

Plants and nutrients

March 16, 2021



Figures from textbooks unless otherwise noted

What essential elements do
plants use?

TABLE 5.1 Tissue levels of essential elements required by most plants

Element	Chemical symbol	Concentration in dry matter (% or ppm) ^a	Relative number of atoms with respect to molybdenum
Obtained from water or carbon dioxide			
Hydrogen	H	6	60,000,000
Carbon	C	45	40,000,000
Oxygen	O	45	30,000,000
Obtained from the soil			
Macronutrients			
Nitrogen	N	1.5	1,000,000
Potassium	K	1.0	250,000
Calcium	Ca	0.5	125,000
Magnesium	Mg	0.2	80,000
Phosphorus	P	0.2	60,000
Sulfur	S	0.1	30,000
Silicon	Si	0.1	30,000
Micronutrients			
Chlorine	Cl	100	3,000
Iron	Fe	100	2,000
Boron	B	20	2,000
Manganese	Mn	50	1,000
Sodium	Na	10	400
Zinc	Zn	20	300
Copper	Cu	6	100
Nickel	Ni	0.1	2
Molybdenum	Mo	0.1	1

Source: Epstein 1972, 1999.

^aThe values for the nonmineral elements (H, C, O) and the macronutrients are percentages. The values for micronutrients are expressed in parts per million.

What do they use them for?

TABLE 5.2 Classification of plant mineral nutrients according to biochemical function

Mineral nutrient	Functions
Group 1	Nutrients that are part of carbon compounds
N	Constituent of amino acids, amides, proteins, nucleic acids, nucleotides, coenzymes, hexosamines, etc.
S	Component of cysteine, cystine, methionine. Constituent of lipoic acid, coenzyme A, thiamine pyrophosphate, glutathione, biotin, 5'-adenylylsulfate, and 3'-phosphoadenosine.
Group 2	Nutrients that are important in energy storage or structural integrity
P	Component of sugar phosphates, nucleic acids, nucleotides, coenzymes, phospholipids, phytic acid, etc. Has a key role in reactions that involve ATP.
Si	Deposited as amorphous silica in cell walls. Contributes to cell wall mechanical properties, including rigidity and elasticity.
B	Complexes with mannitol, mannan, polymannuronic acid, and other constituents of cell walls. Involved in cell elongation and nucleic acid metabolism.
Group 3	Nutrients that remain in ionic form
K	Required as a cofactor for more than 40 enzymes. Principal cation in establishing cell turgor and maintaining cell electroneutrality.
Ca	Constituent of the middle lamella of cell walls. Required as a cofactor by some enzymes involved in the hydrolysis of ATP and phospholipids. Acts as a second messenger in metabolic regulation.
Mg	Required by many enzymes involved in phosphate transfer. Constituent of the chlorophyll molecule.
Cl	Required for the photosynthetic reactions involved in O ₂ evolution.
Zn	Constituent of alcohol dehydrogenase, glutamic dehydrogenase, carbonic anhydrase, etc.
Na	Involved with the regeneration of phosphoenolpyruvate in C ₄ and CAM plants. Substitutes for potassium in some functions.
Group 4	Nutrients that are involved in redox reactions
Fe	Constituent of cytochromes and nonheme iron proteins involved in photosynthesis, N ₂ fixation, and respiration.
Mn	Required for activity of some dehydrogenases, decarboxylases, kinases, oxidases, and peroxidases. Involved with other cation-activated enzymes and photosynthetic O ₂ evolution.
Cu	Component of ascorbic acid oxidase, tyrosinase, monoamine oxidase, uricase, cytochrome oxidase, phenolase, laccase, and plastocyanin.
Ni	Constituent of urease. In N ₂ -fixing bacteria, constituent of hydrogenases.
Mo	Constituent of nitrogenase, nitrate reductase, and xanthine dehydrogenase.

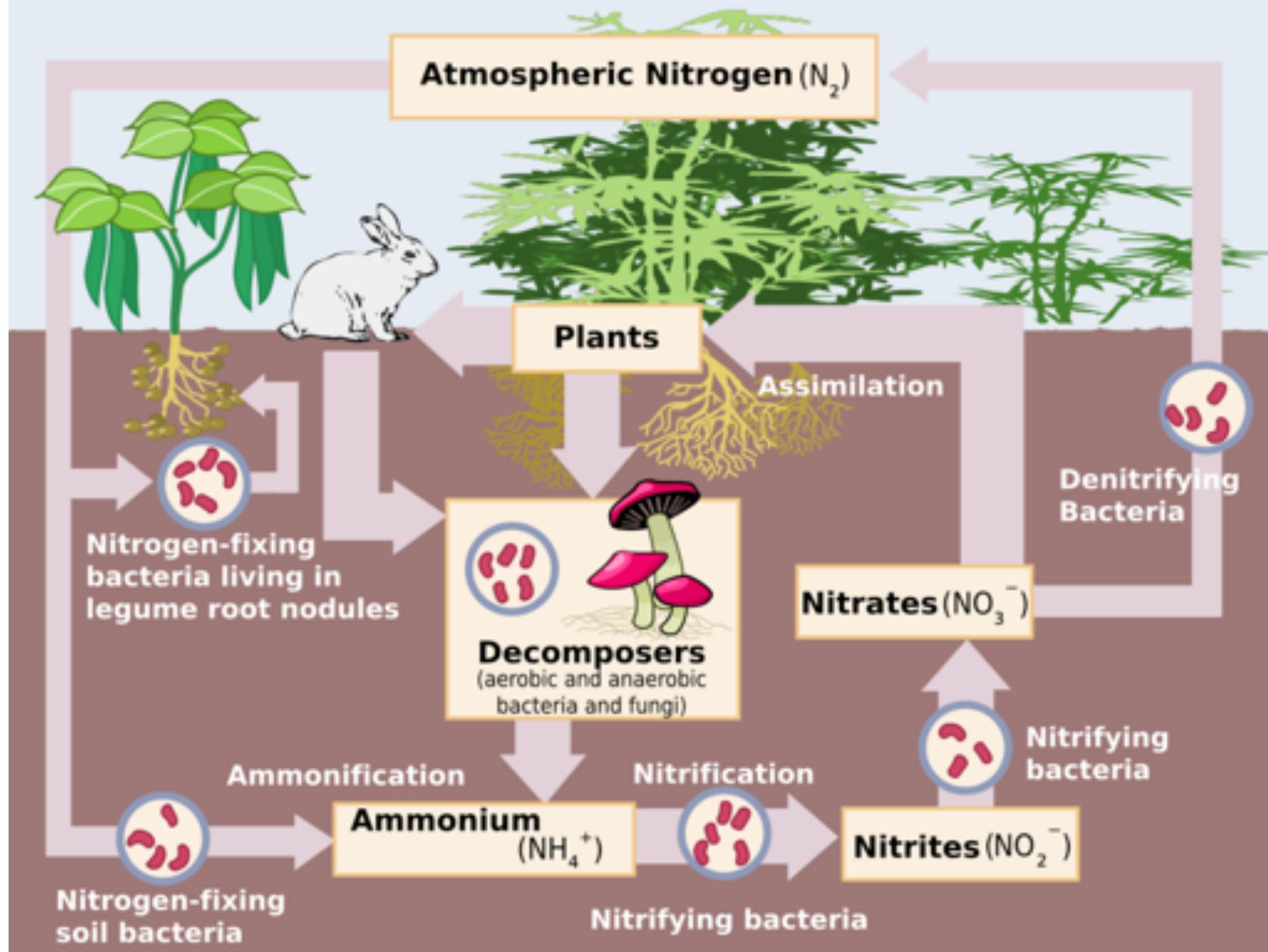
Source: After Evans and Sorger 1966 and Mengel and Kirkby 2001.

How do nutrients get into the soil?

TABLE 1. Major sources of available nutrients that enter the soil.

Nutrient	Source of nutrient (% of total)		
	Atmosphere	Weathering	Recycling
Temperate forest			
N	7	0	93
P	1	<10?	>89
K	2	10	88
Ca	4	31	65
Arctic tundra			
N	4	0	96
P	4	<1	96

Source: Chapin 1991.

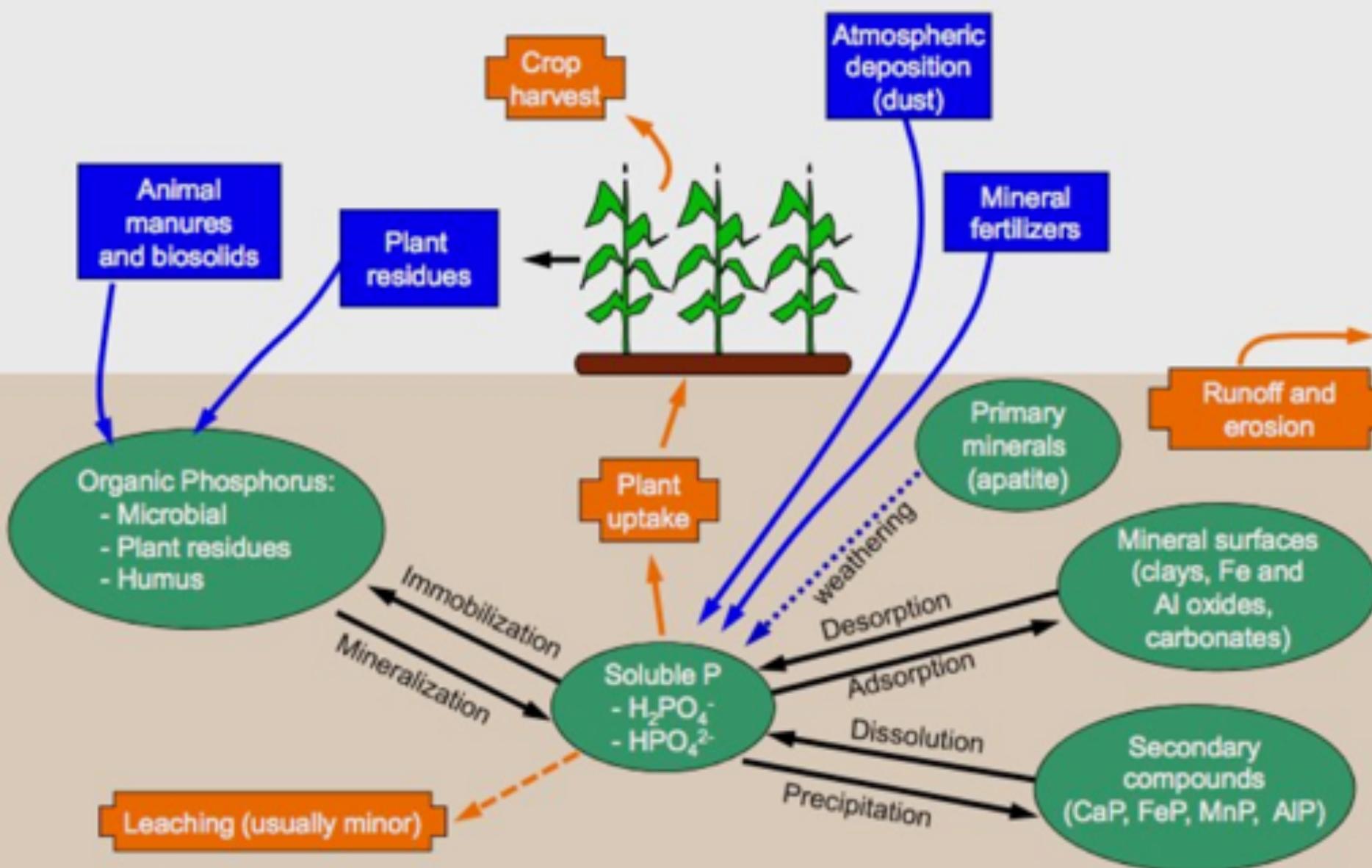


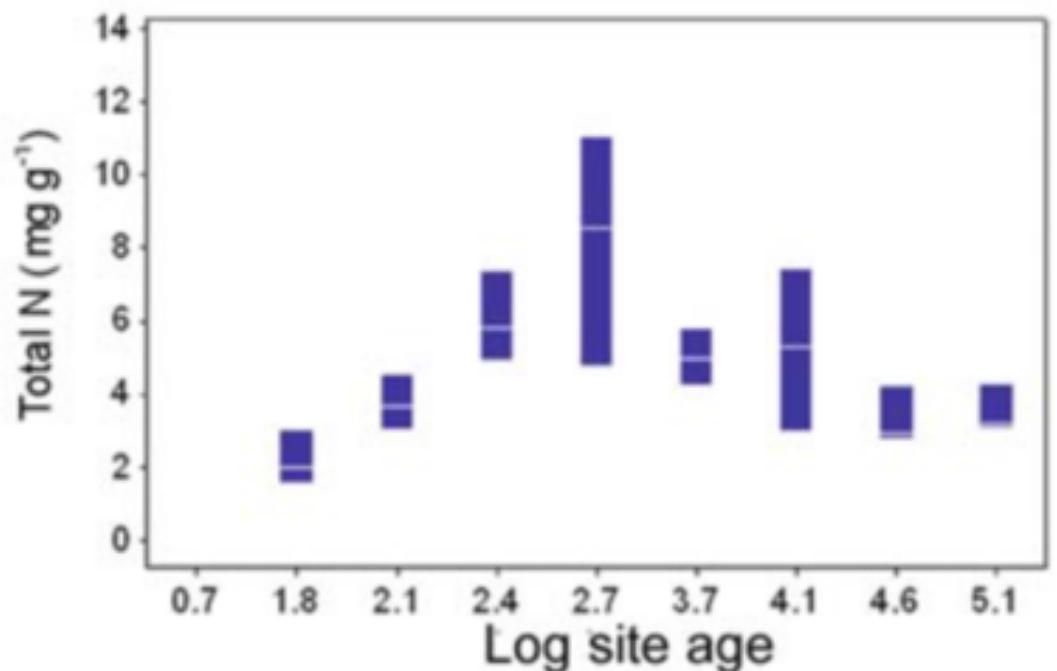
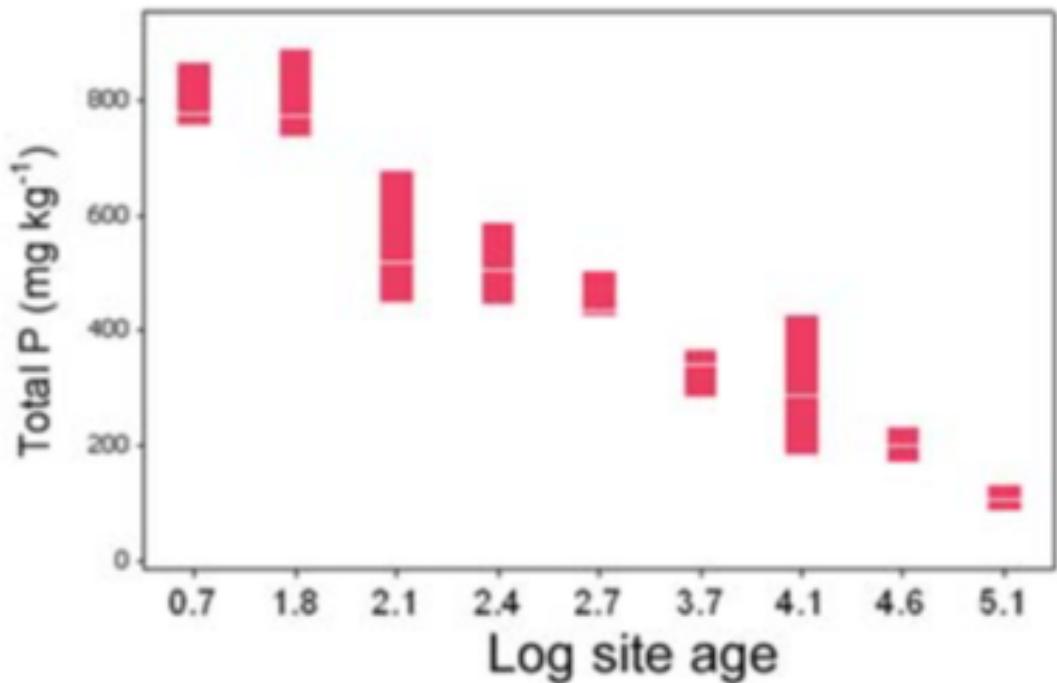
The Phosphorus cycle

Component

Input to soil

Loss from soil





What could explain these trends?

Nutrition impacts: NPP

N addition increases NPP by 29% (Lebauer and Treseder, 2008)

TABLE 1. Effects of nitrogen on plant growth, overall and grouped by biome.

Grouping	<i>n</i>	<i>R</i>	95% CI	<i>Q</i>	<i>P</i>
Overall	126	1.29	1.22–1.35	1032	<0.0001
Biome	7			20.5	0.0022
Temperate forest	22	1.19	1.11–1.28		<0.0001
Tropical forest	16	1.60	1.30–1.97		<0.0001
Excluding young Hawaiian soils	8	1.20	1.04–1.40		0.013
Young Hawaiian soils	8	2.13	1.48–3.08		<0.0001
Tundra	10	1.35	1.12–1.64		0.0018
Tropical grassland	6	1.26	1.04–1.54		0.021
Desert	3	1.11	0.80–1.55		0.53
Temperate grassland	32	1.53	1.37–1.71		<0.0001
Wetland	36	1.16	1.00–1.34		0.045

Notes: The response ratio, *R*, is the ratio of estimated aboveground net primary productivity in the fertilized to the control plots. An *R* > 1 reflects a positive growth response to nitrogen and indicates nitrogen limitation as defined in *Methods*. The homogeneity statistic *Q* is used to assess homogeneity of effect sizes. Boldface type indicates responses that are significant at *P* < 0.05.

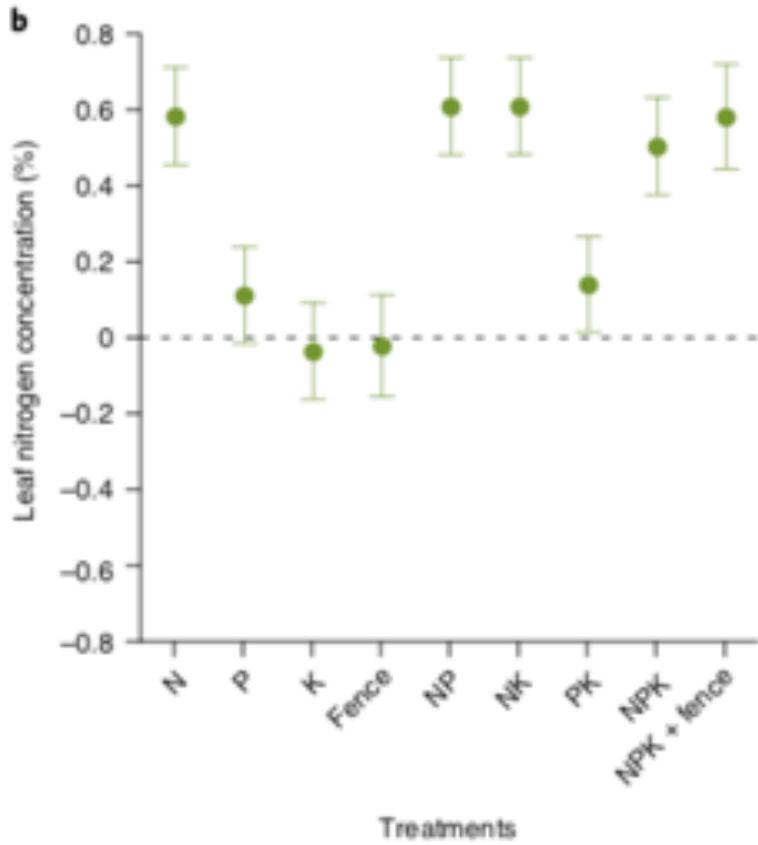
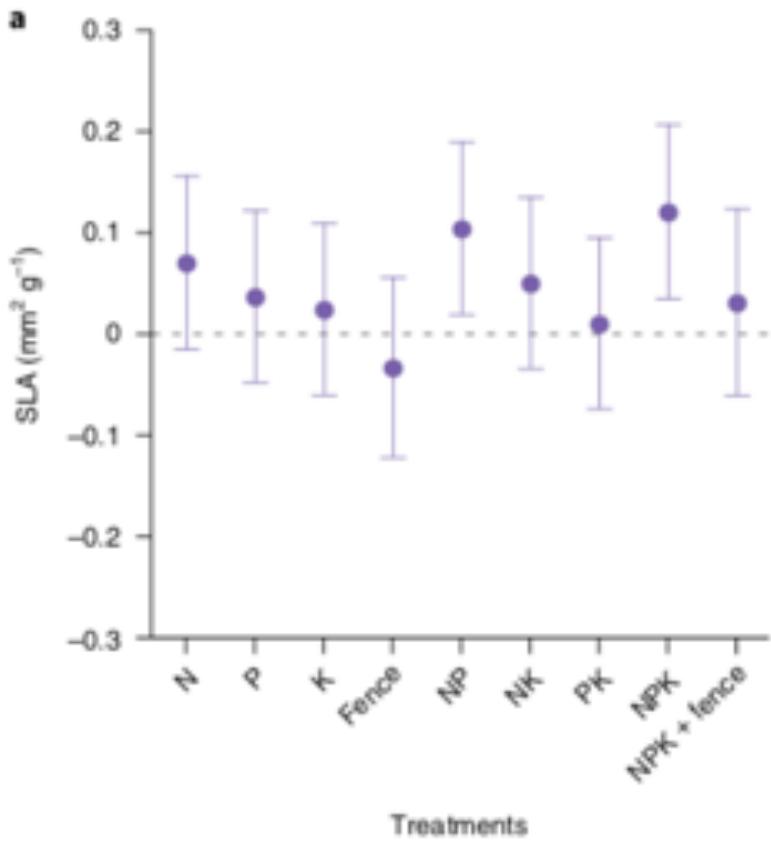
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What could explain this effect?



Leaves are basically the same shape, but get packed with more N

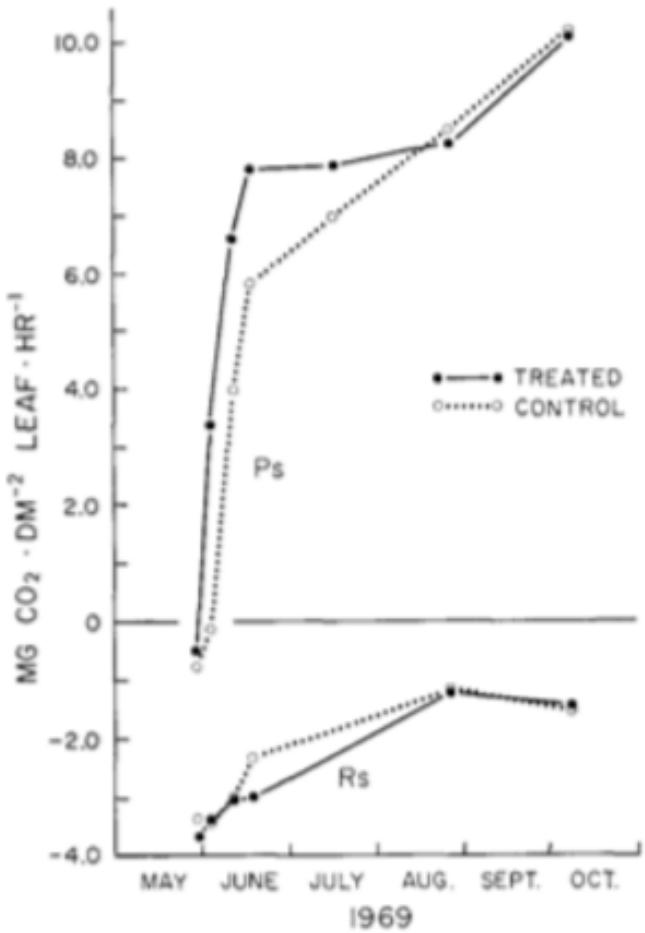


FIGURE 3. Net photosynthesis (Ps) and dark respiration (Rs) in 1969 for current shoots of Douglas-fir trees treated April 1968.

Not necessarily doing more photosynthesis though...

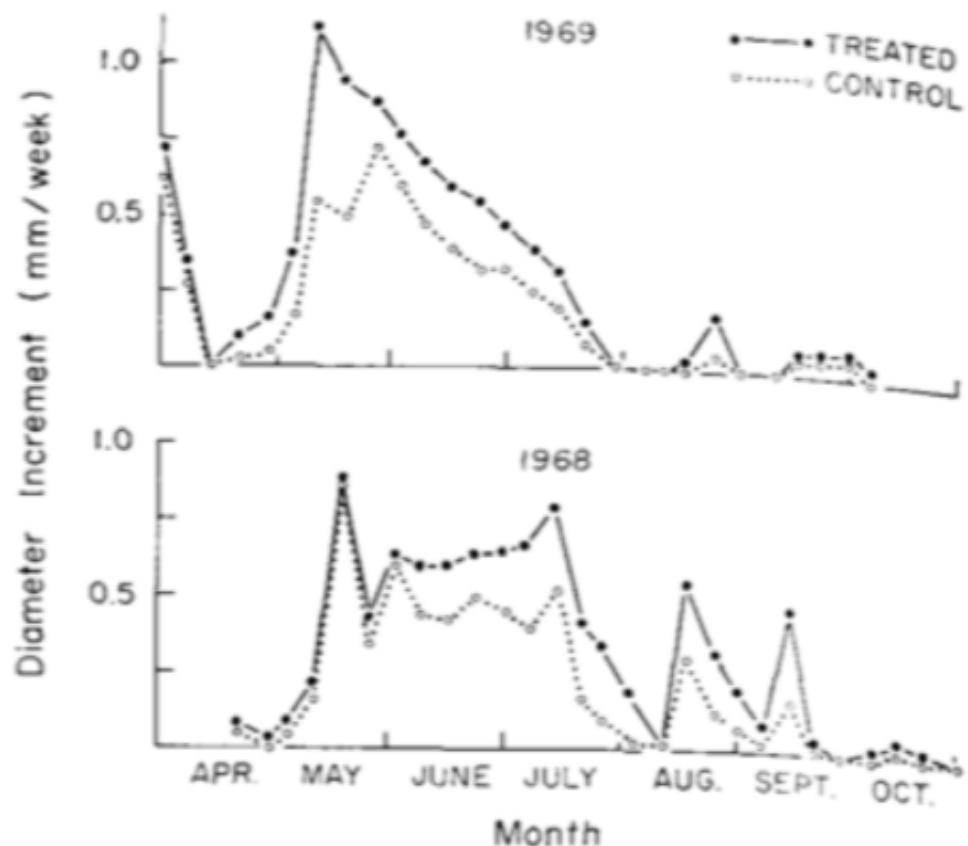
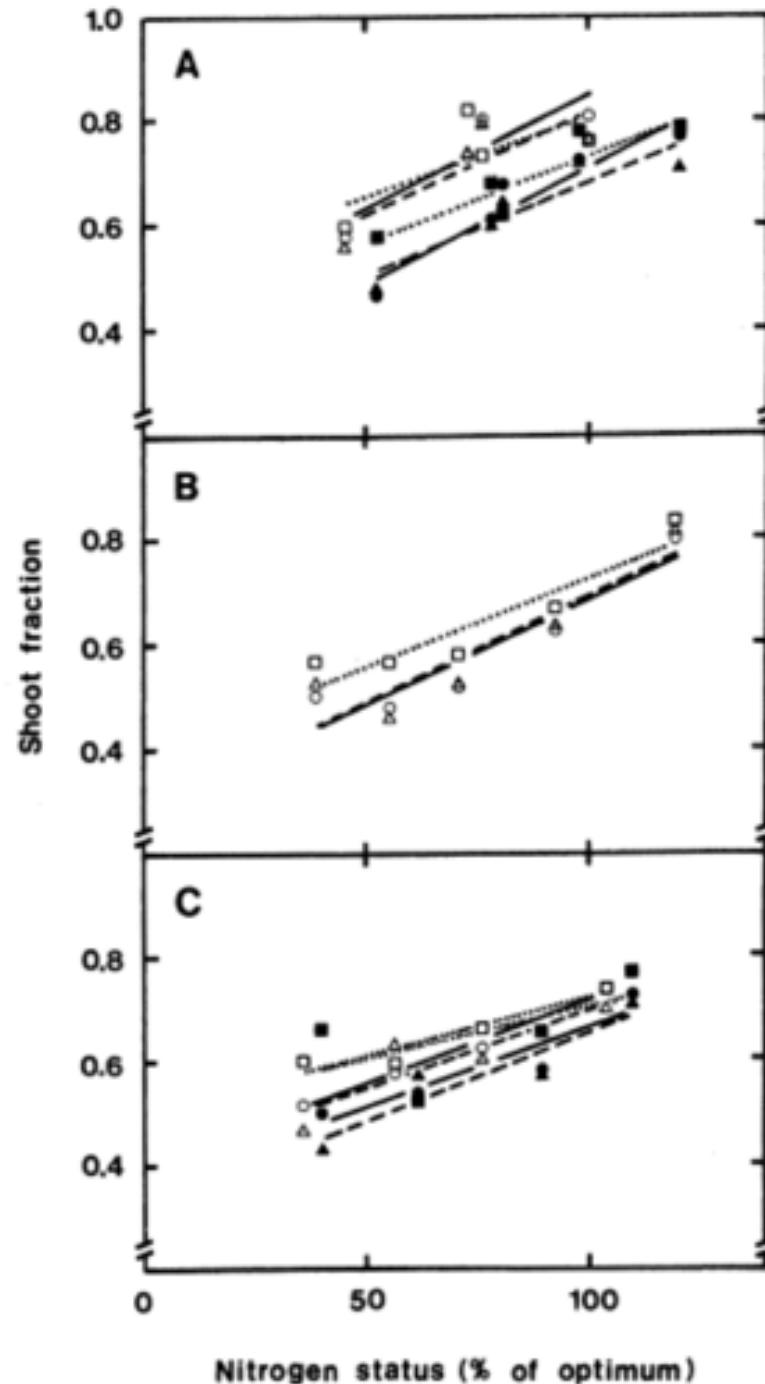


FIGURE 1. *Rates of weekly diameter growth for Douglas-fir in the 2 years following fertilization in April 1968.*

But plants are growing!

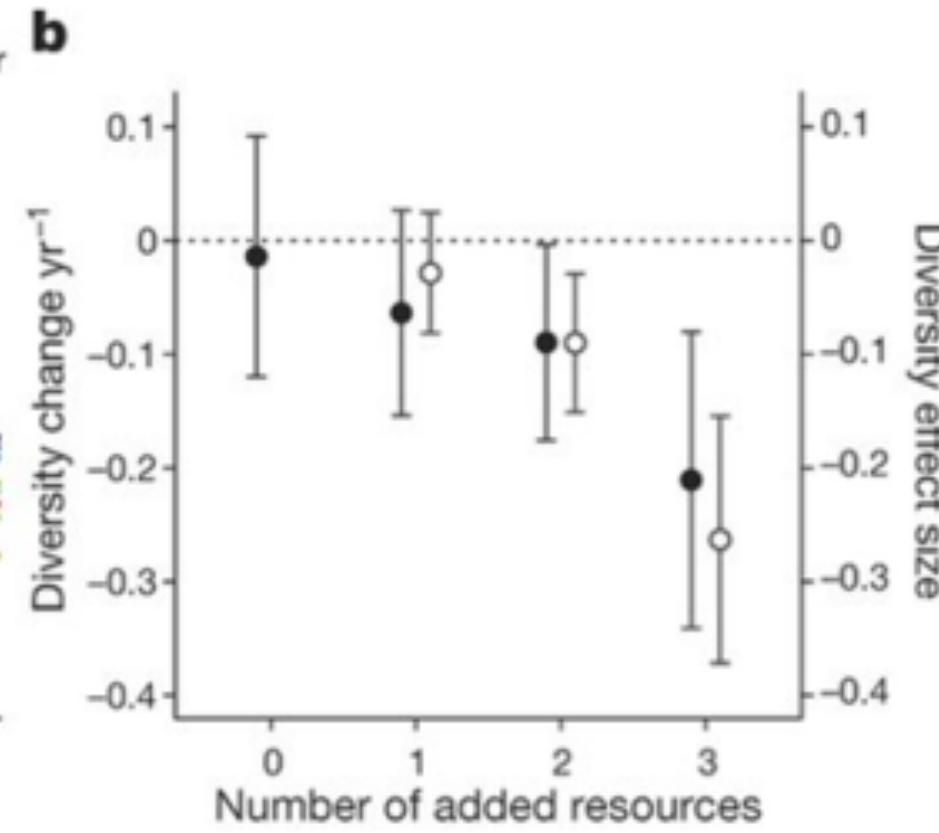
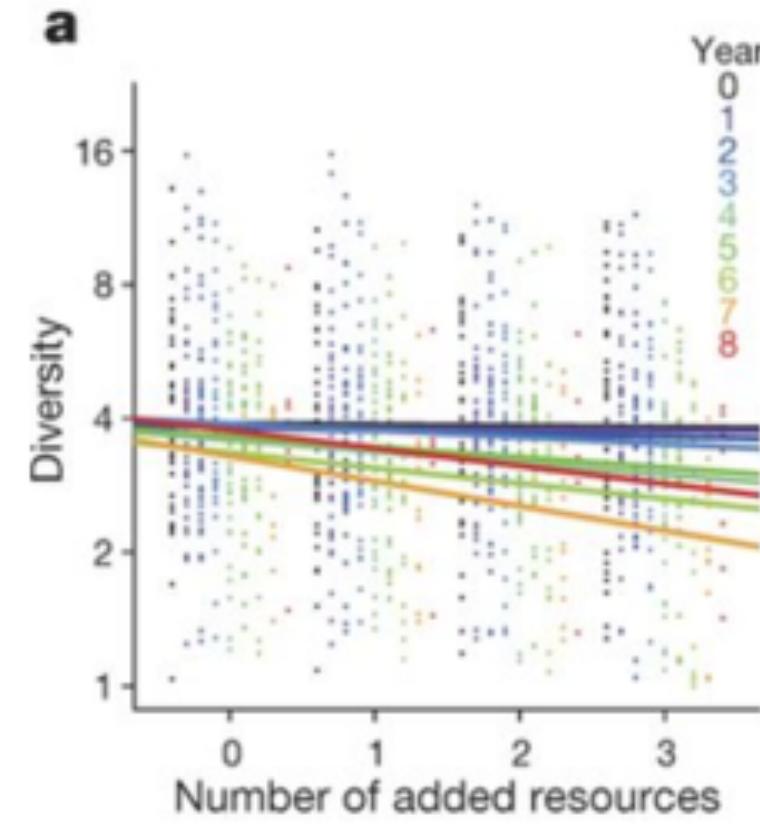


More leaves and shoots are produced
at the expense of roots

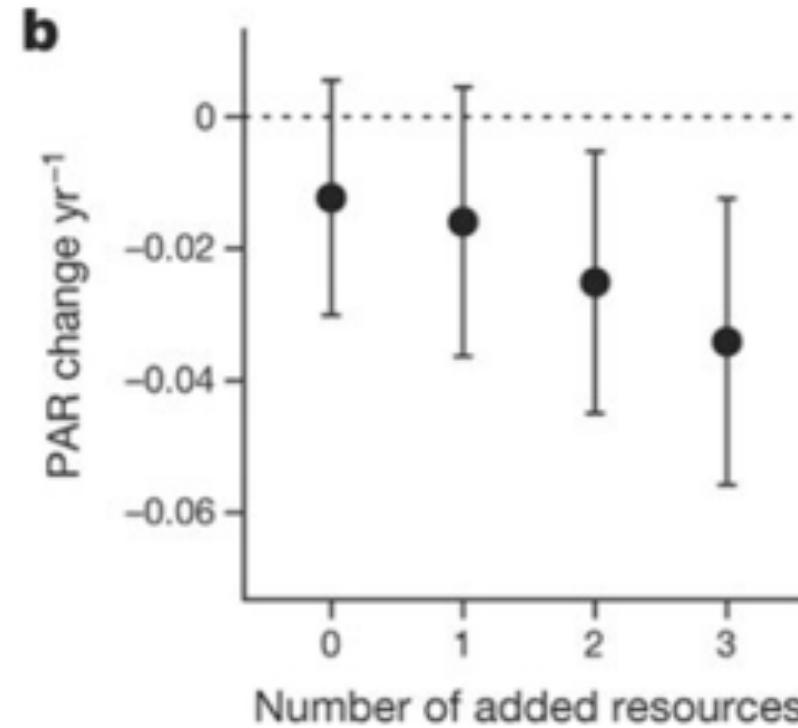
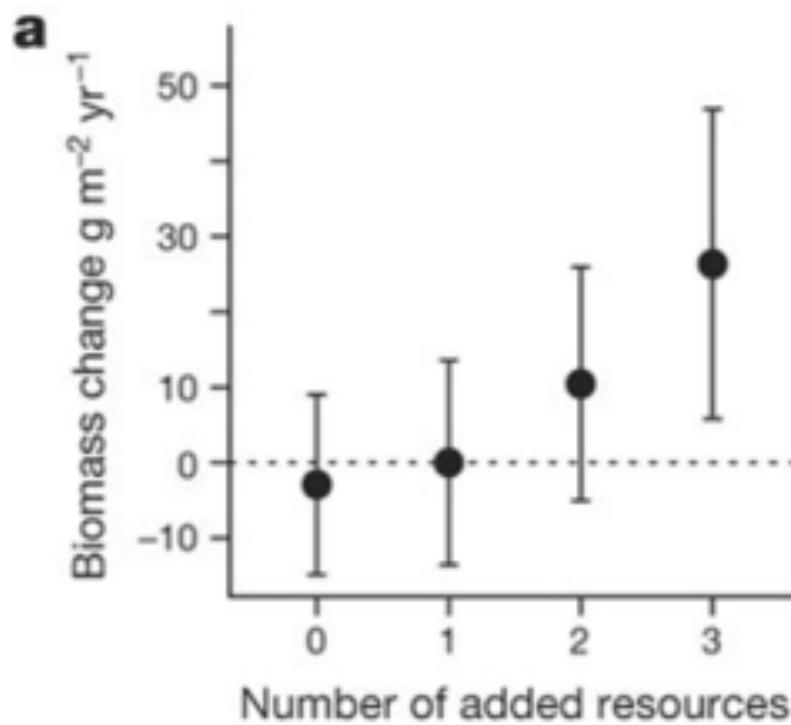
Nutrition effects on physiological processes

- Growth: increases
- Storage: increases
- Photosynthesis: not necessarily impacted
- Allocation: shift to aboveground

Nutrition impacts: Diversity



Why would adding nutrients reduce diversity?



A shift in the
importance of
other resources!

Competition example: tallgrass prairie



Competition example: tallgrass prairie

Wildflowers

- C3
- Fast growing
- Use a lot of resources (e.g., Nitrogen)

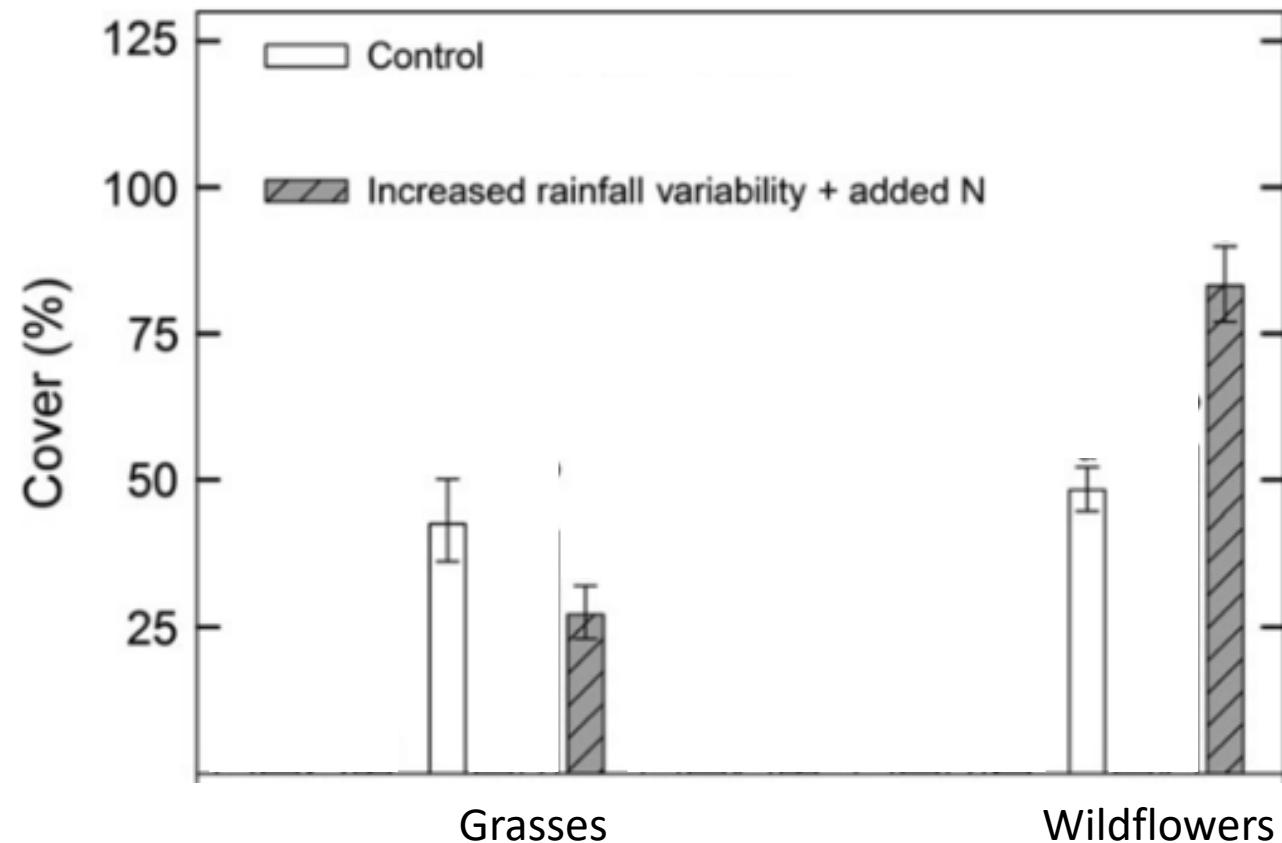


Grasses

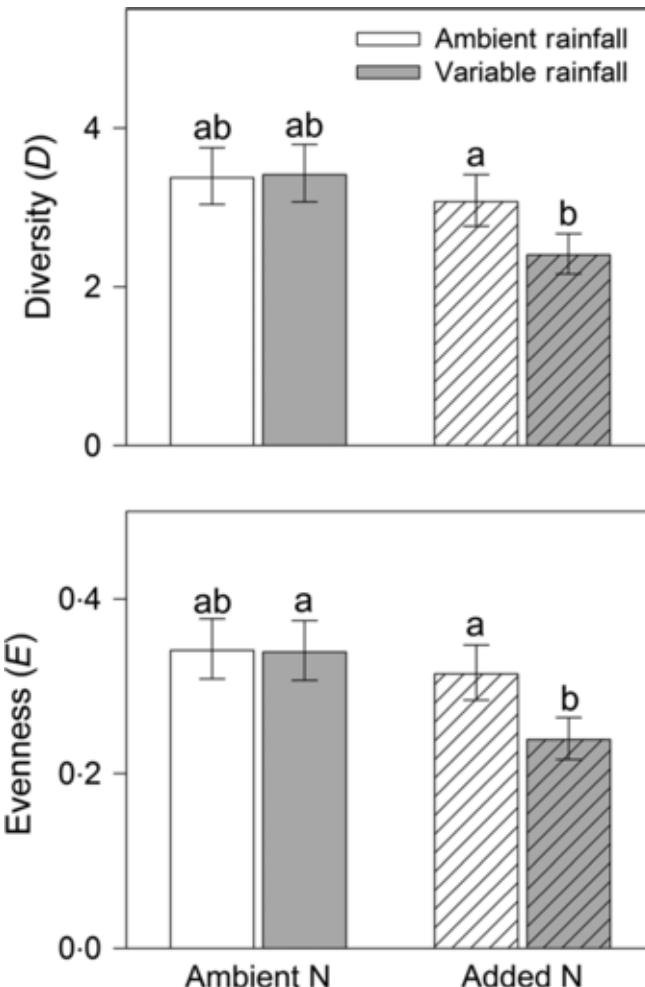
- C4
- Slow growing
- Efficient resource use



Competition example: tallgrass prairie



Competition example: tallgrass prairie

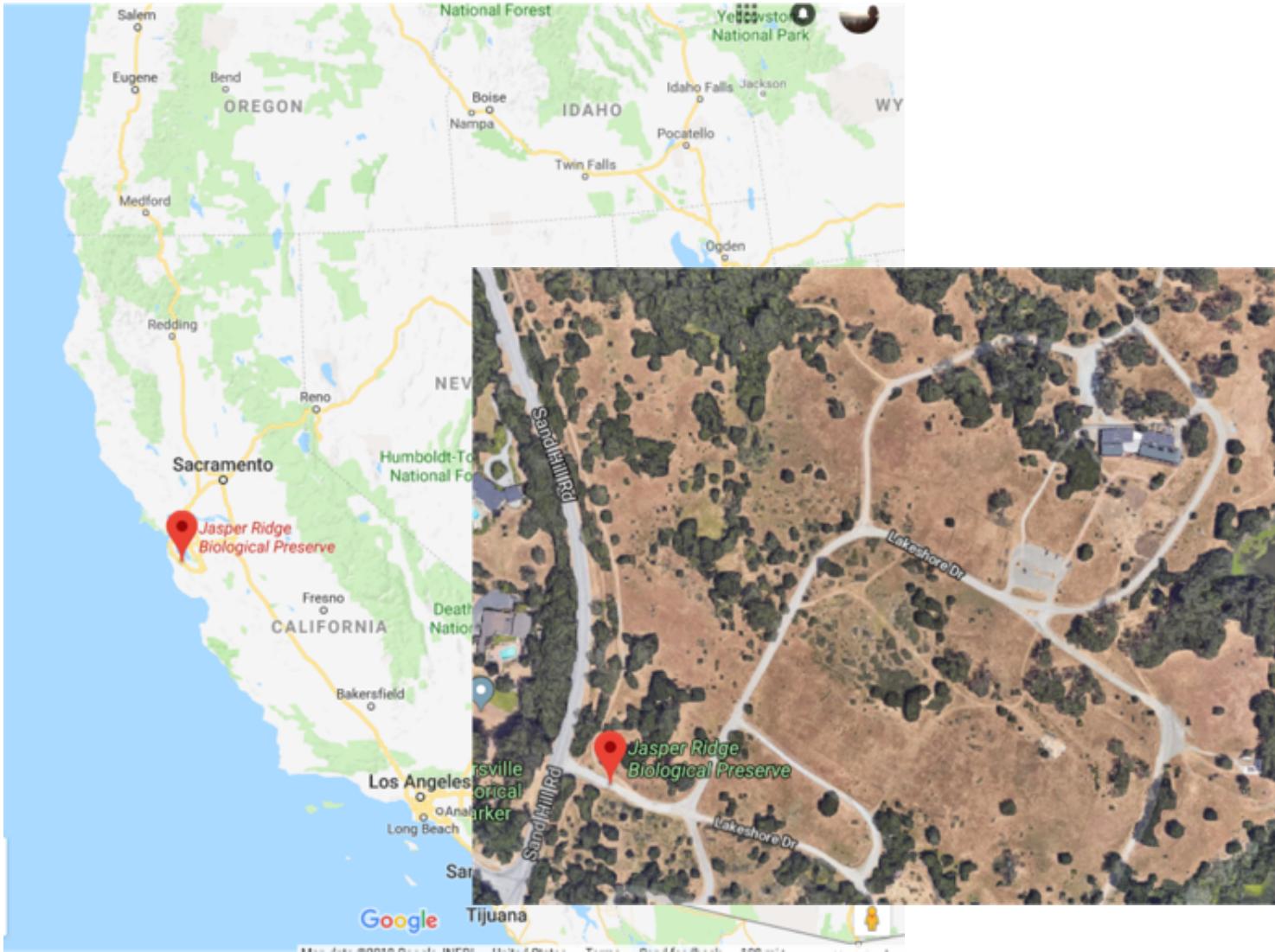


Tying together global change

The Jasper Ridge Global Change Experiment



The Jasper Ridge GCE: location



Annual grassland
Mediterranean climate

The Jasper Ridge GCE: treatments



CO₂ (FACE)

1. Ambient
2. 680 ppm

Temperature (heaters)

1. Ambient
2. Ambient + 1°C

Precipitation (sprinklers)

1. Ambient
2. 150% Ambient

Nitrogen (fertilizer)

1. None
2. $+5 \text{ g m}^{-2} \text{ yr}^{-1}$

Treatments included all combinations

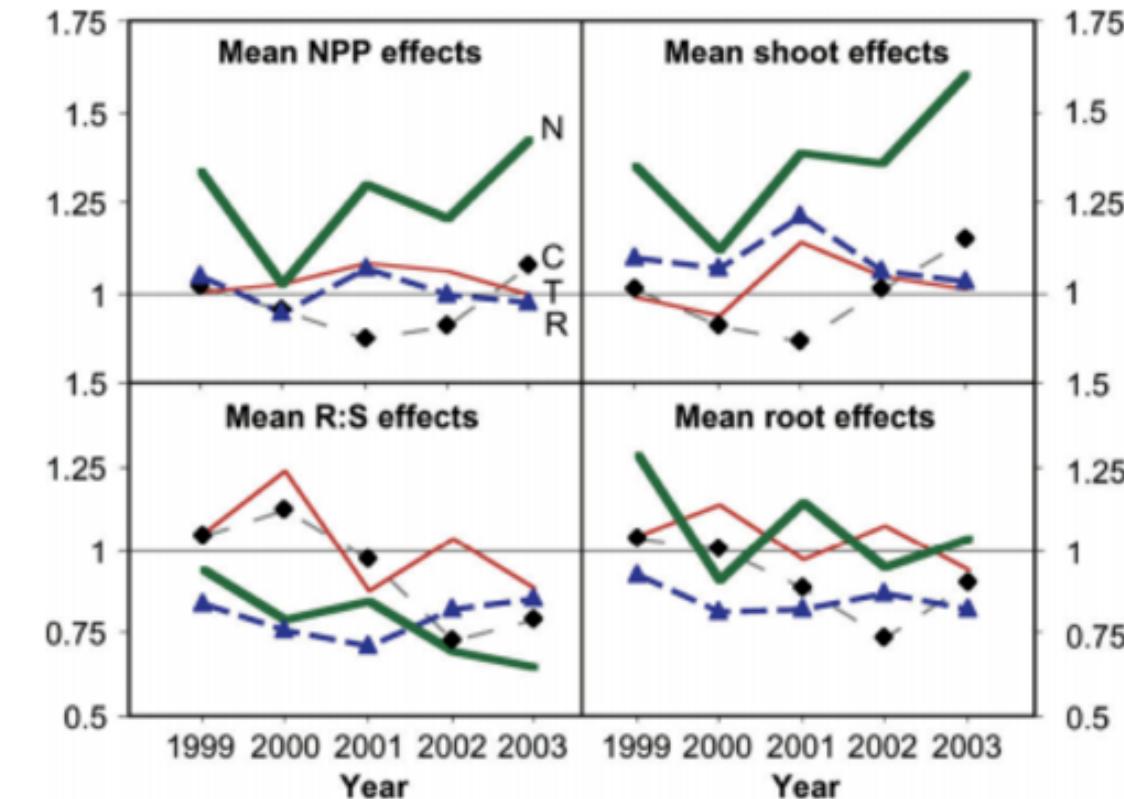
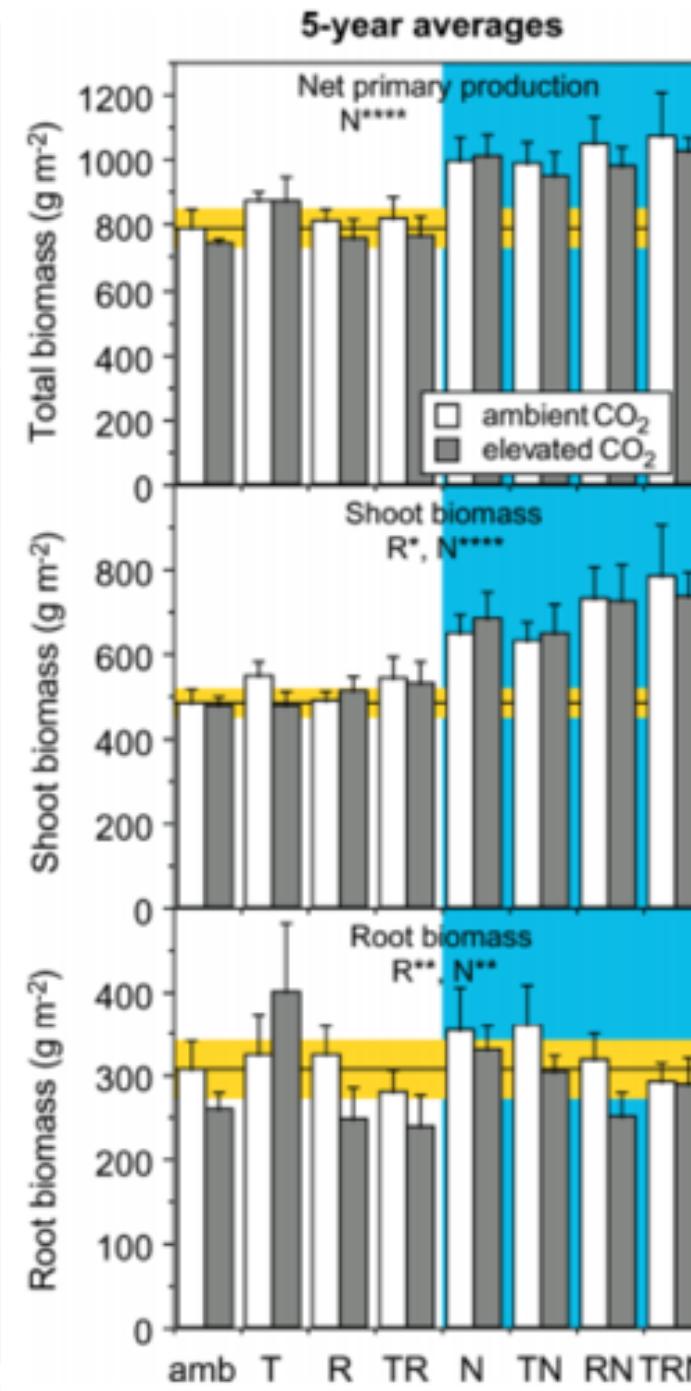
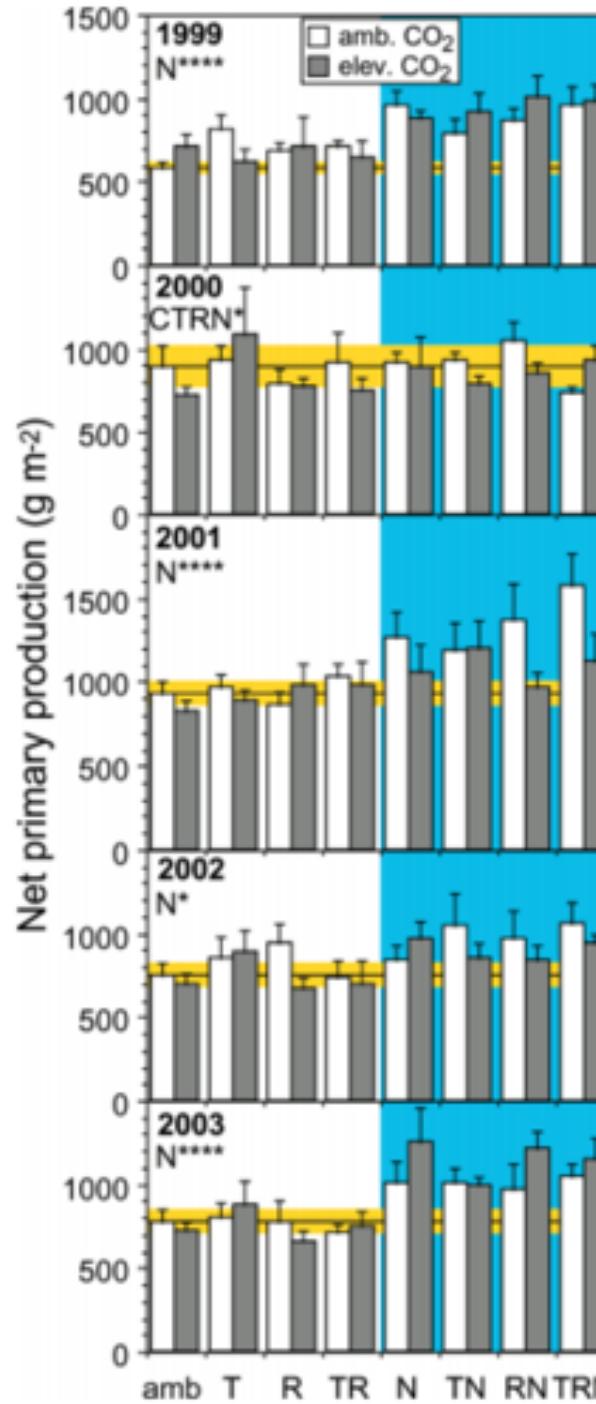
The Jasper Ridge GCE: measurements



- Root and shoot biomass
- Plant community diversity

Assignment: develop a hypothesis for how you would expect the treatments to impact the measured variables.

Biomass



Diversity

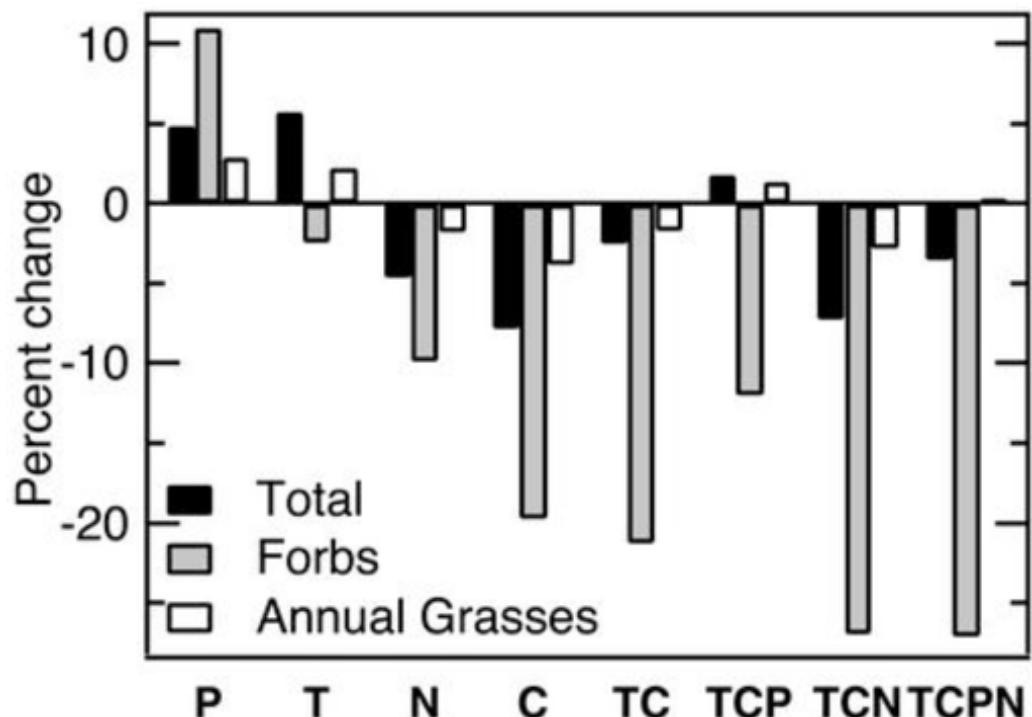


Table 1.

Plant diversity responses to single and combined global change treatments

Treatment	Level	<i>n</i>	Annual grasses	Forbs	Perennial grasses	Total
C	Low	64	6.0	4.0	0.35	10.5
	High	64	5.7	3.2*	0.47	9.7**
T	Low	64	5.8	3.6	0.34	9.8
	High	64	5.9	3.5	0.47	10.4
N	Low	64	5.9	3.8	0.39	10.3
	High	64	5.8	3.4***	0.43	9.8*
P	Low	64	5.7	3.4	0.42	9.8
	High	64	5.9	3.8*	0.39	10.3*
C + T	Low	32	5.9	4.1	0.36	10.3
	High	32	5.8	3.2***	0.59**	10.0
C + T + N	Low	16	5.9	4.4	0.24	10.7
	High	16	5.7	3.2	0.57	9.9
C + T + P	Low	16	5.9	3.8	0.62	10.5
	High	16	6.0	3.4	0.48	10.6
C + T + N + P	Low	8	5.9	4.3	0.35	10.4
	High	8	5.9	3.1*	0.54**	10.0

Diversity shown in mean number of species. Diversity means are ANCOVA-adjusted for preexisting differences among plots. C, elevated CO₂; T, elevated temperature; N, N deposition; P, precipitation. *, *P* = 0.05. **, *P* = 0.10. ***, *P* = 0.01.