.09)

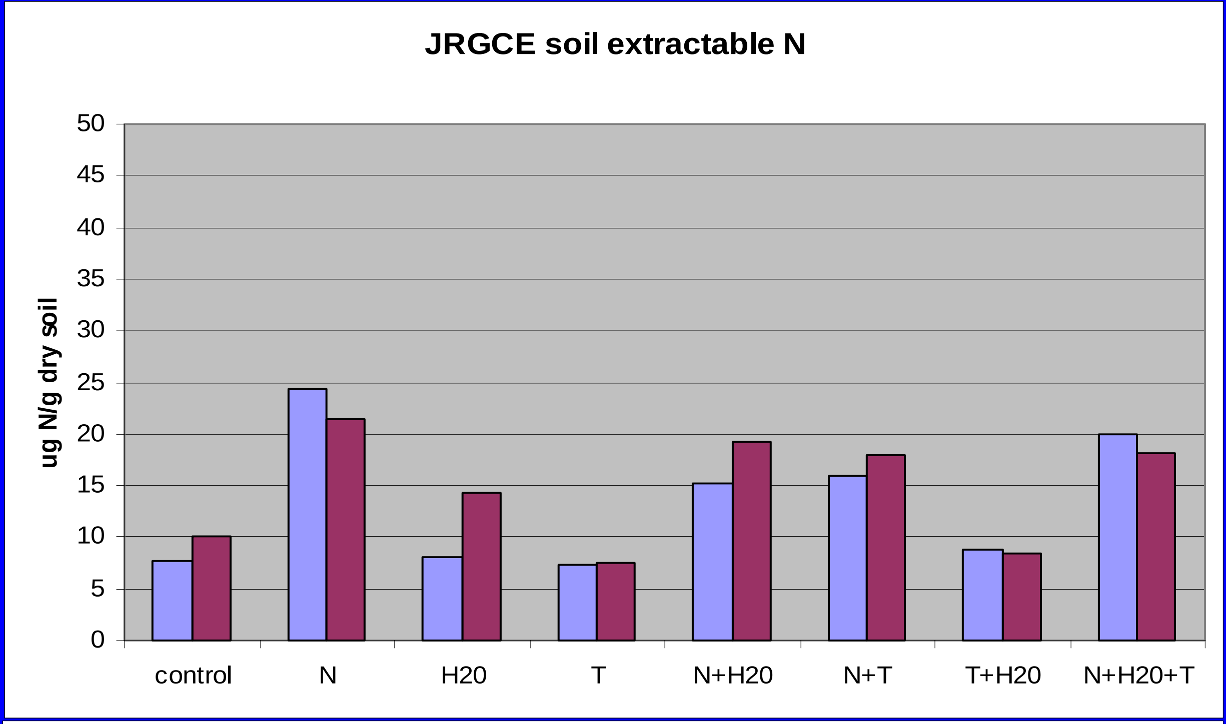




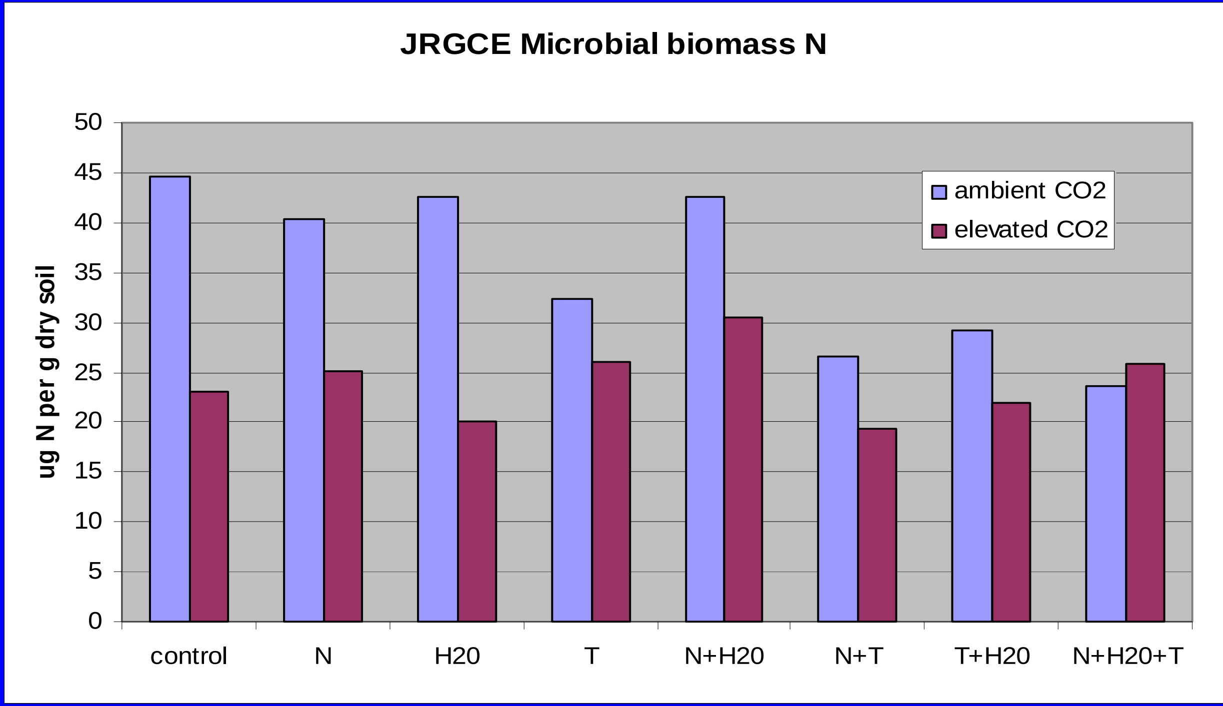
Ambient CO_2

Elevated CO_2

N-deposition increases N-availability, but elevated CO_2 has no consistent effect



Generally, there is more N in the microbial than the available pool

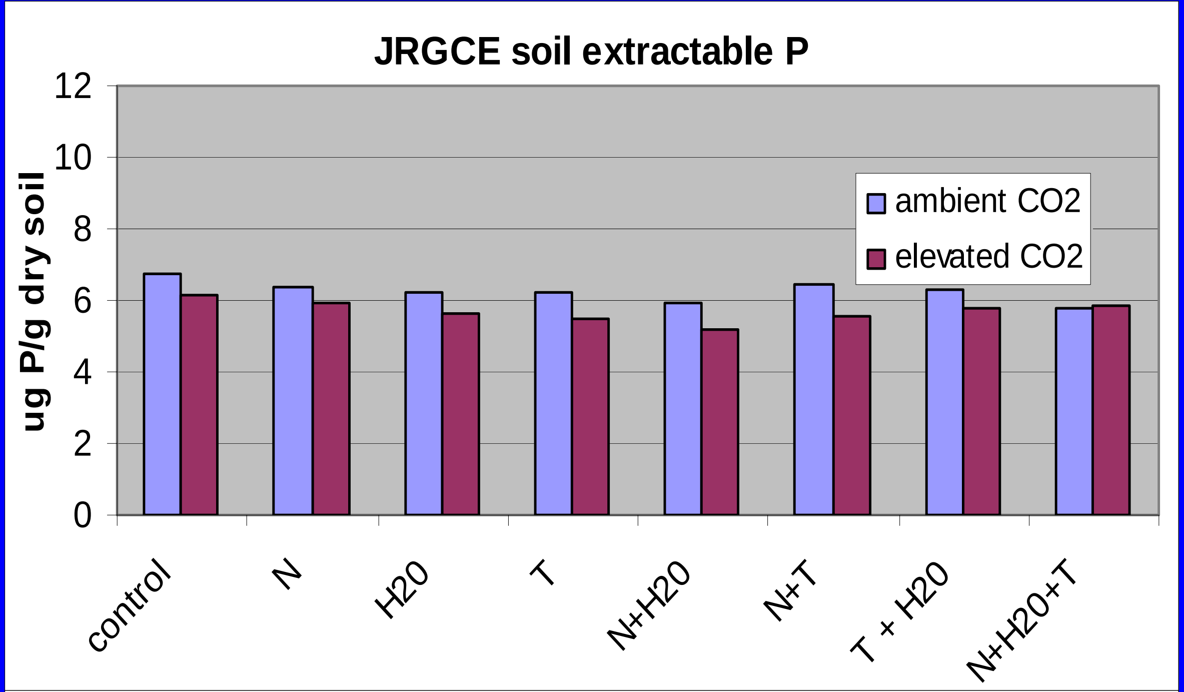


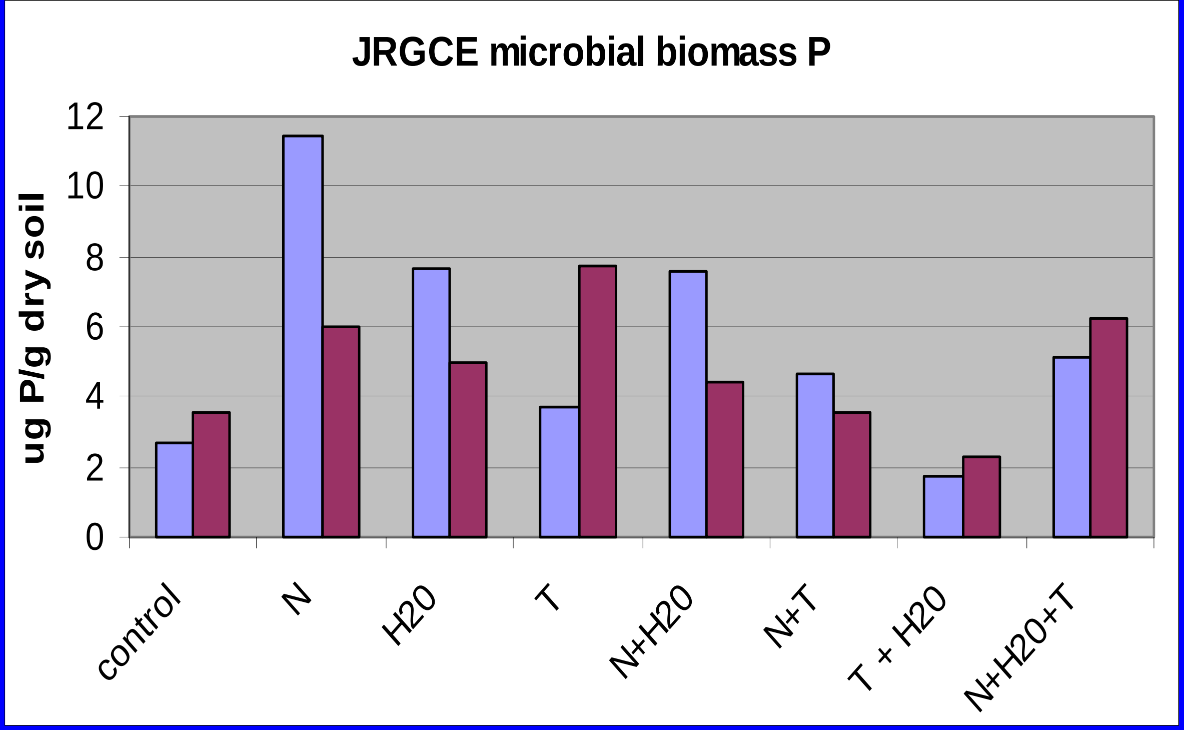
Elevated CO_2 consistently lowers the microbial N pool (no significant results)

Elevated CO_2 consistently lowers soil available P, ($p=0.19$)

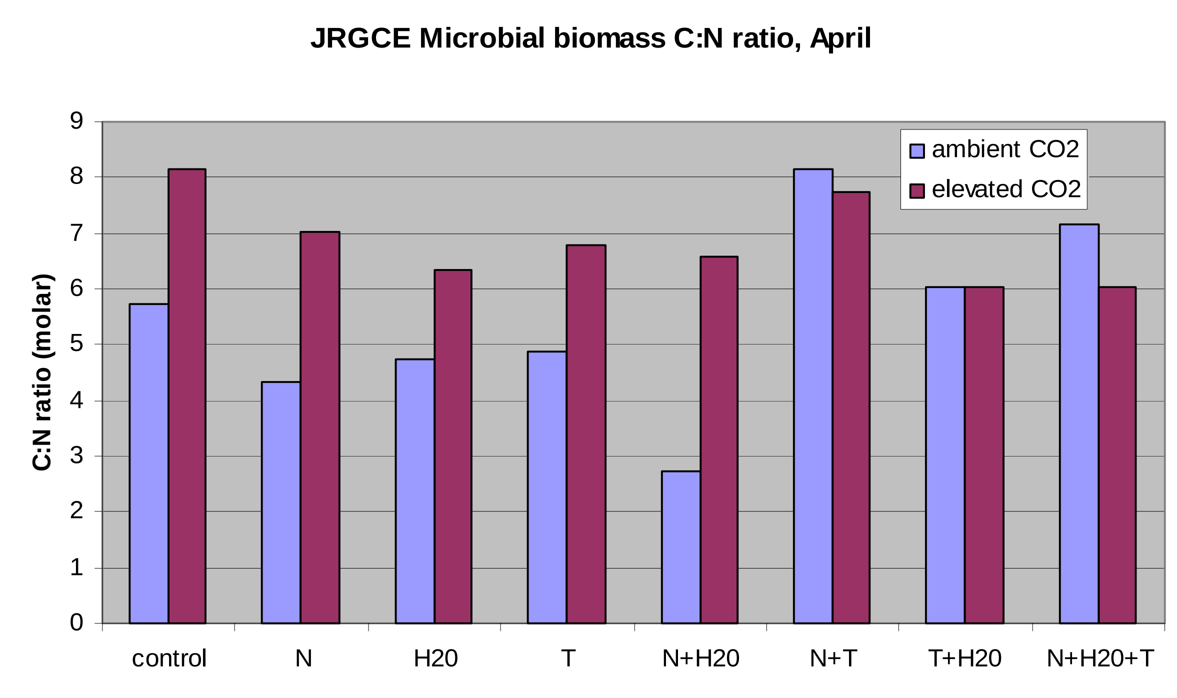
Microbial P is more variable than soil available P

N-deposition increases microbial uptake of P ($p=0.10$). Increased precipitation and heat interact to lessen the effect of N-depostition

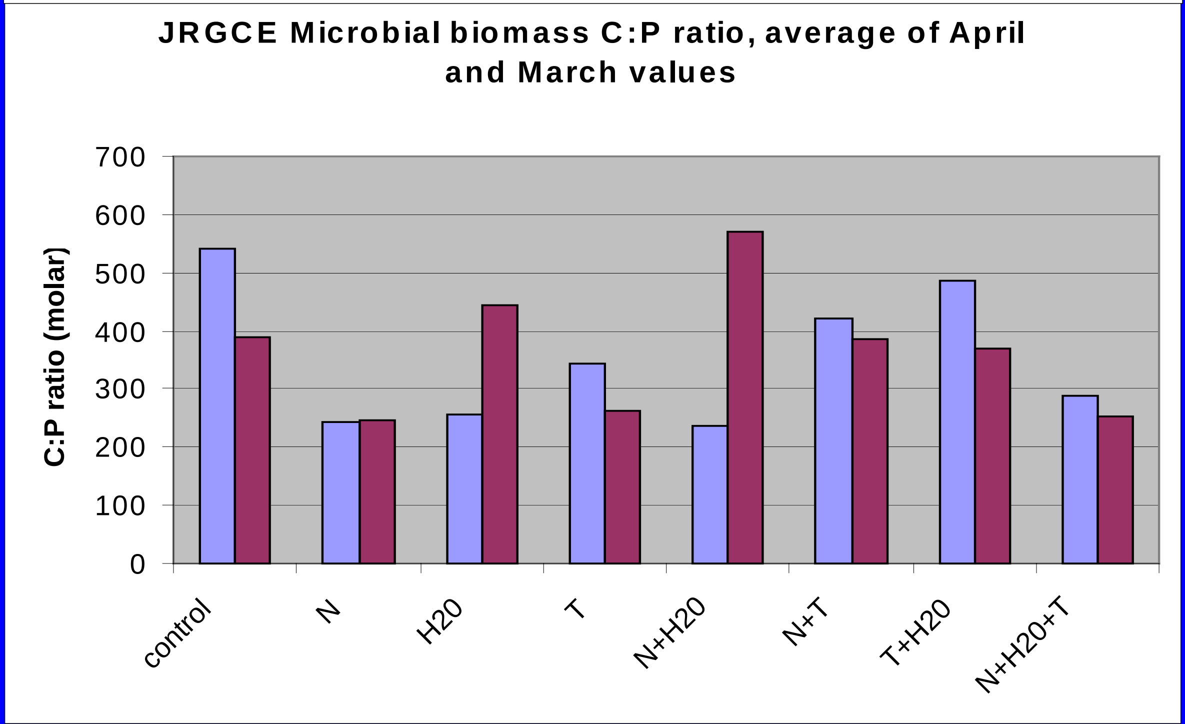




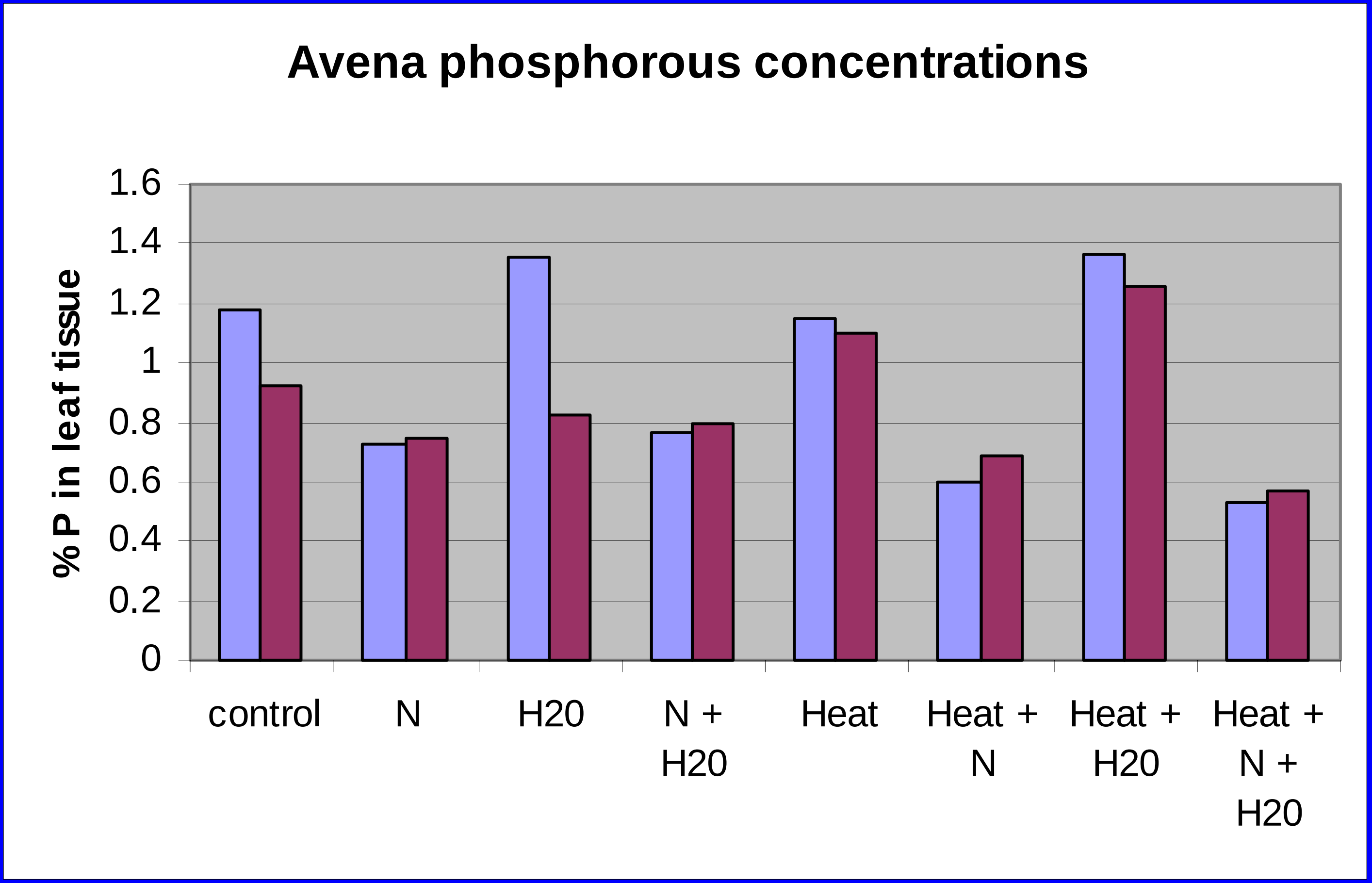
Elevated CO_2 consistently increases the C:N ratio of microbial biomass, less with multiple global changes



C:P ratios are high overall, but complicated



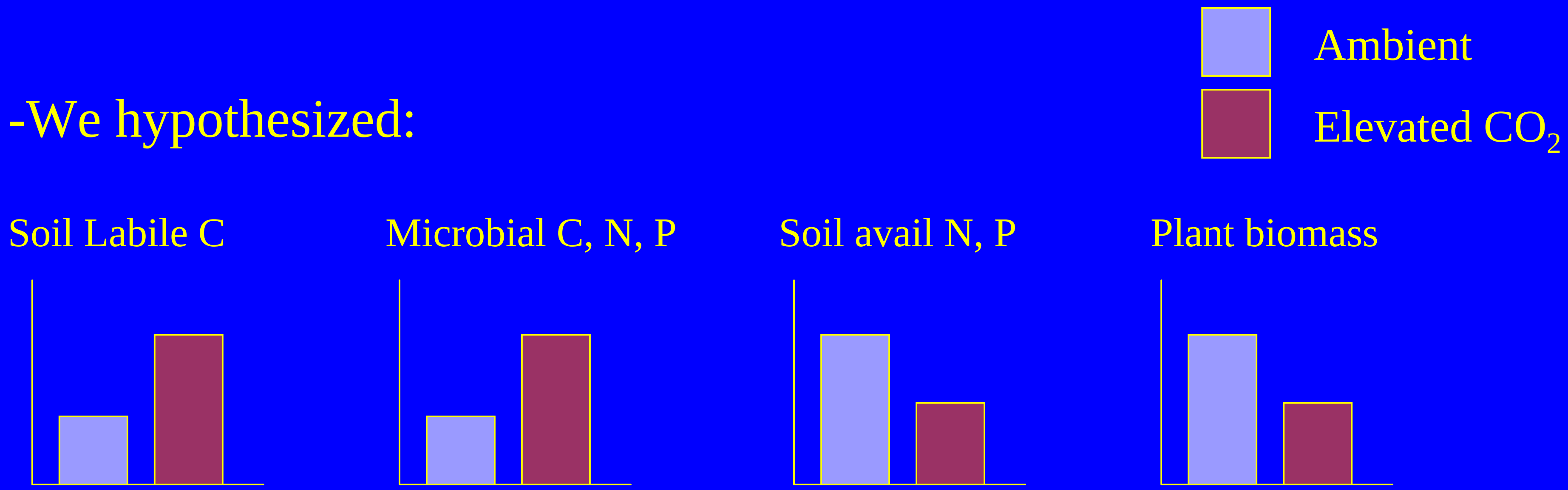
- N-deposition lowers foliar P concentrations, but no other global changes have significant effects



Data thanks to Duncan Menge

Can microbes limit plant growth responses to elevated CO_2 by immobilizing nutrients?

-We hypothesized:



Can microbes limit plant growth responses to elevated CO_2 by immobilizing nutrients?

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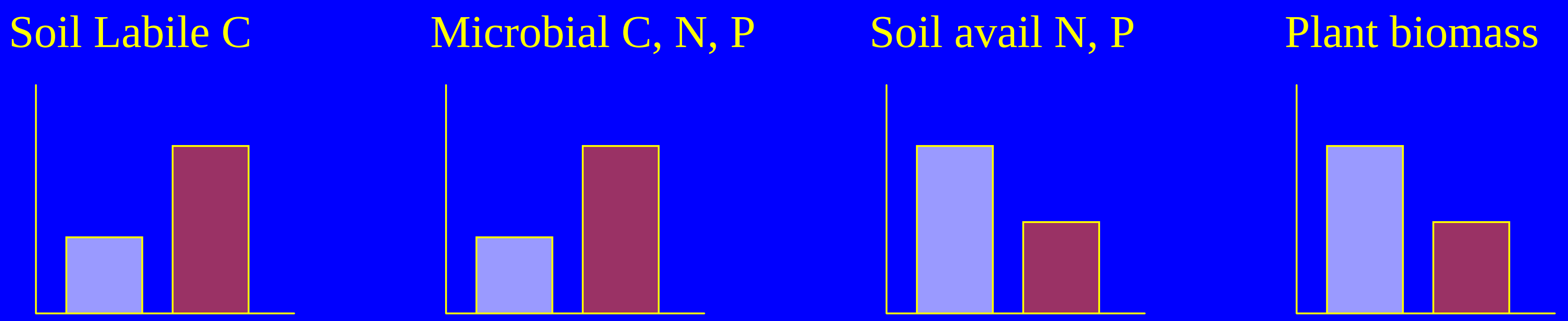
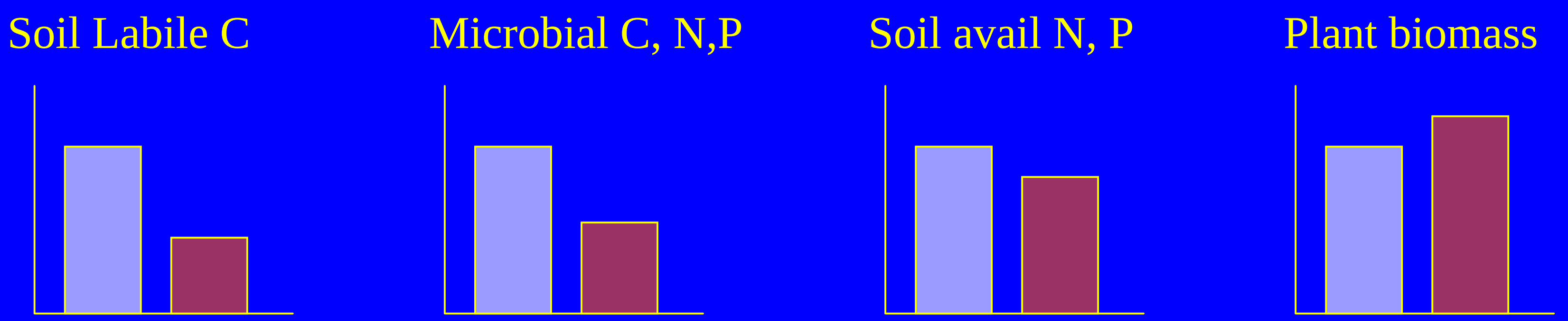


- But we found:



Summary

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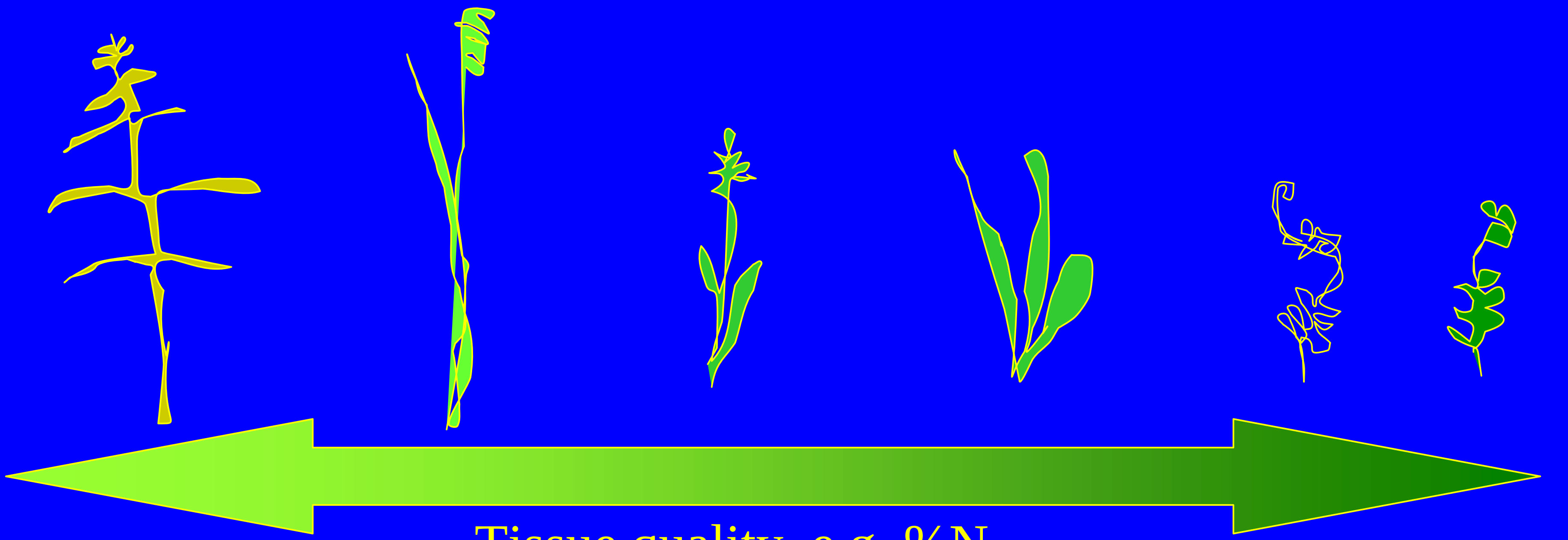
- What next?
- Decomposition experiment to address feedbacks

Plant community defined along a functional axis



Tissue quality, e.g. %N

↓ % N
↓ Quality for herbivores
↓ decomposition

↑ %N
↑ Quality for herbivores
↑ decomposition

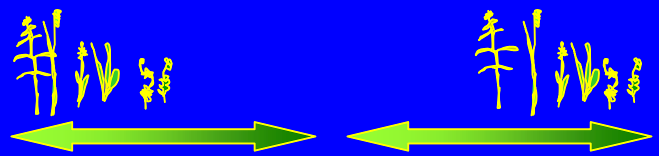
Plant responses and feedbacks to global change

Global changes

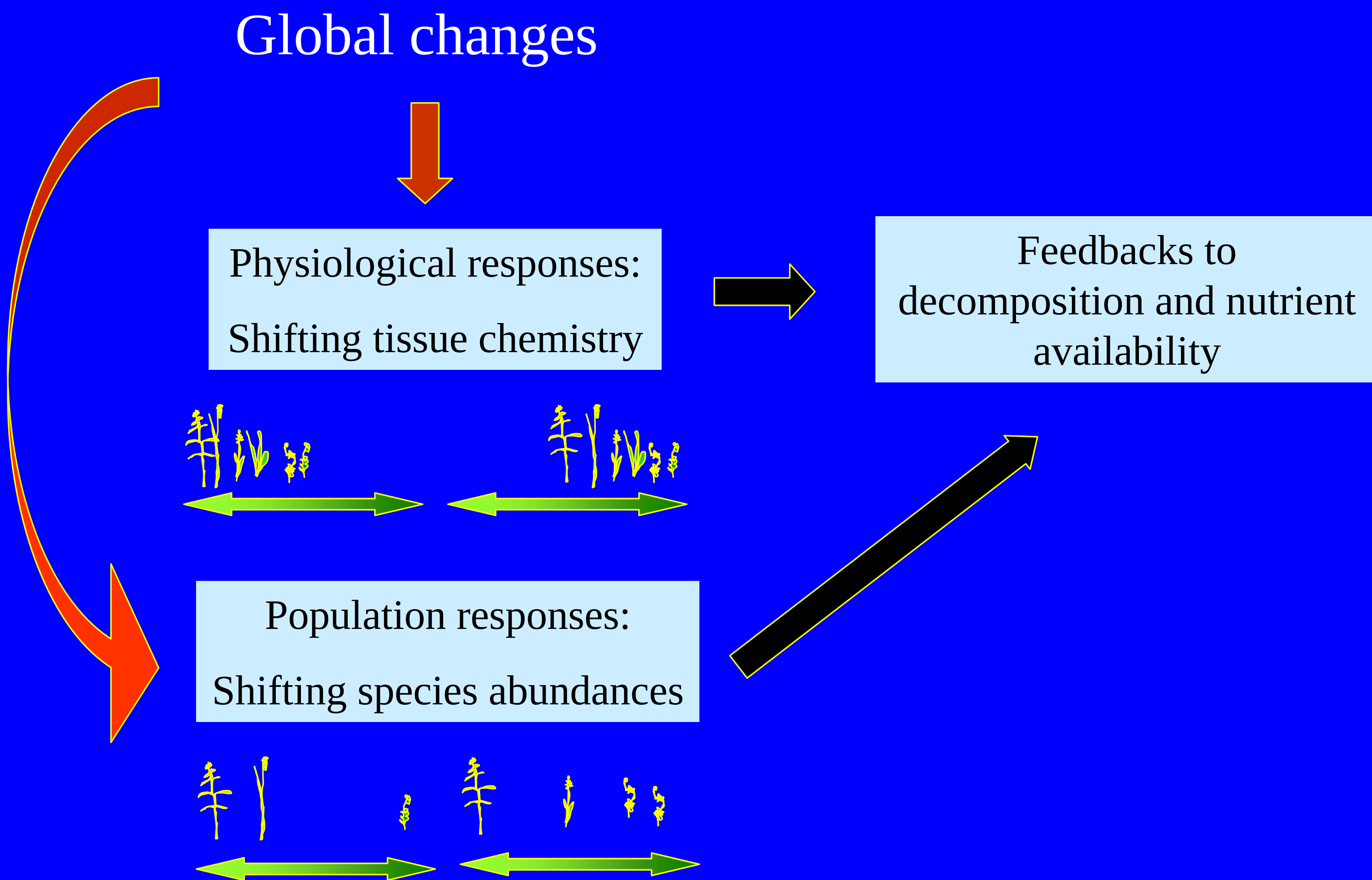
Physiological responses:

Shifting tissue chemistry

Feedbacks to decomposition and nutrient availability



Plant responses and feedbacks to global change



Decomposition experiment:

Global changes

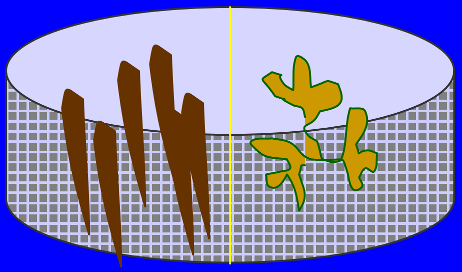
tissue chemistry

proportion of grasses & forbs

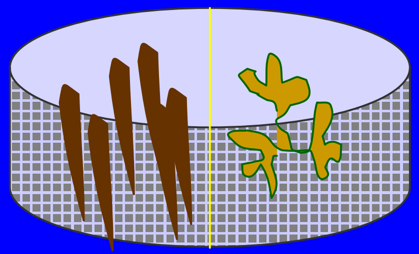
microclimate

Decomposition rate:

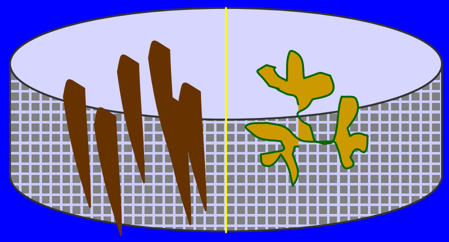
mass loss, rate of N &P return to soil



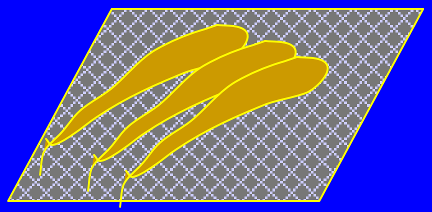
Decomposition = Shifting tissue chemistry + Shifting species composition + microclimate



Decompose material from each plot in place



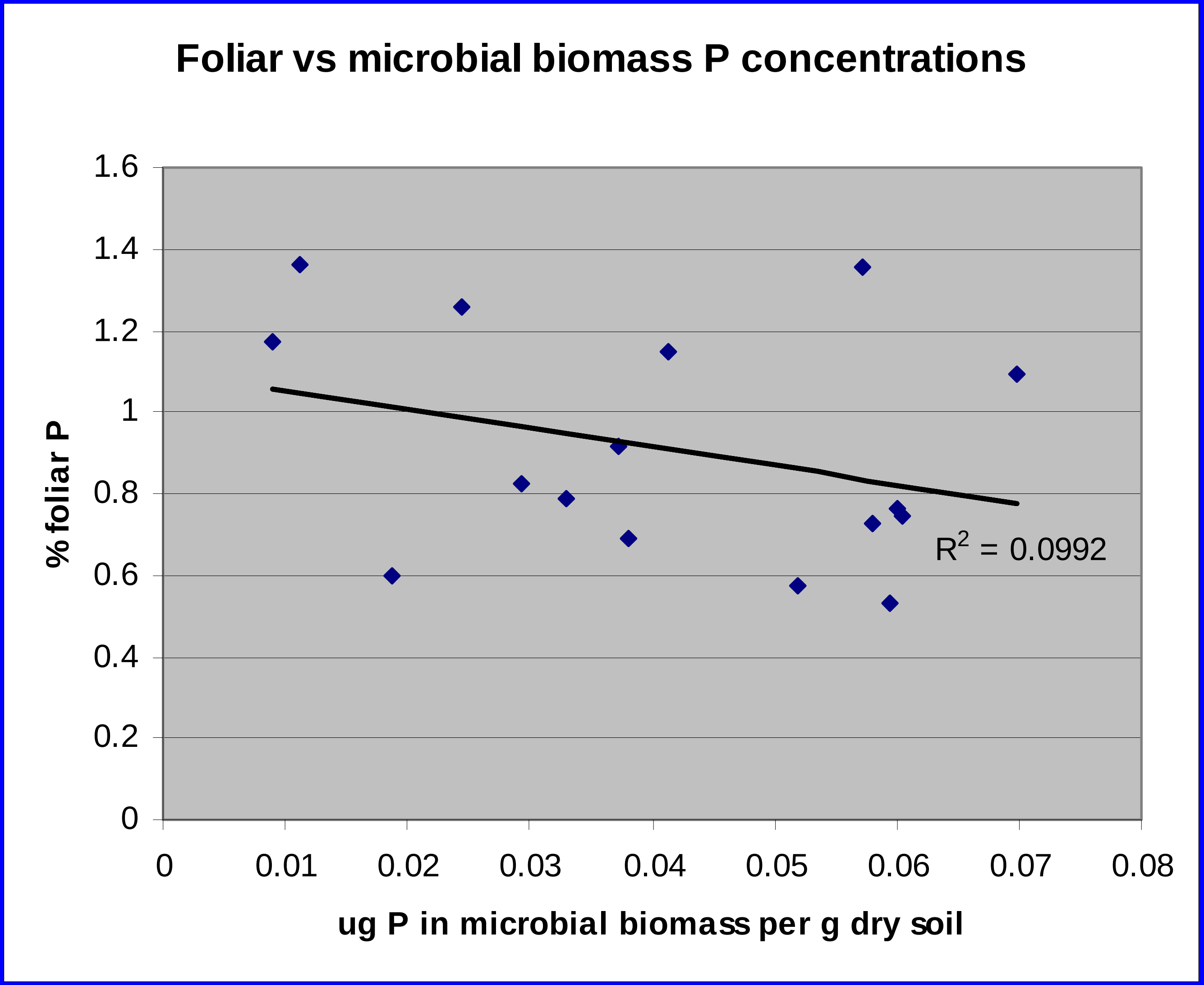
Decompose material in a "common garden", to isolate the effects of shifting tissue chemistry



Decompose a "common substrate" in the plots, to isolate the abiotic effects of globalchanges

Acknowledgements

- Thanks to the DOE GREF Fellowship program for support
- Thanks to NSF, the Mellon Foundation, and the California Native Plant Society for funding the JRGCE research
- Thanks to many collaborators including Chris Field, Hal Mooney, Nona Chiariello, Becky Shaw, Erika Zavaletta, Hugh Henry and Duncan Menge


Foliar vs microbial biomass P concentrations
% foliar P
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
R^2 = 0.0992
ug P in microbial biomass per g dry soil