Long Term Ecological Research at Cedar Creek Minnesota, USA

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Outline

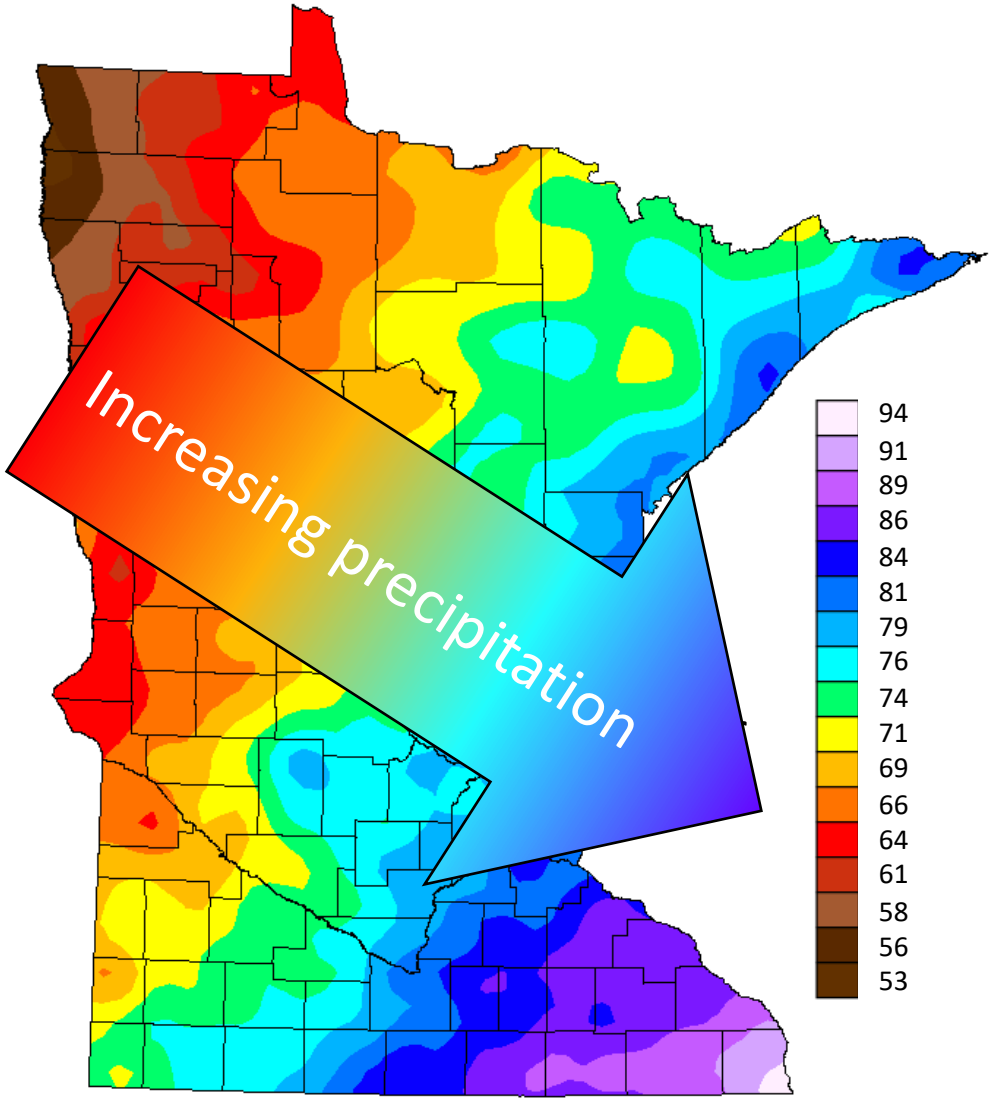
- Natural history of Cedar Creek Ecosystem Science Reserve
- Overview of Cedar Creek Long Term Ecological Research (LTER) program
- Focus on global change research
- Long-term research during a pandemic

Minnesota, USA

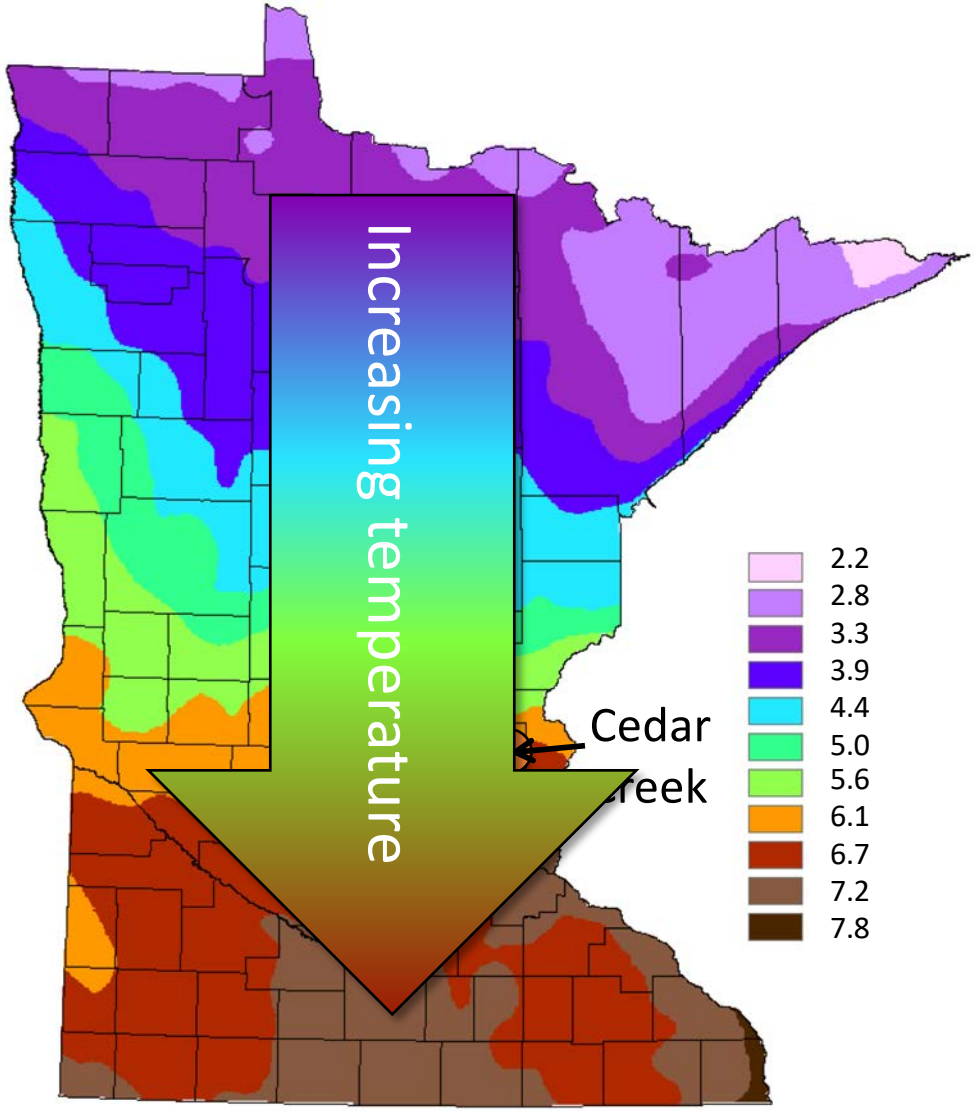
Cedar Creek Ecosystem Science Reserve

- Established in 1942
- 2100 hectares
- 50 km north of Minneapolis-St. Paul, Minnesota

Minnesota climate (1981-2010)



Mean annual precipitation (cm)

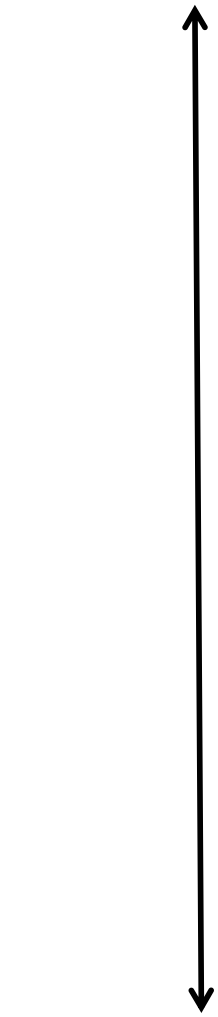


Mean annual temperature (°C)

Source: Minnesota Department of Natural Resources

Minnesota biomes

Boreal



Temperate

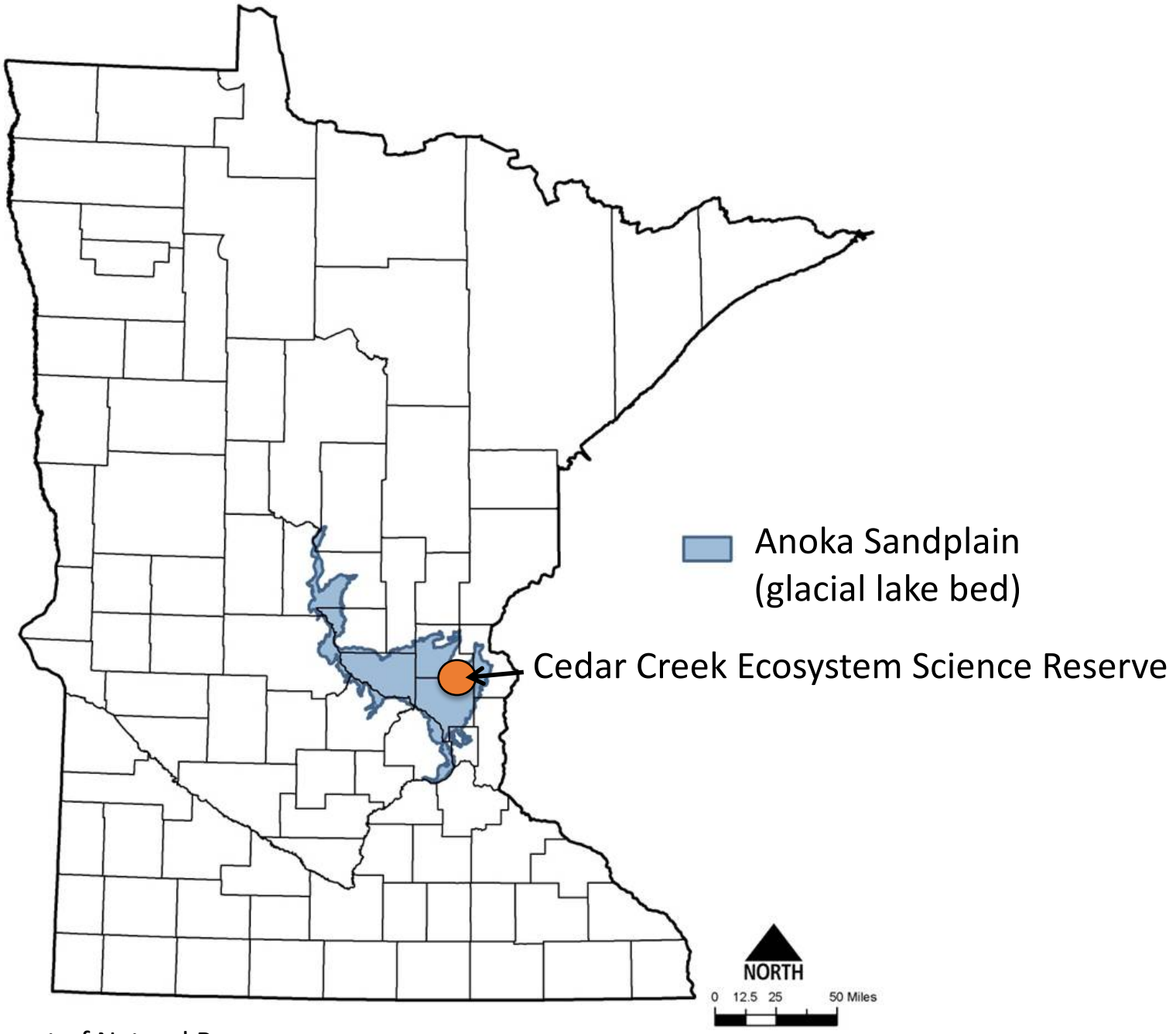
Plants of Cedar Creek

Boreal conifer forest

Temperate prairie grassland

Temperate deciduous forest

Cedar Creek geology



Source: Minnesota Department of Natural Resources

Cedar Creek soils

- extremely sandy (≈ 90%)
- low in organic matter
- well drained
- low in nitrogen
- shallow water table

Tillery Bailey

Upland habitats of Cedar Creek


Jacob Miller

Quercus savanna and sand prairie

Dry *Quercus* forest


Jacob Miller

Mesic *Acer-Tilia* forest


Jacob Miller

Abandoned agricultural “old” fields

Wetland habitats of Cedar Creek

Jacob Miller

Open wetlands

Wooded swamps

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US Long-Term Ecological Research (LTER) Program

- Funded by the National Science Foundation
- 28 sites in network
- 6-year funding cycle for individual sites
- Cedar Creek LTER funded since 1982

LTER NETWORK

NSF

Cedar Creek LTER Investigators

Sarah Hobbie, co-lead

Eric Seabloom, co-lead

Elizabeth Borer

Jeannine Cavender-Bares

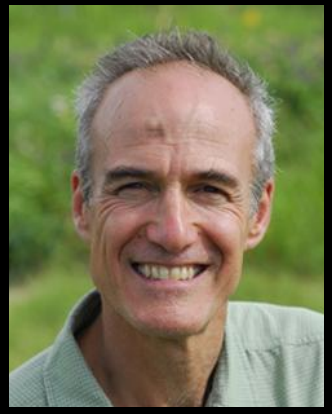
Forest Isbell

Peter Kennedy

Linda Kinkel

Rebecca Montgomery

Caitlin Potter



Peter Reich

David Tilman

Cedar Creek Long-Term Ecological Research (LTER) Program

Overarching research question:
How do multiple environmental changes interact to affect ecological systems across biological, spatial, and temporal scales?

Jacob Miller

Theory, experiments, and observations

Forest Isbell

Research Theme: Nutrient Enrichment

Example Research Questions:

- How do nutrients structure ecosystems?
- How do communities and ecosystems recover from nutrient enrichment?
- How do effects of nutrients compare to effects of consumers ("bottom-up" vs. "top-down" effects)?

Jacob Miller

Research Theme: Biodiversity

Example Research Questions:

- How does biodiversity influence
  - the stability of communities?
  - ecosystem processes?
  - ecosystem response to global change?

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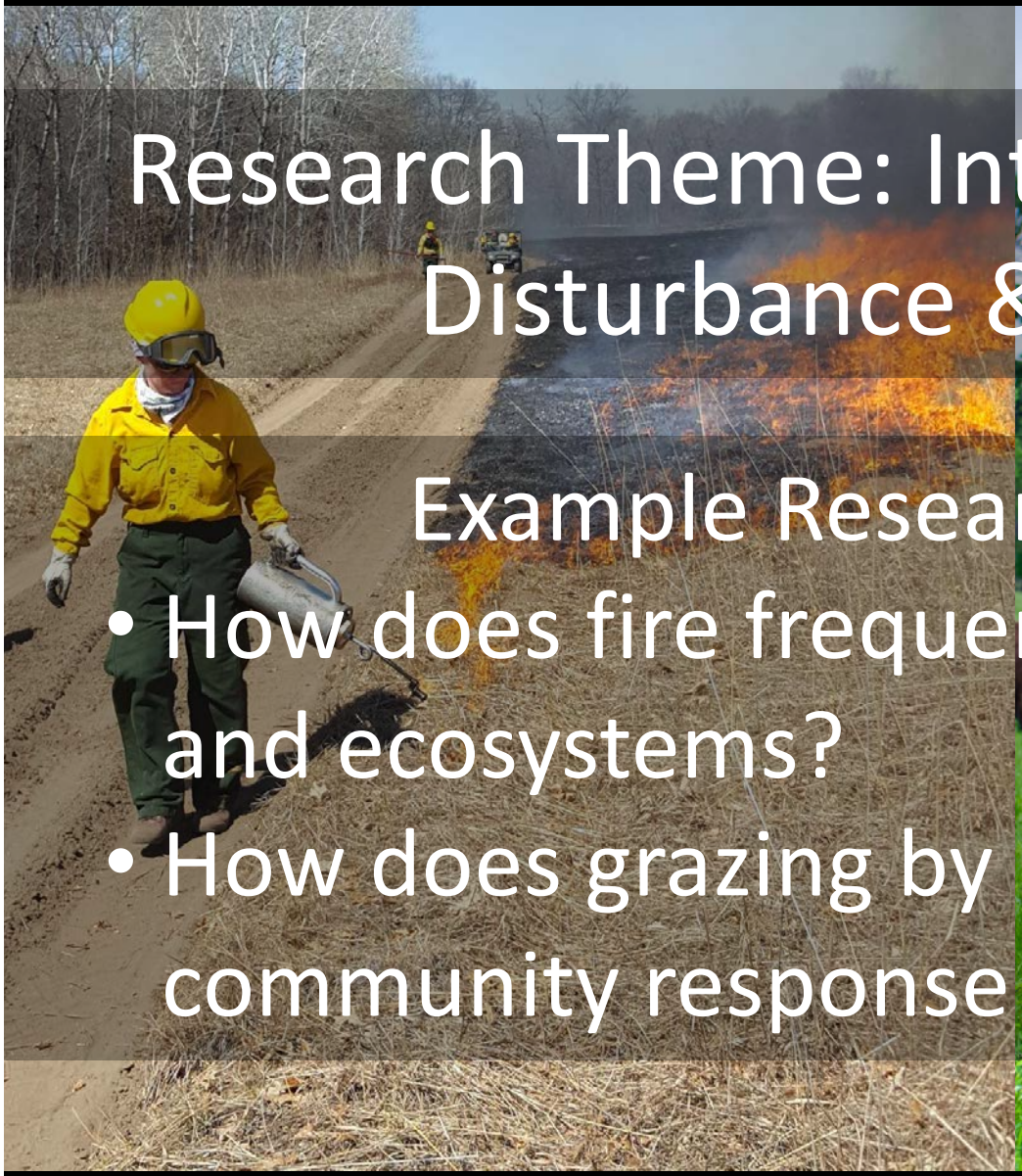

Research Theme: Interactions between Disturbance & Consumers

Example Research Questions:

- How does fire frequency alter communities and ecosystems?
- How does grazing by bison affect plant community response to fire?

Susan Barrott and Chad Zirbel

Research Theme: Interactions among Multiple Environmental Change Drivers

Example Research Questions:

- How do different global change drivers interact to influence communities and ecosystems?

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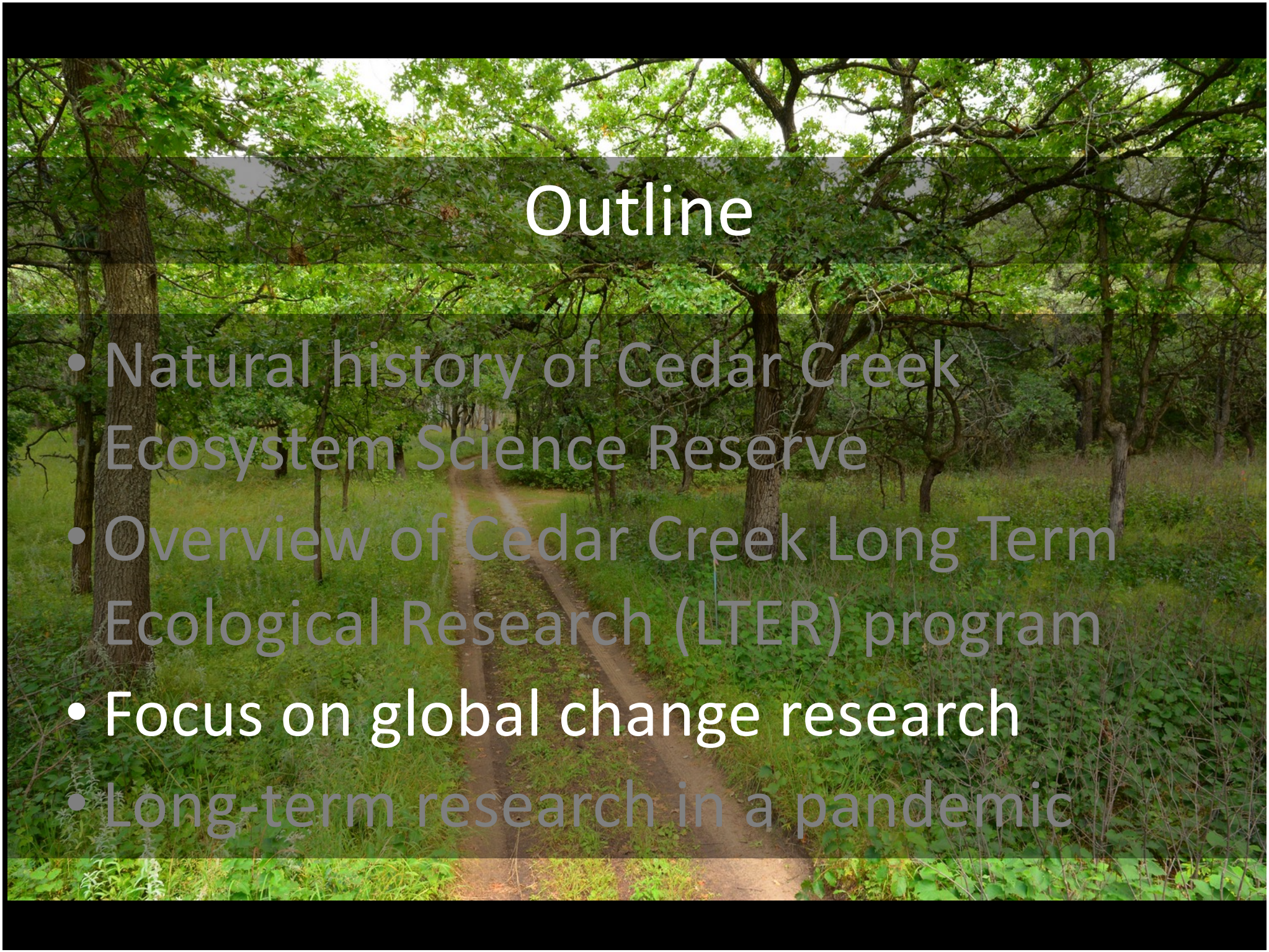

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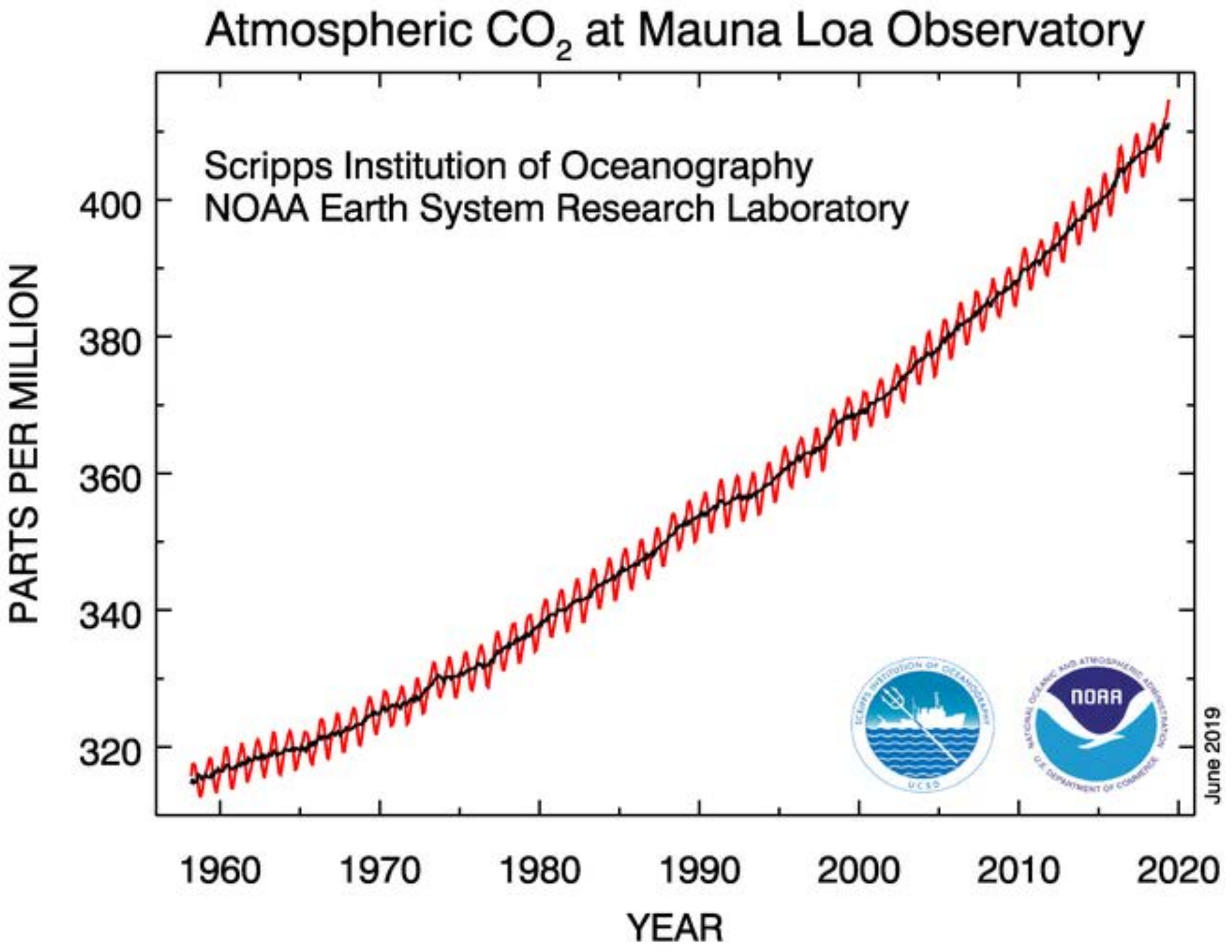
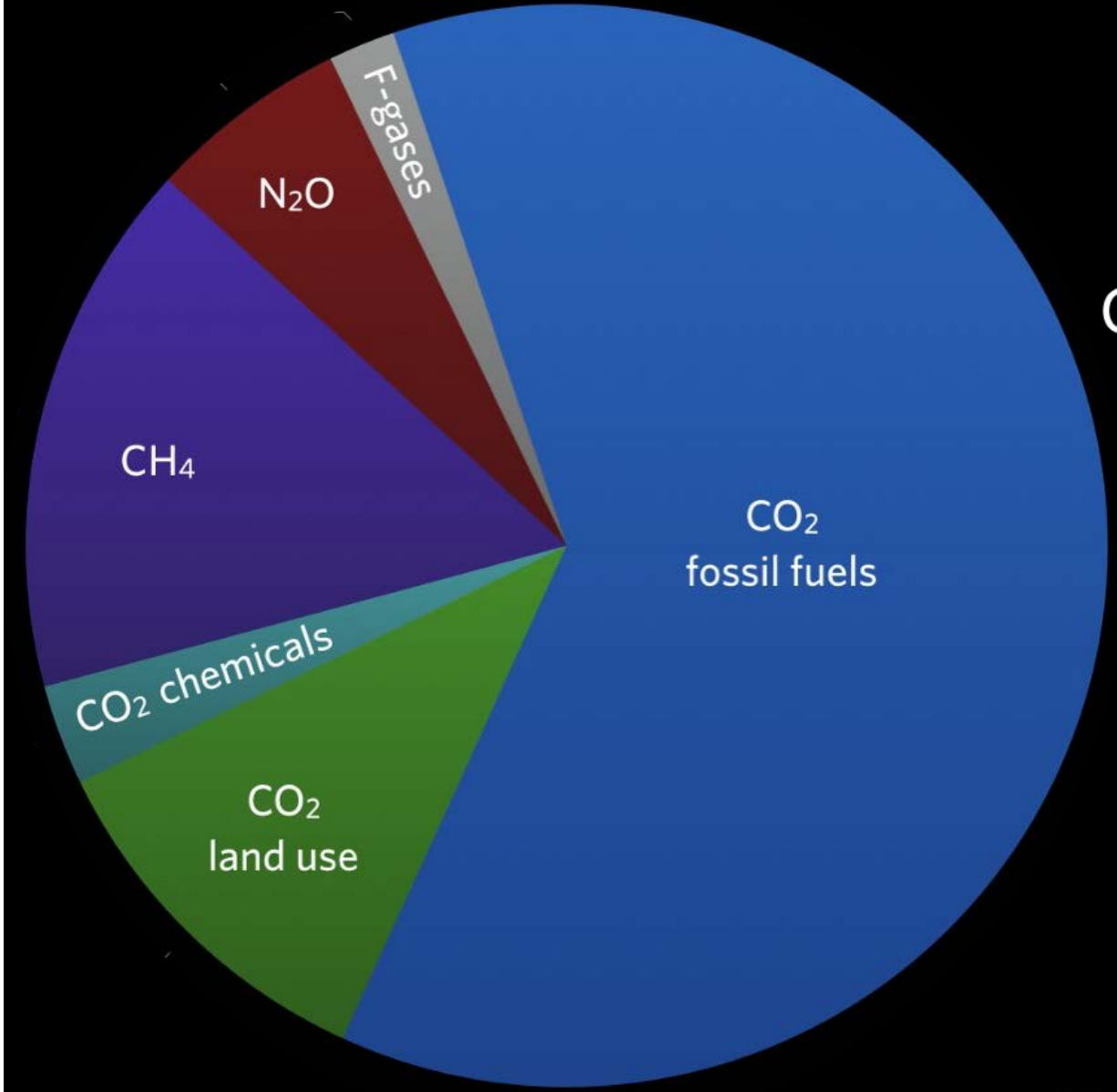

Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
PARTS PER MILLION
400
380
360
340
320
1960
1970
1980
1990
2000
2010
2020
YEAR
June 2019



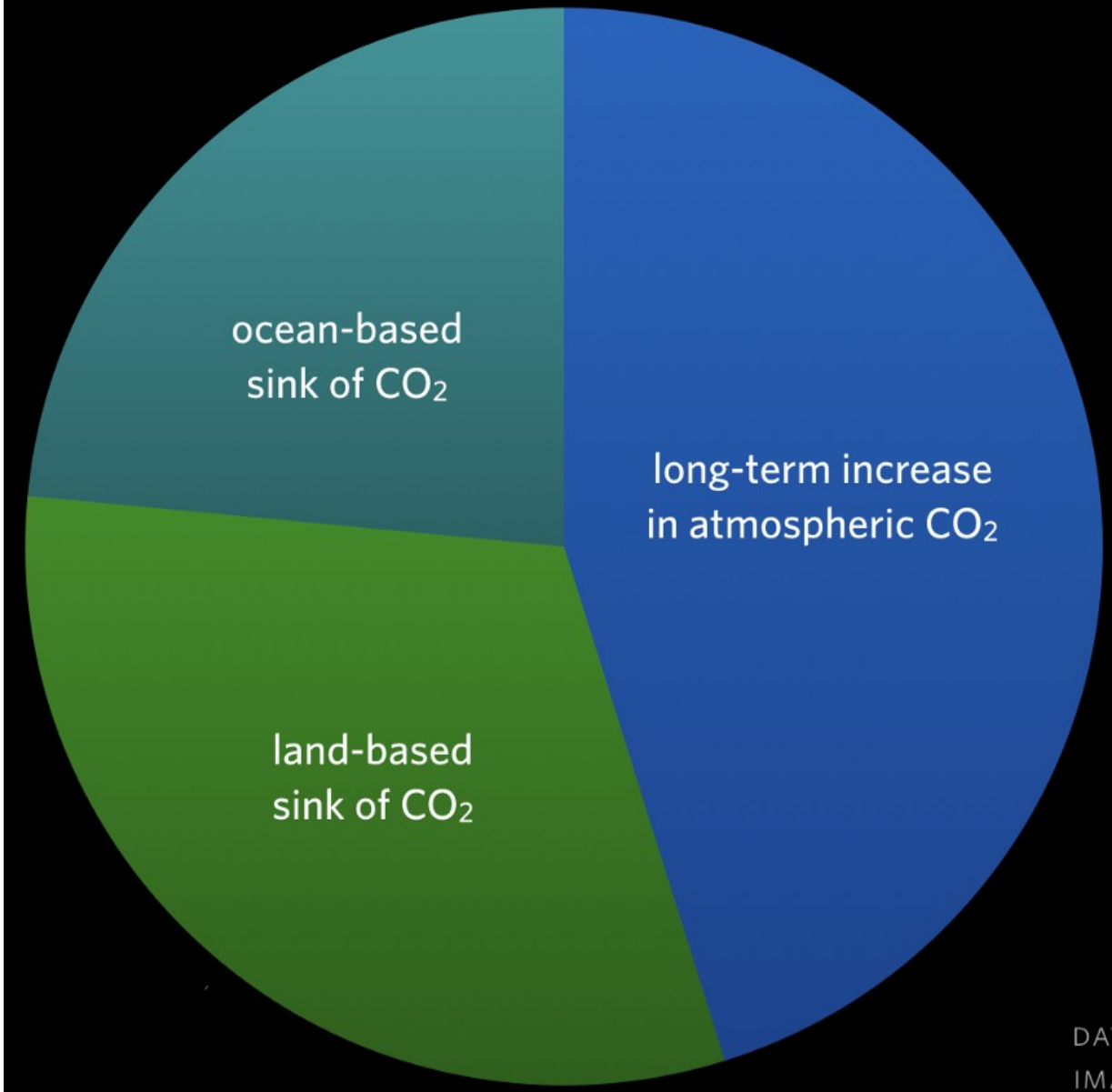
Greenhouse Gas Emissions

by major gas

(non-CO2 gases converted with their equivalent "global warming potential")

DATA FROM EPA

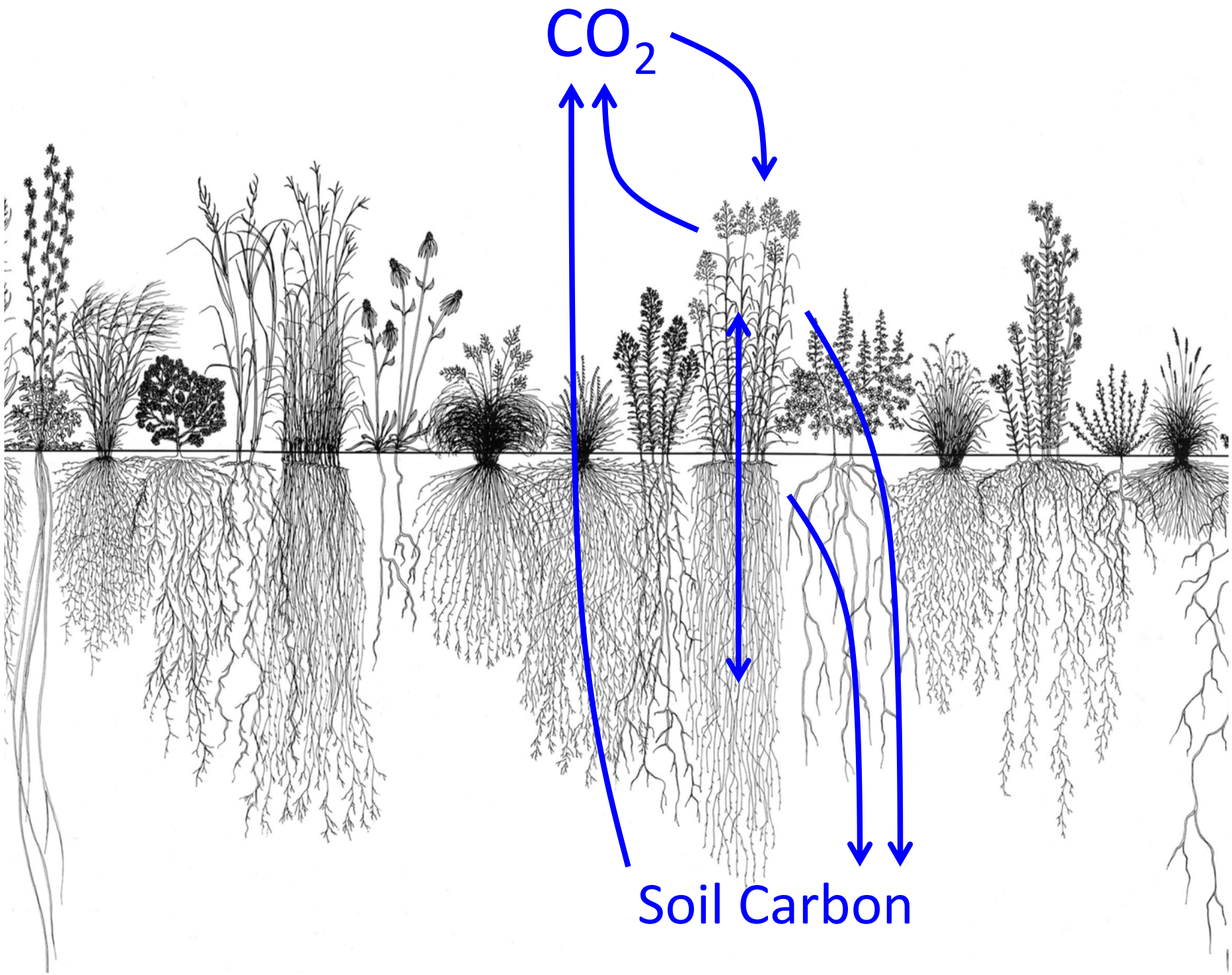
IMAGE BY J. FOLEY, PROJECT DRAWDOWN

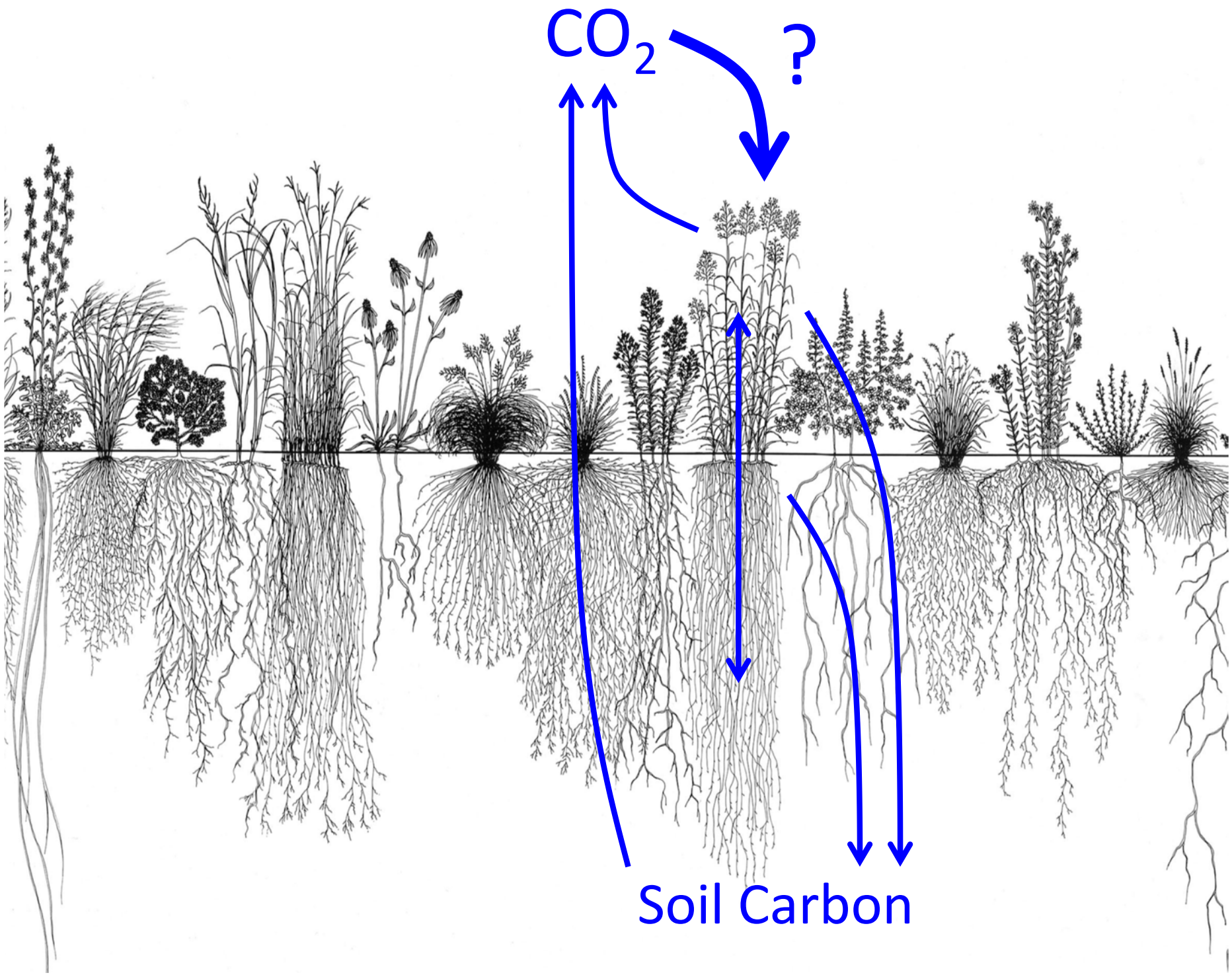


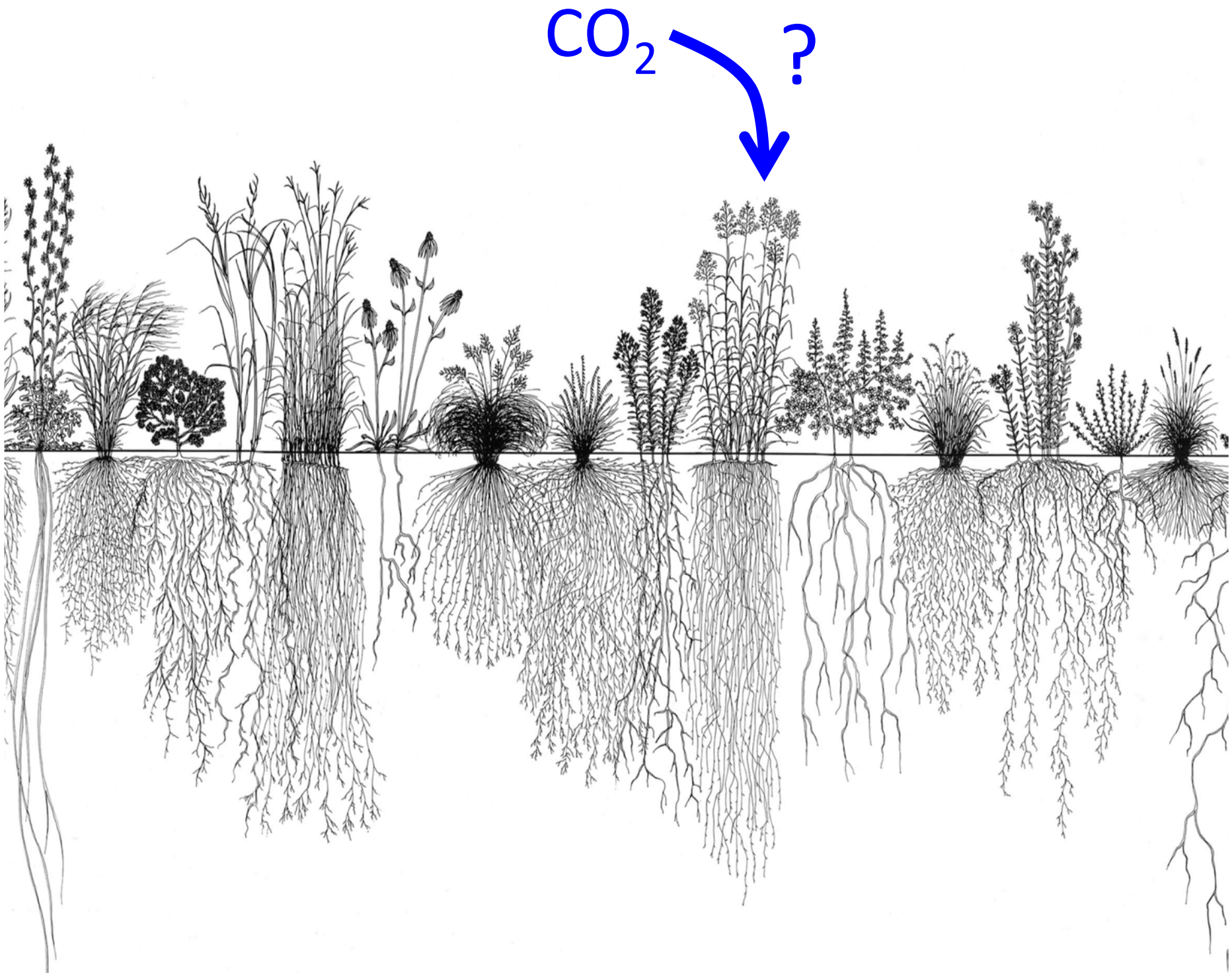
Fate of Carbon Dioxide Emissions

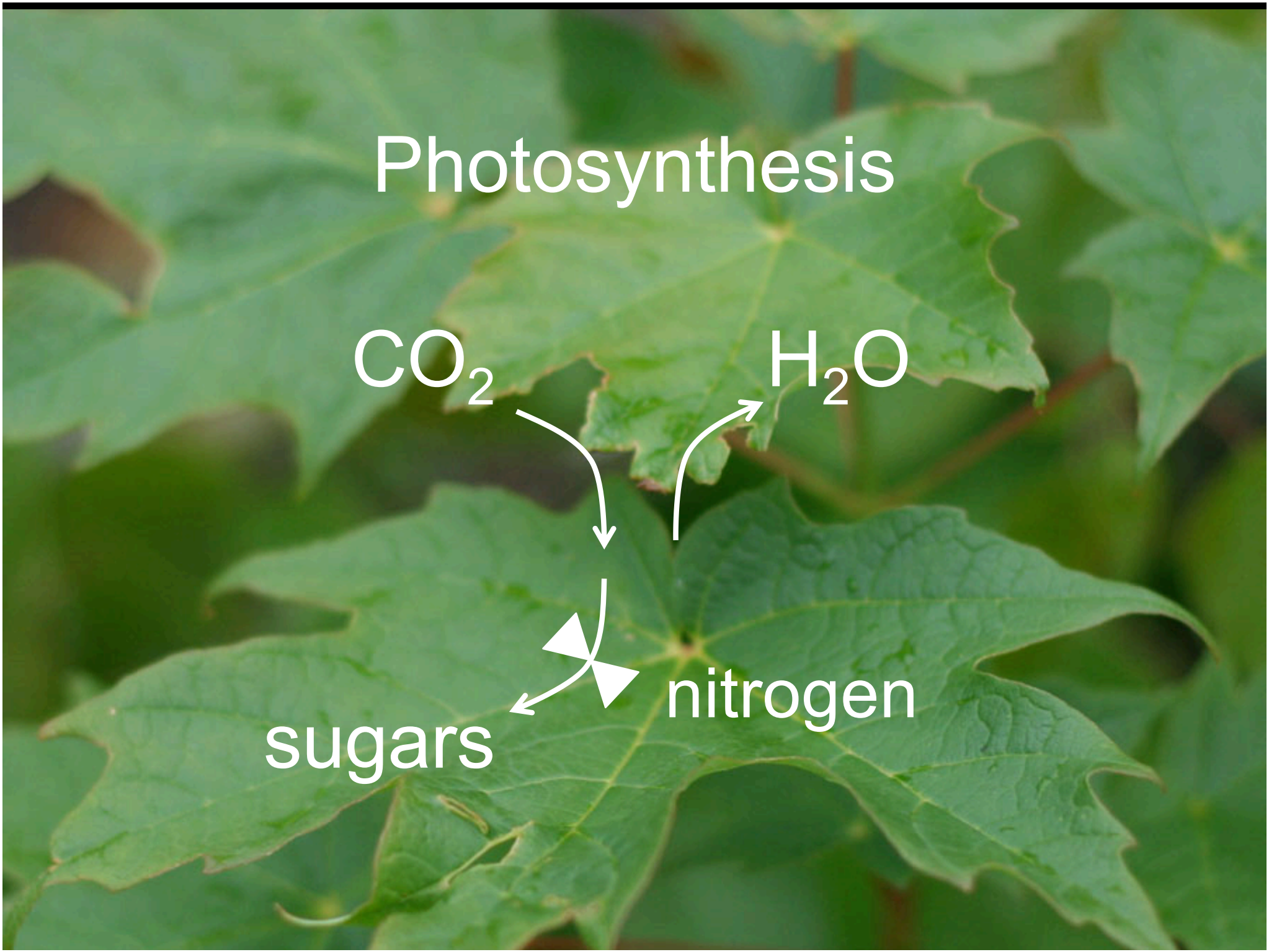
DATA FROM GLOBALCARBONPROJECT.ORG

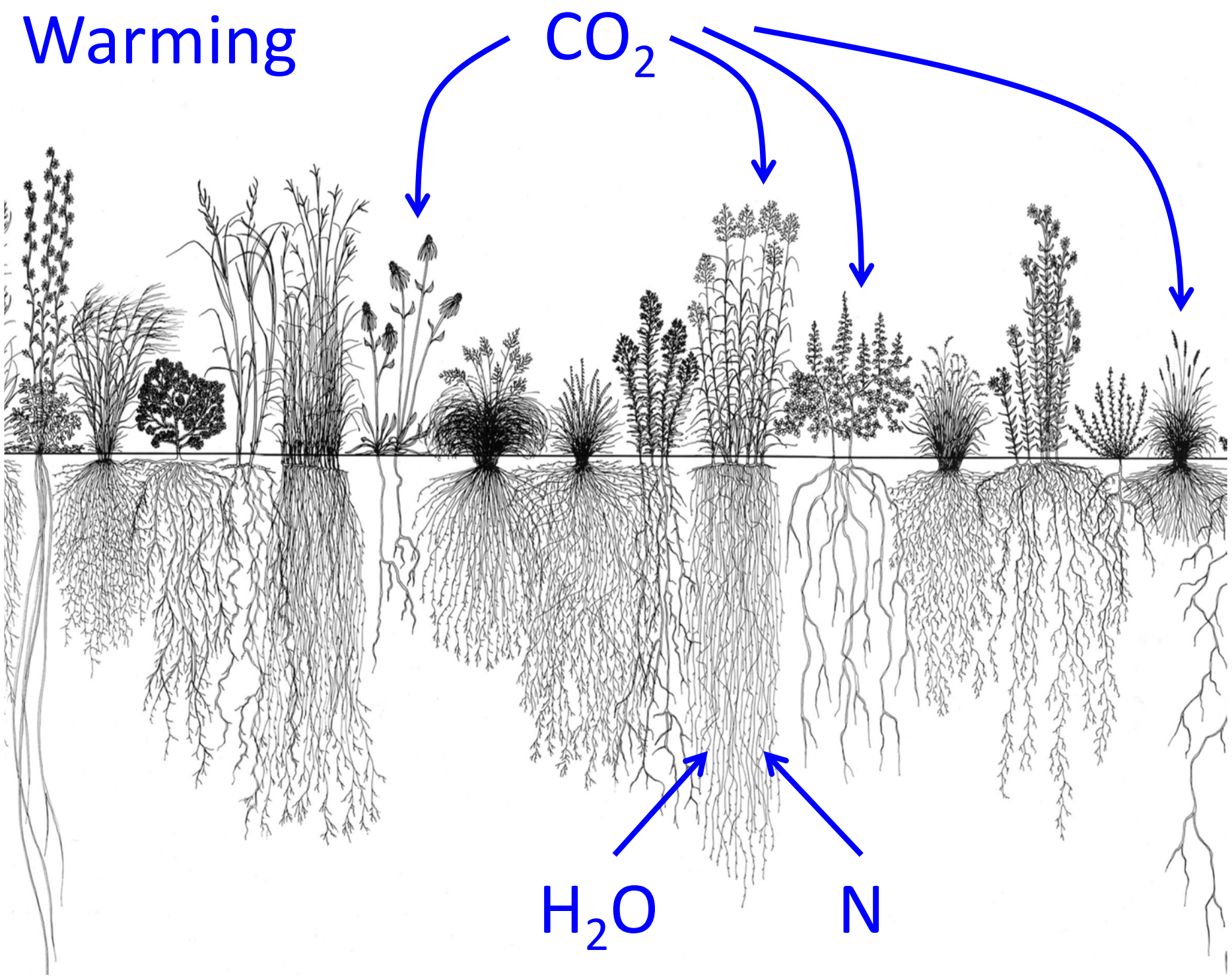
IMAGE BY J. FOLEY, PROJECT DRAWDOWN


CO_2
Soil Carbon


CO_2
?
Soil Carbon

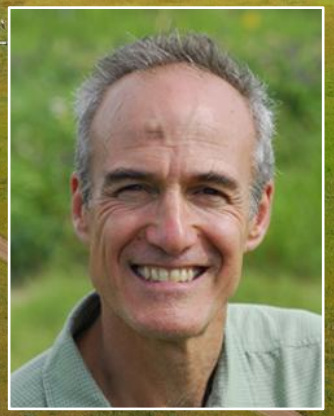

CO_2
?


Photosynthesis
CO_2
H_2O
nitrogen
sugars


Warming
CO_2
H_2O
N

Motivating Questions:

- How does plant response to elevated CO_2 depend on:
  - belowground resource supply?
  - plant species composition and diversity?
  - climate warming?


Peter Reich


Melissa Pastore


Tali Lee


Kally Worm


BioCON
Biodiversity, CO_2, Nitrogen
• Planted in 1997
• 296 2x2 m plots


Biodiversity
• 0, 1, 4, 9, 16 perennial plant species
• Four plant “functional groups”

BioCON Functional Groups

legume

Amorpha canescens
Lespedeza capitata
Lupinus perennis
Petalostemum purpureum

forb

Achillea millefolium
Asclepias tuberosa
Anemone cylindrica
Solidago rigida

C_3 grass

Agropyron repens
Bromus inermis
Koeleria cristata
Poa pratensis

C_4 grass

Andropogon gerardii
Boutelous gracilis
Shizachyrium scoparium
Sorghastrum nutans

CO_2

- FACE (Free Air CO_2 Enrichment) technology
- 6 20-m diameter FACE rings
- 3 ambient rings, 3 +180 ppm rings
- Growing season only

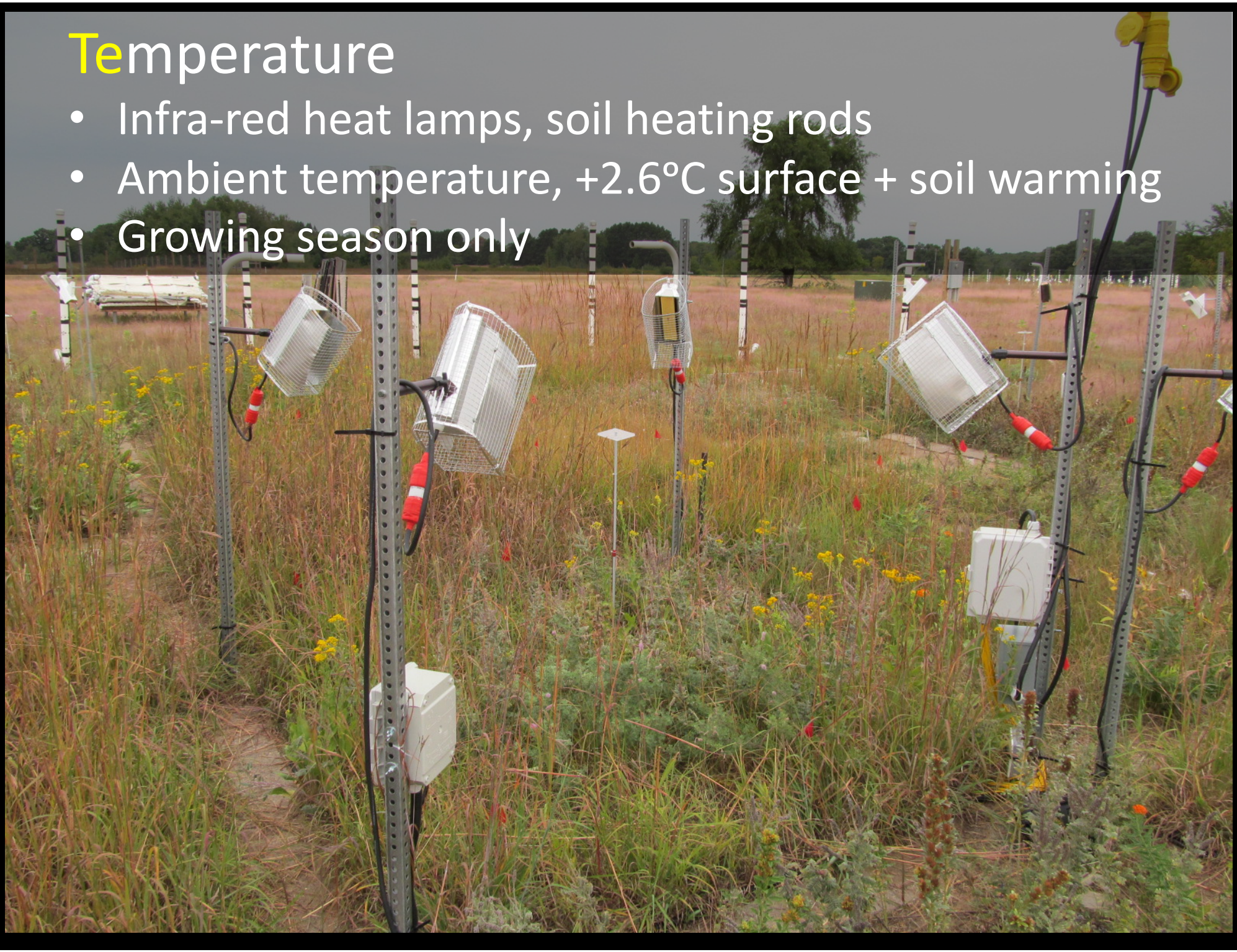
Nitrogen

- Ambient, +4 g m^{-2} y^{-1} as ammonium nitrate


TeRaCON
Temperature, Rainfall, CO_2, Nitrogen
• Established in 2007 (rainfall) and 2012 (temperature)
• 48 plots, all planted with 9 species

Temperature

- Infra-red heat lamps, soil heating rods
- Ambient temperature, +2.6°C surface + soil warming
- Growing season only



Rainfall reduction

- Temporary rainout shelters
- Ambient rainfall, -40% rainfall events
- Growing season only

Motivating Questions:

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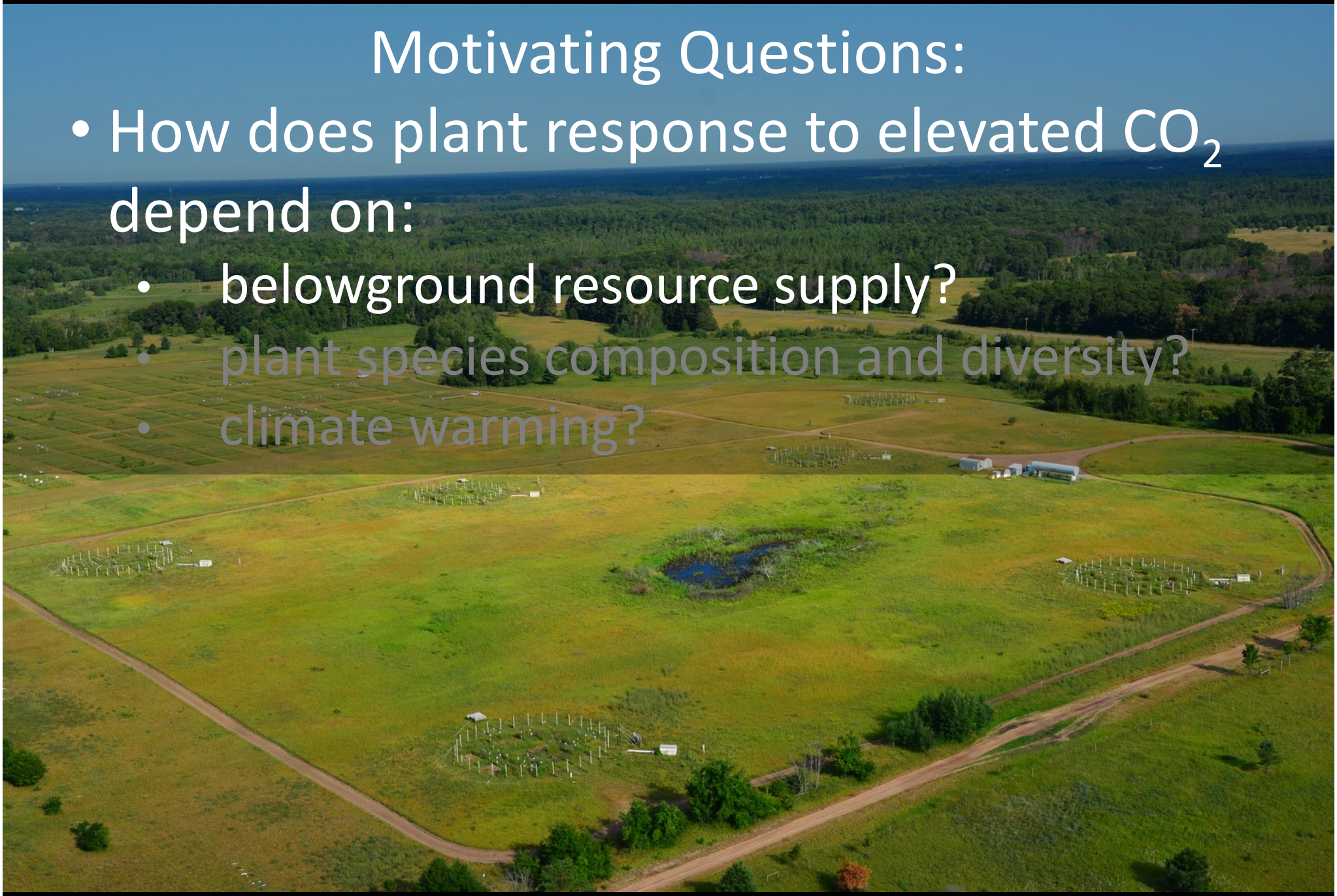
  - climate warming?



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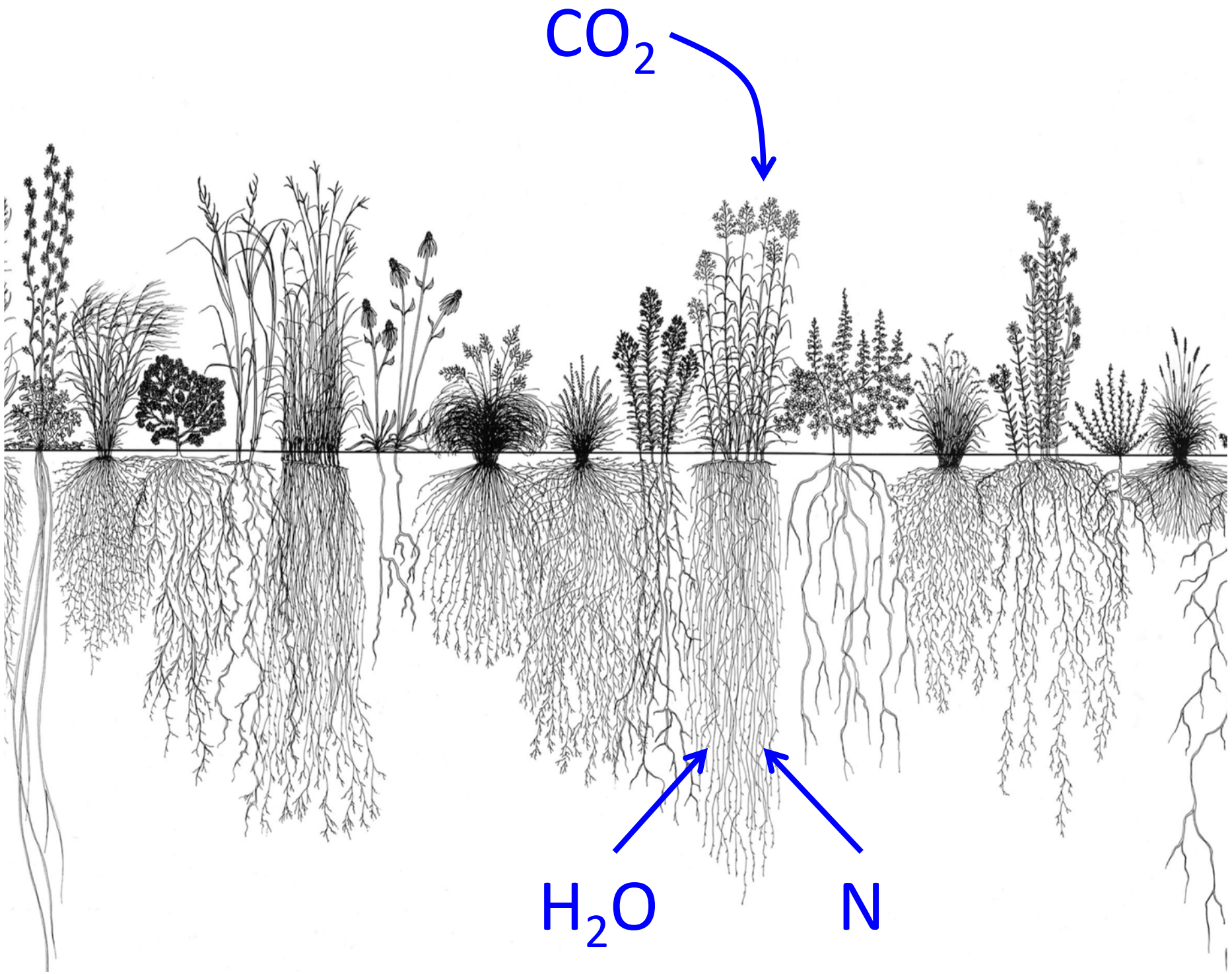
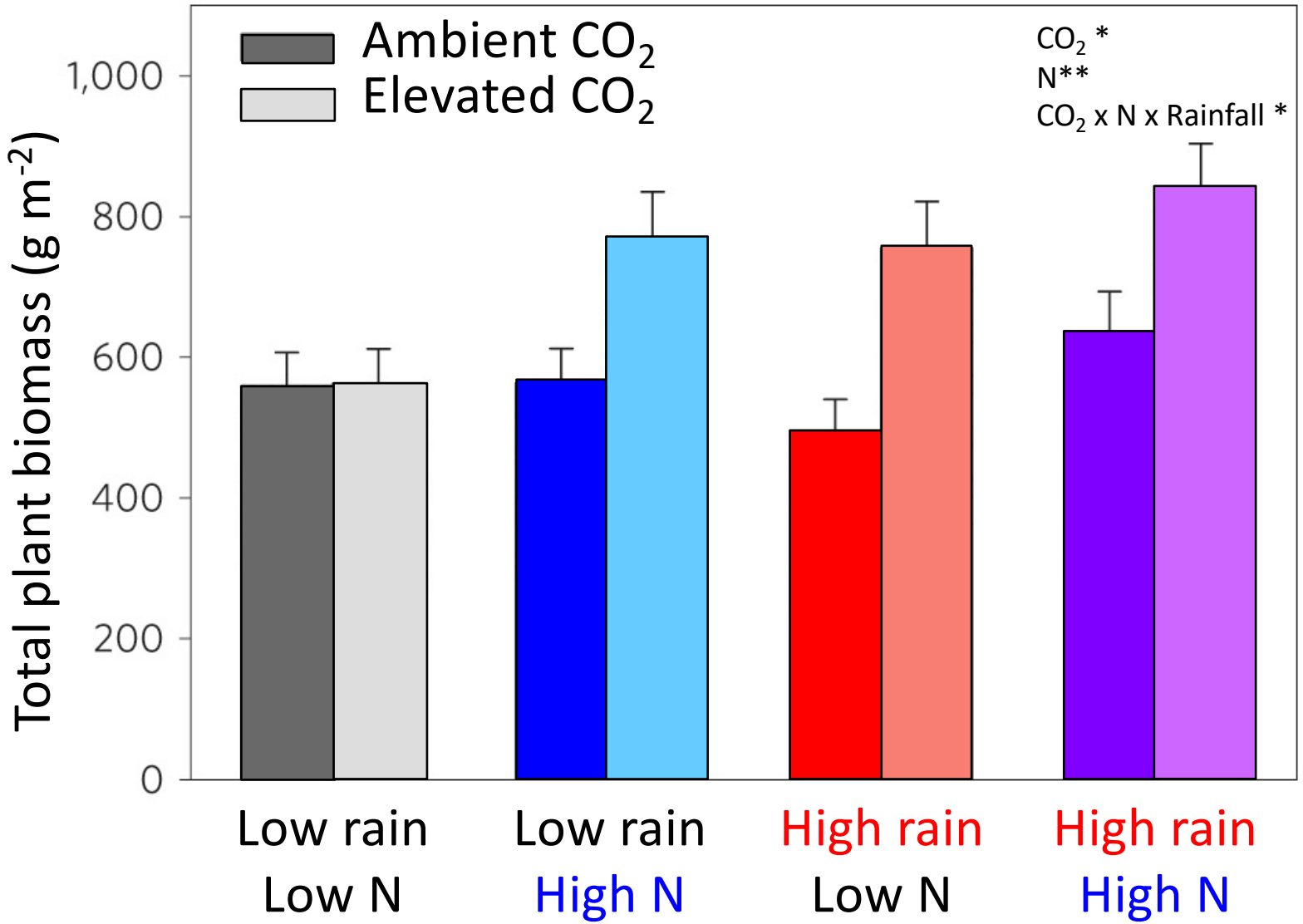

CO_2
H_2O
N

N and H_2O constrain how plant growth respond to elevated CO_2



2007-2011 average

Reich, Hobbie and Lee 2014 *Nature GeoScience*

Motivating Questions:

- How does plant response to elevated CO_2 depend on:
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  - plant species composition and diversity?
  - climate warming?

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Comparison of monoculture and 4-species plots containing single functional groups

legume

Amorpha canescens
Lespedeza capitata
Lupinus perennis
Petalostemum purpureum

forb

Achillea millefolium
Asclepias tuberosa
Anemone cylindrica
Solidago rigida

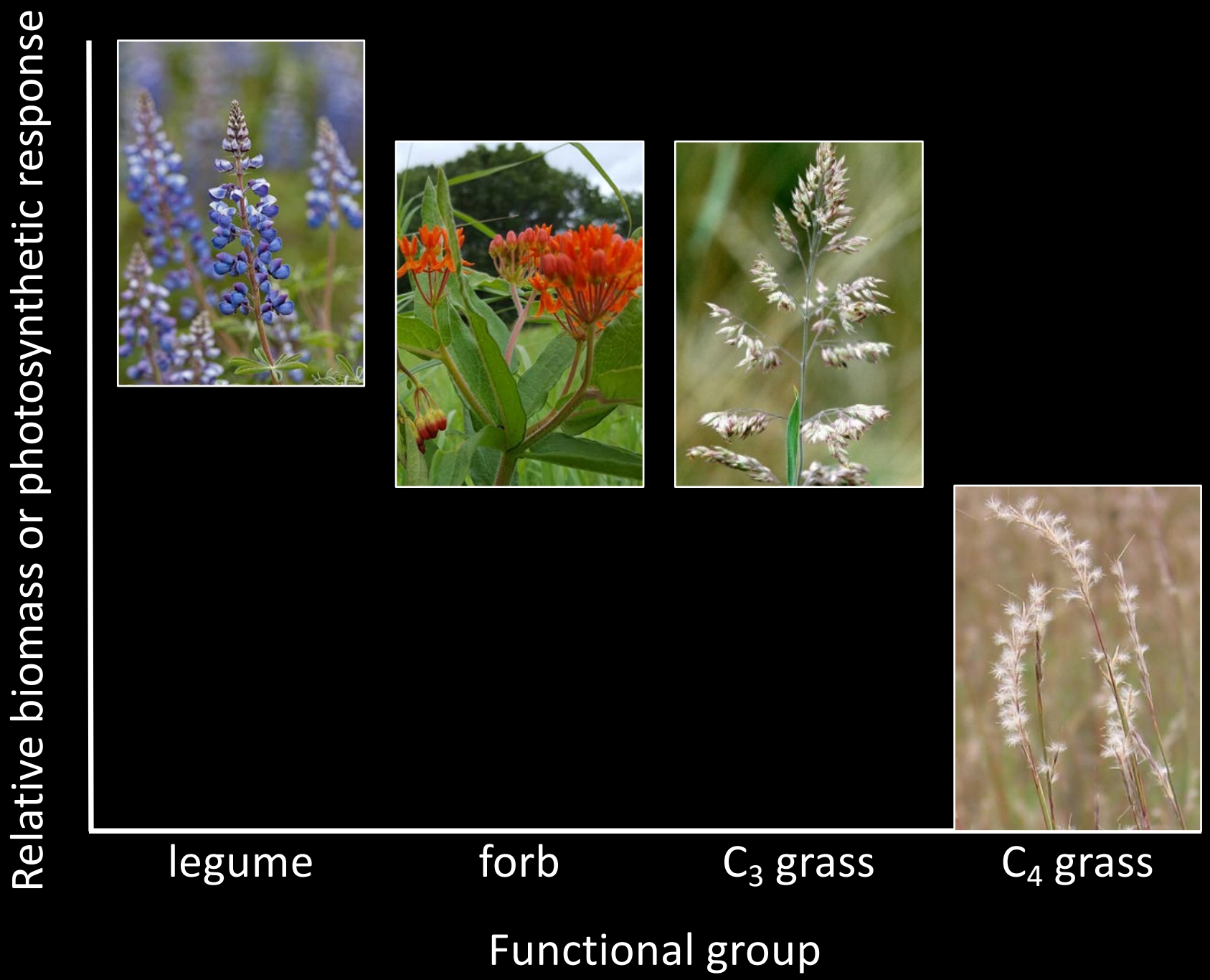
C_3 grass

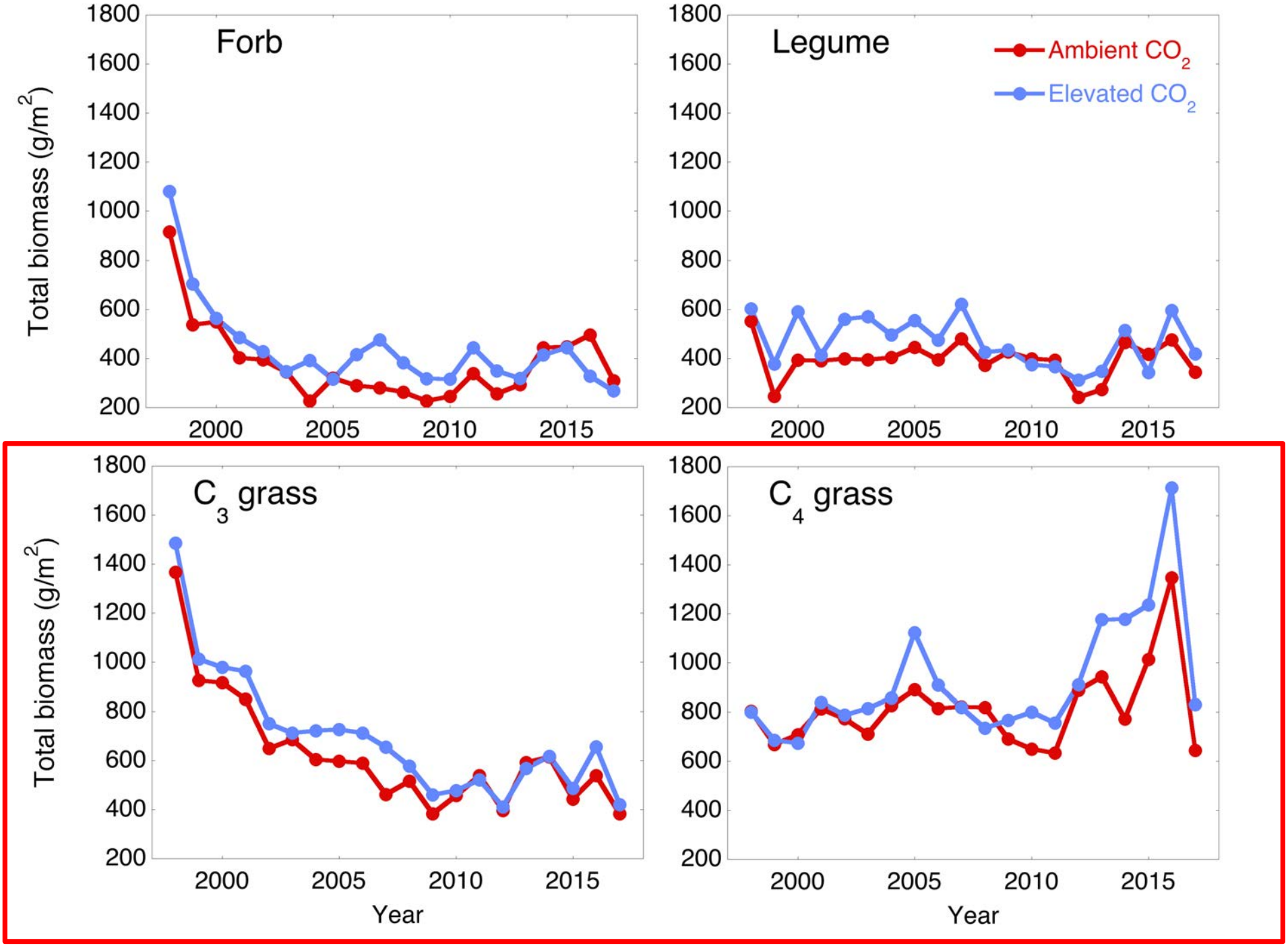
Agropyron repens
Bromus inermis
Koeleria cristata
Poa pratensis

C_4 grass

Andropogon gerardii
Boutelous gracilis
Shizachyrium scoparium
Sorghastrum nutans

Hypothesized functional group responses to elevated CO_2




Forb
Legume
Ambient CO2
Elevated CO2
C3 grass
C4 grass
Total biomass (g/m2)
Year
1800
1600
1400
1200
1000
800
600
400
200
2000
2005
2010
2015

Theoretical predictions based on physiology

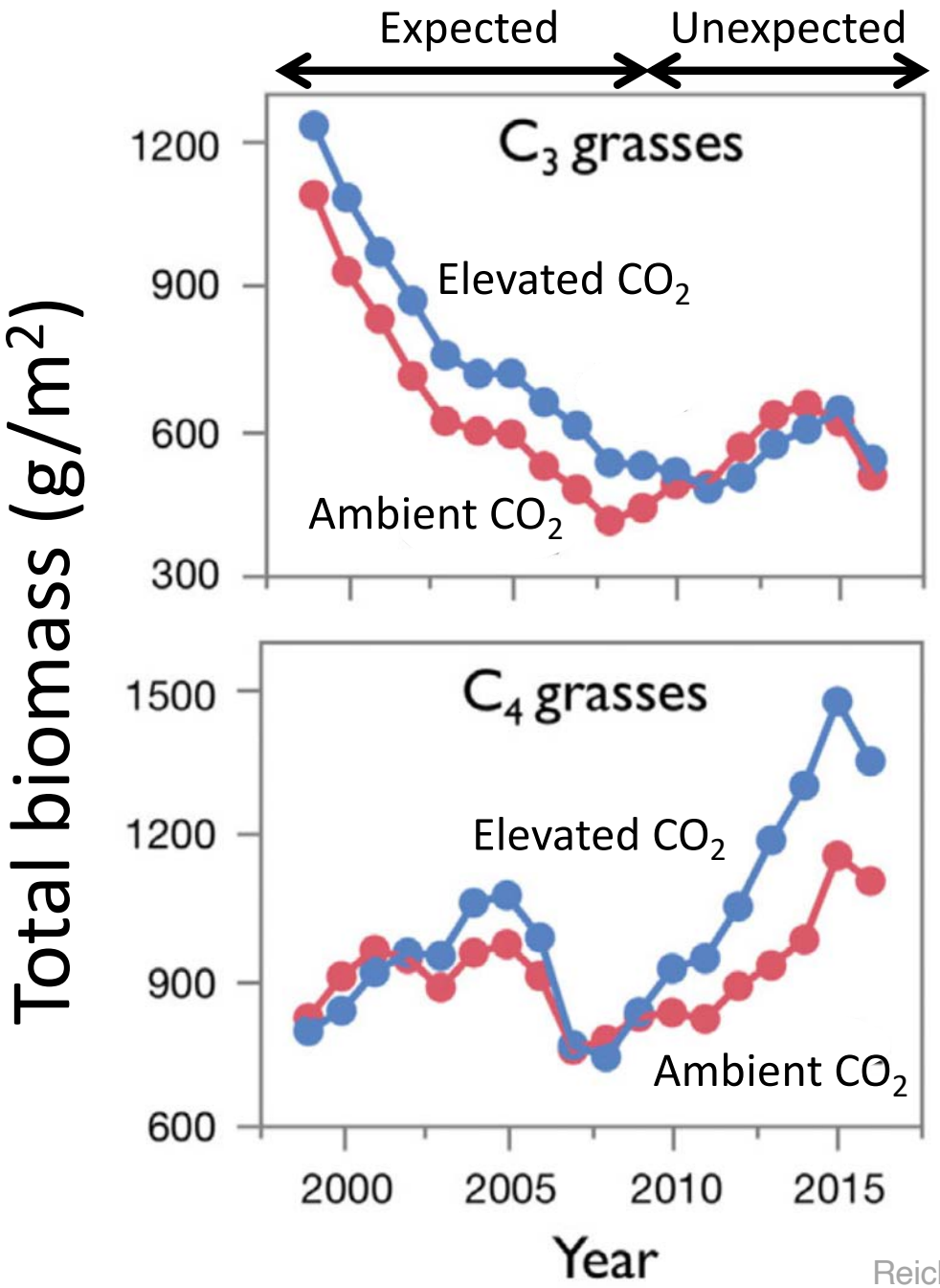
C_3 grass

Photosynthesis should increase with rising CO_2

C_4 grass

Photosynthesis saturated at current CO_2

Unexpected reversal of CO_2 effects on C_3 and C_4 grasses over time



3-year running average

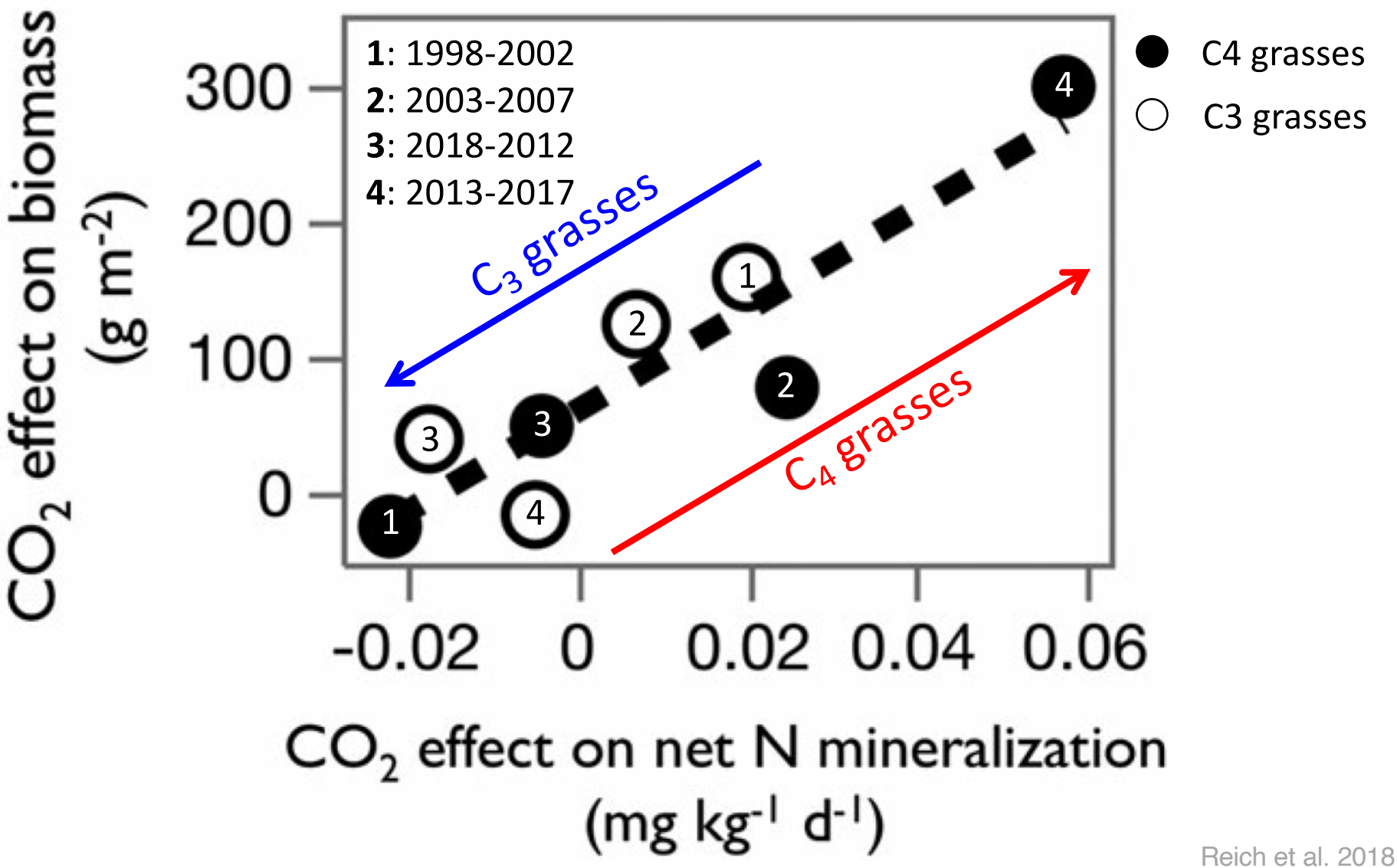
Reich, Hobbie, Lee, and Pastore 2018 *Science*

Why the shift over time in CO_2 effects on C_3 and C_4 grasses?

C_3 grass

C_4 grass

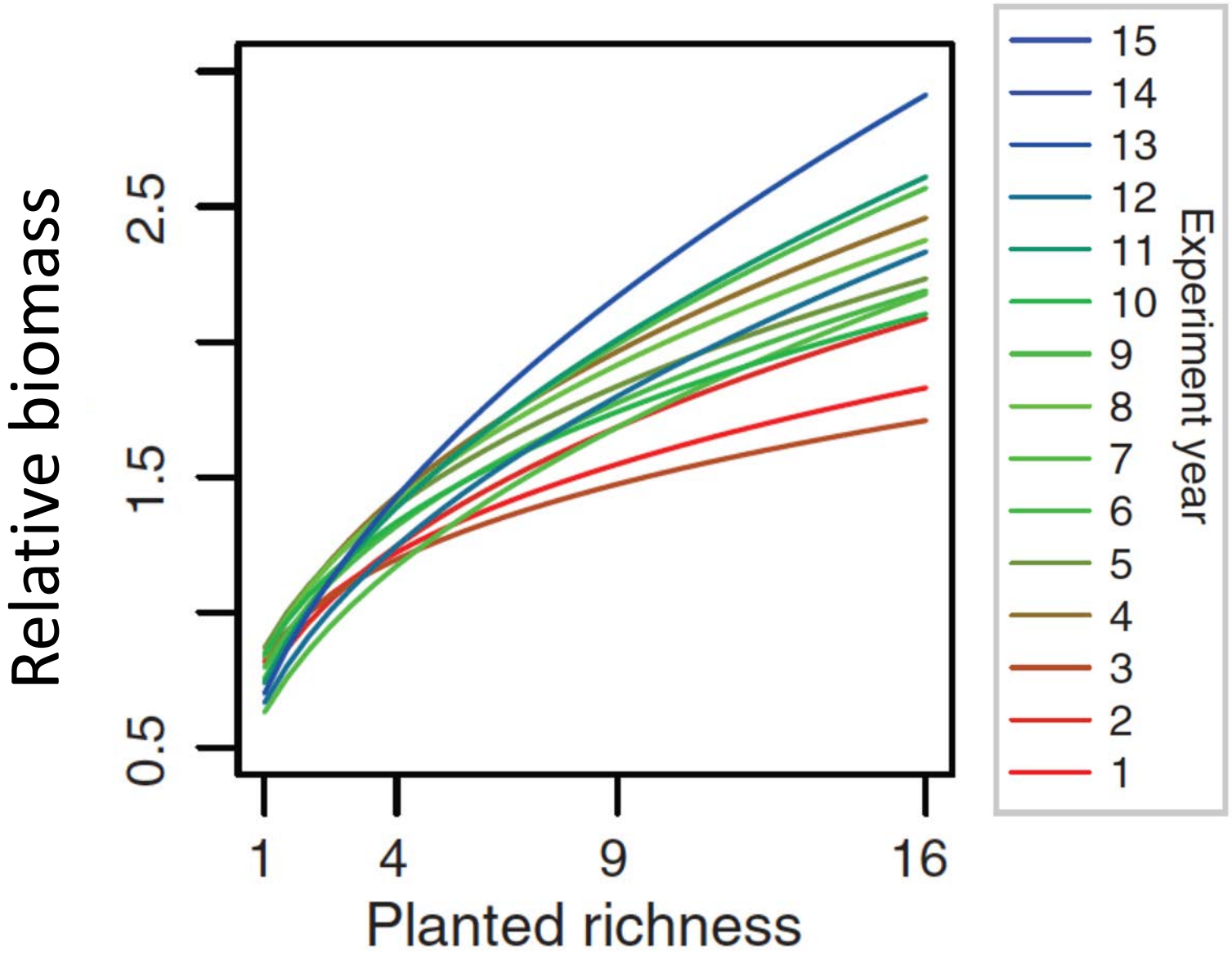
CO_2 effects on biomass are related to CO_2 effects on N supply



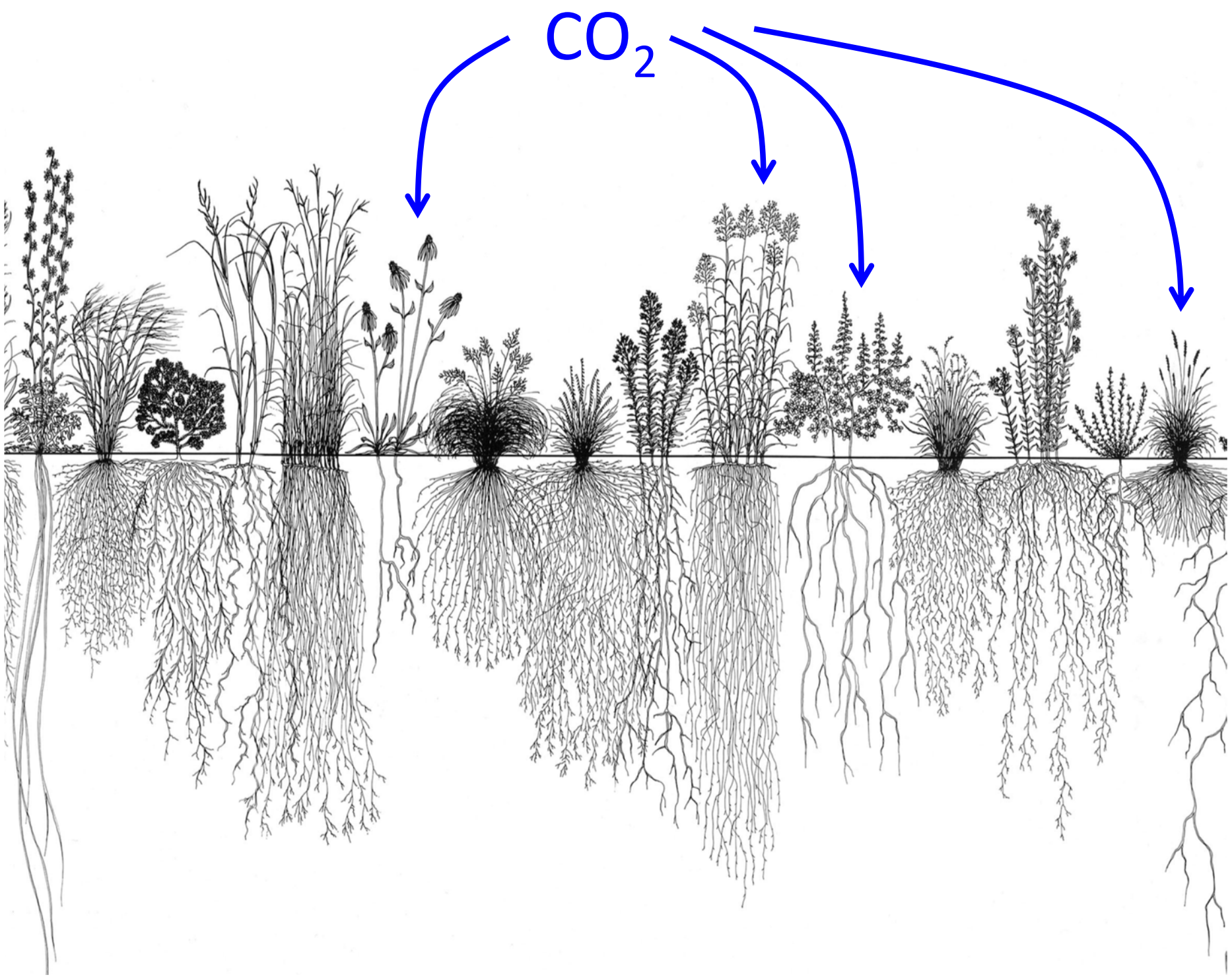
Reich et al. 2018 *Science*


Biodiversity
• 1, 4, 9, 16 perennial plant species

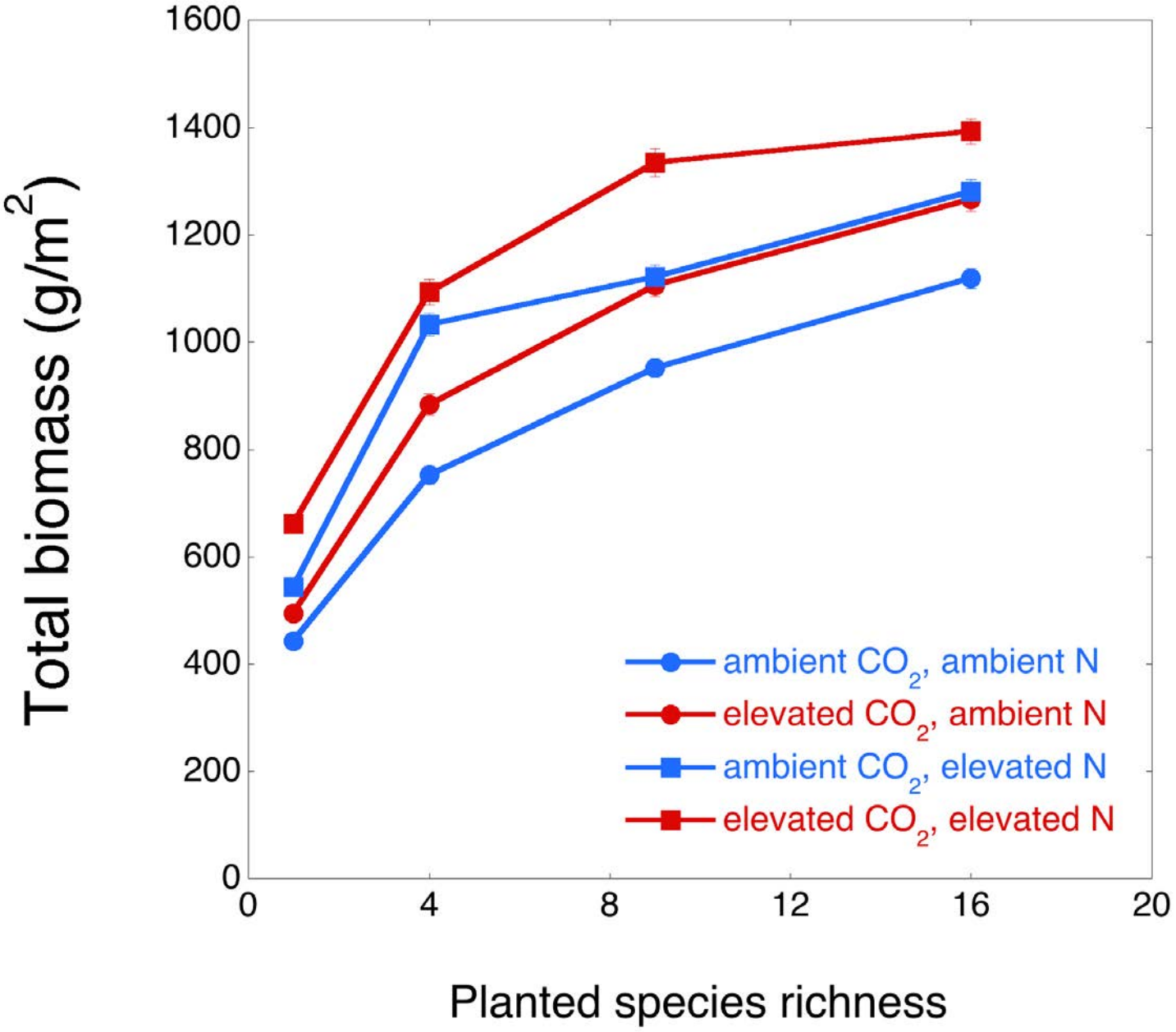
Diversity effects on biomass have increased over time



Reich et al. 2012 *Science*


CO_2

Elevated CO_2 effects on biomass are larger in more diverse plots



CO_2 ***
N***
Species richness***
Year***
Year x SR***
Year x N x SR***
CO_2 x SR*
Year x N*
Year x CO_2 x N*

1998-2017 average

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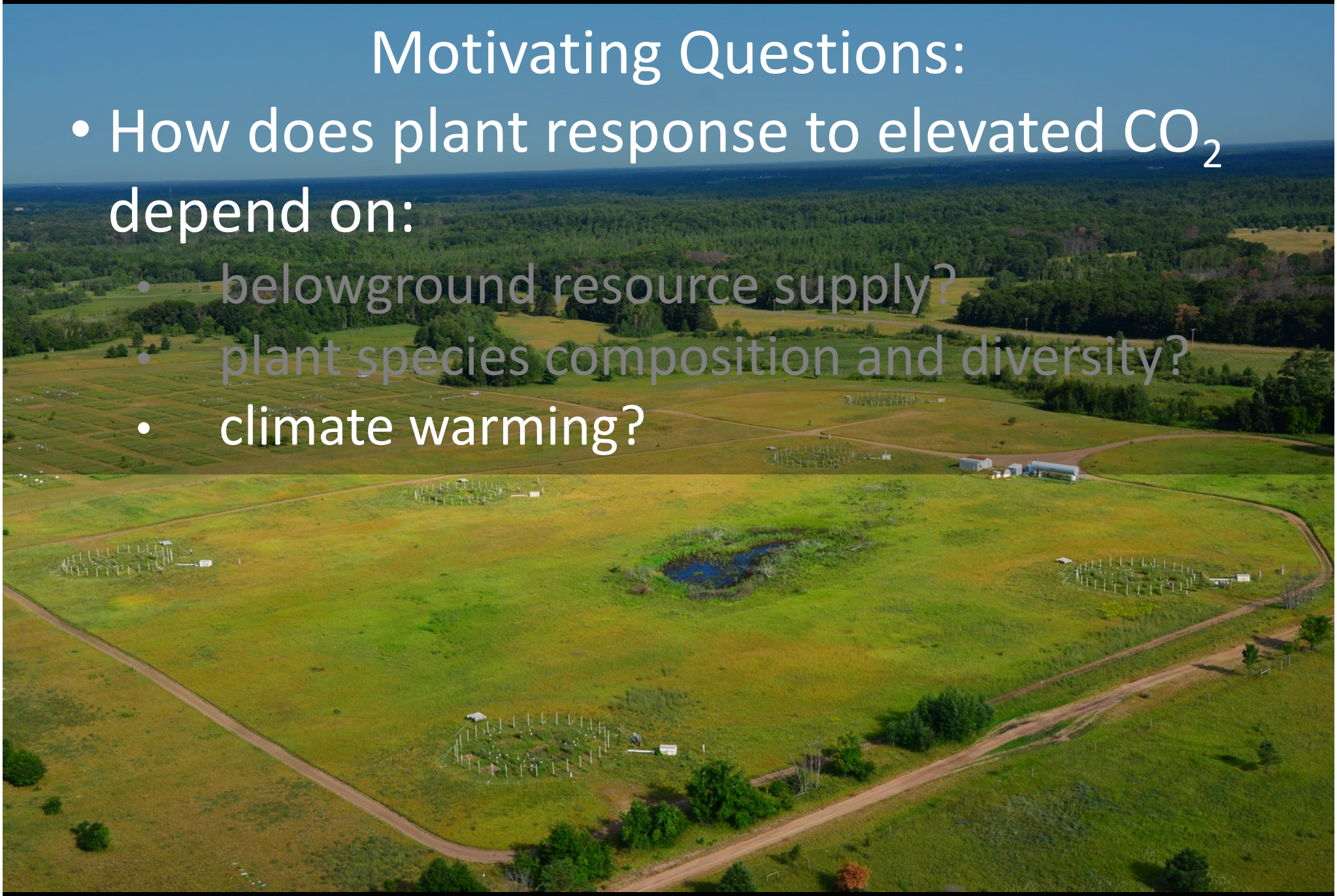

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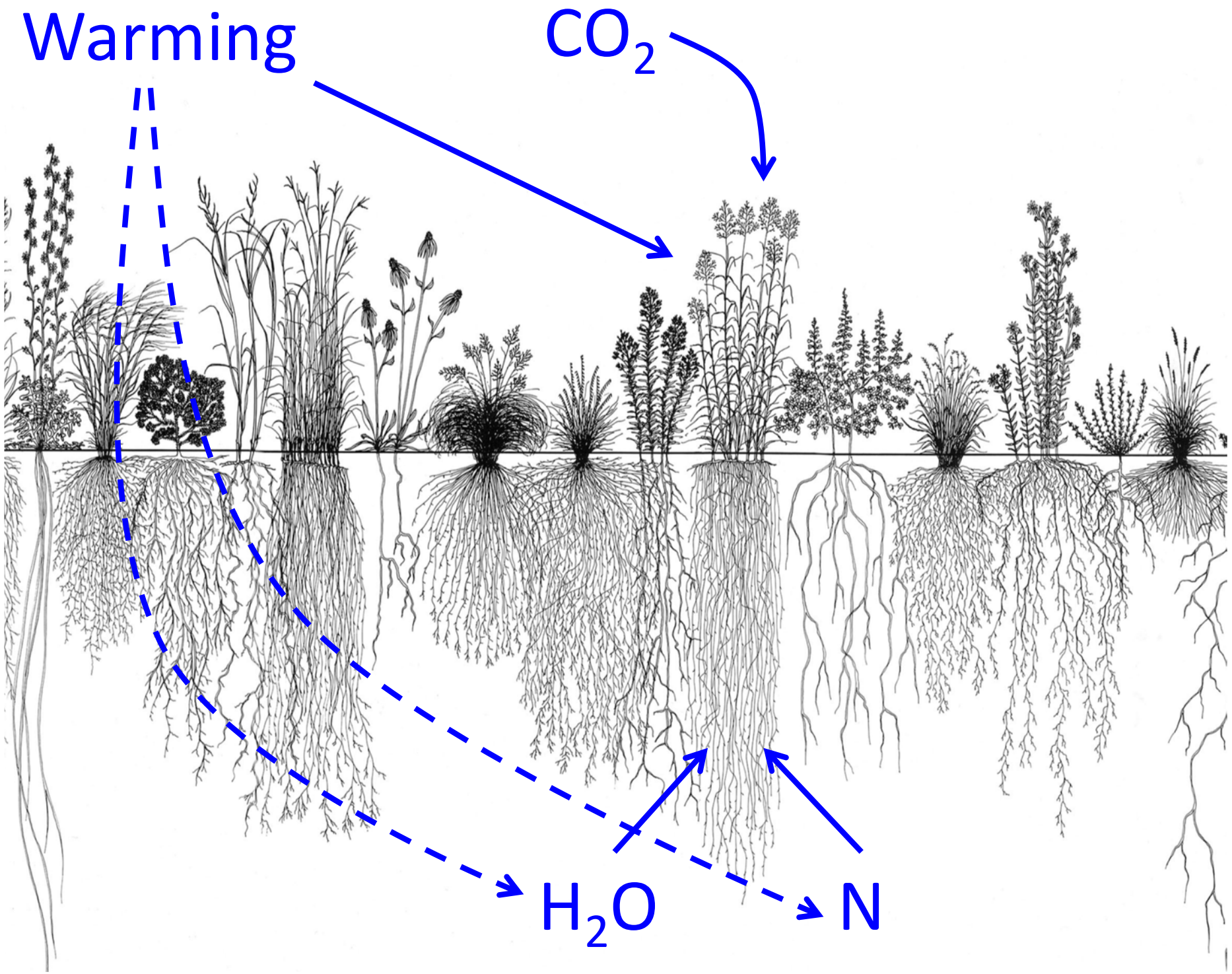
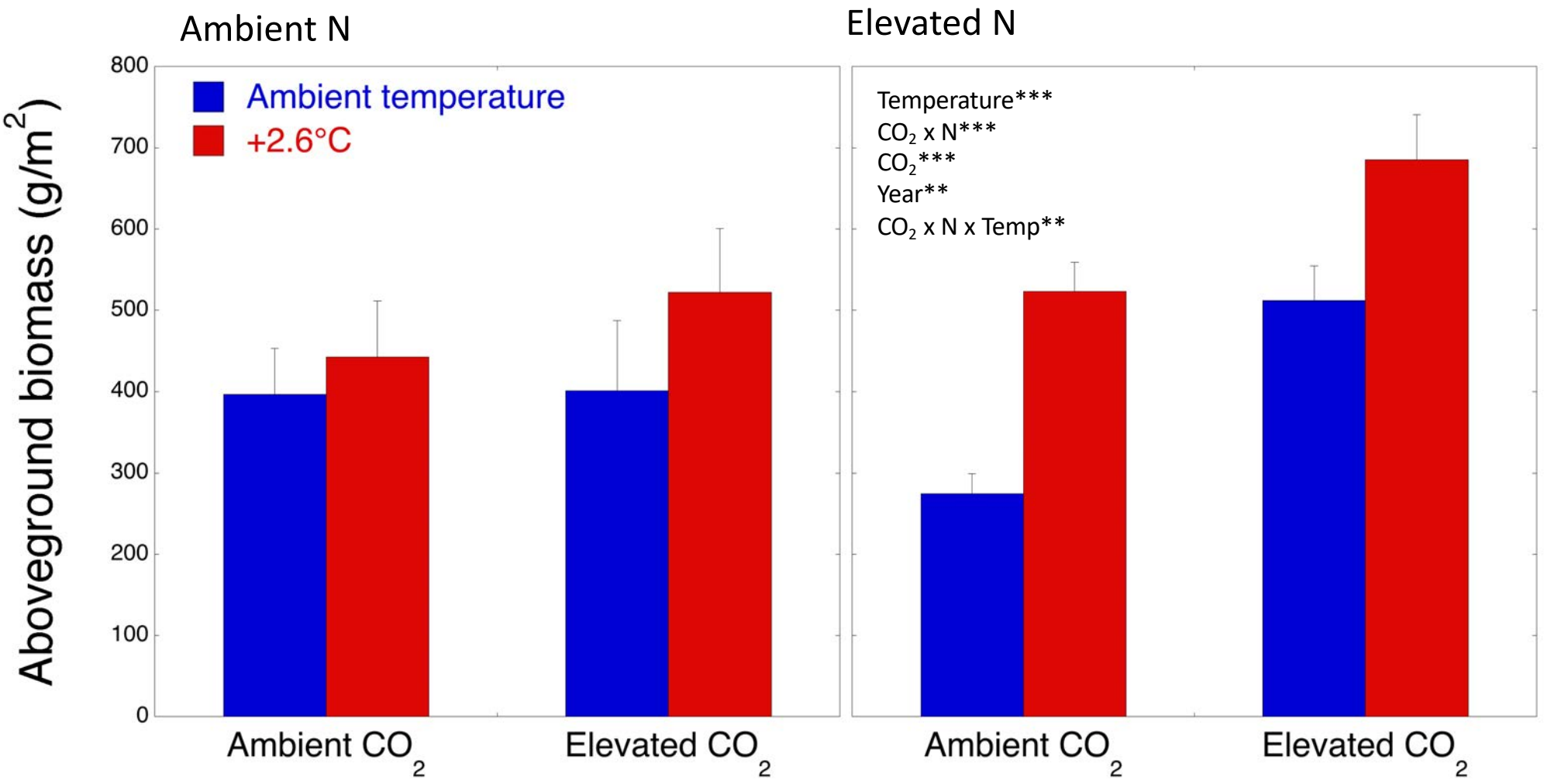

Warming
CO_2
H_2O
N

Warming, CO_2, and N all increased aboveground biomass
Complex interactions



2012-2018 average

Theoretical predictions based on physiology

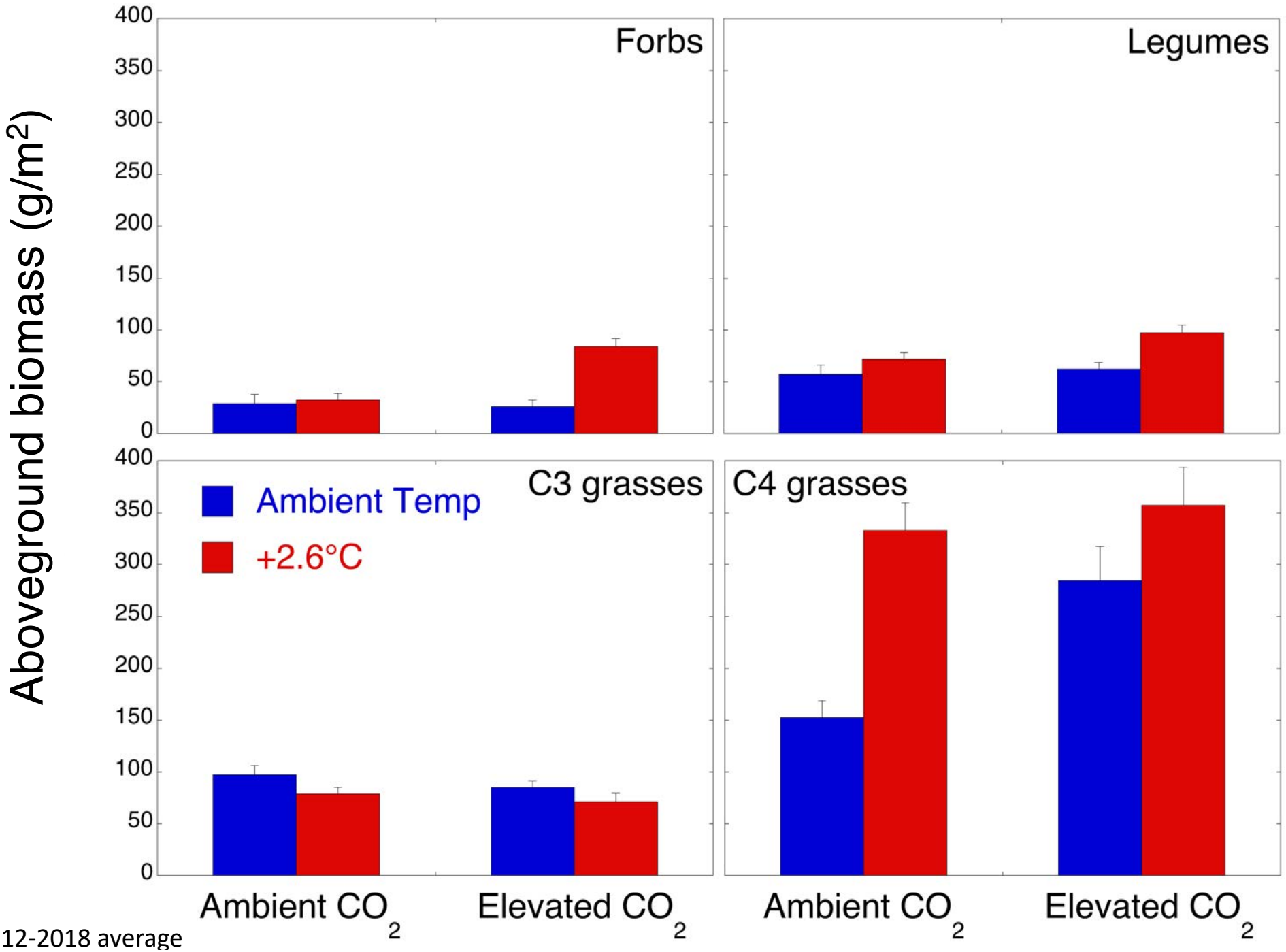
C_3 grass

Negative effects of temperature offset by elevated CO_2

C_4 grass

Positive effects of temperature

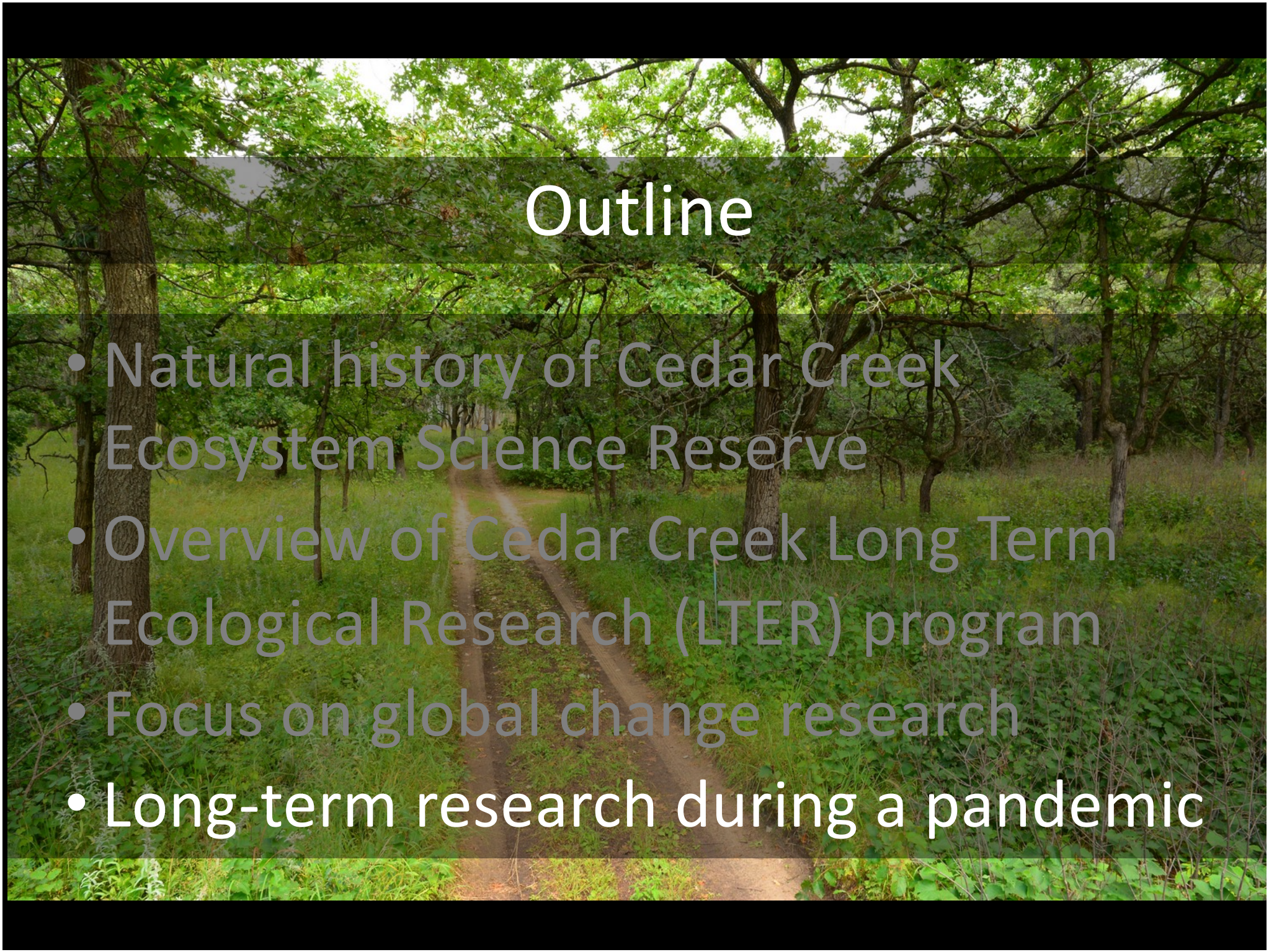
Warming decreased C_3 grasses and increased other groups



2012-2018 average

Summary

- Elevated CO_2:
  - Increased biomass when belowground resource supply was relatively high
  - Increased C_3 grasses initially, but C_4 grasses over time
  - Increased biomass more in more diverse plots
- Warming:
  - Increased total biomass because of increased C4 grass biomass
  - Effects were as large as CO_2 and N effects



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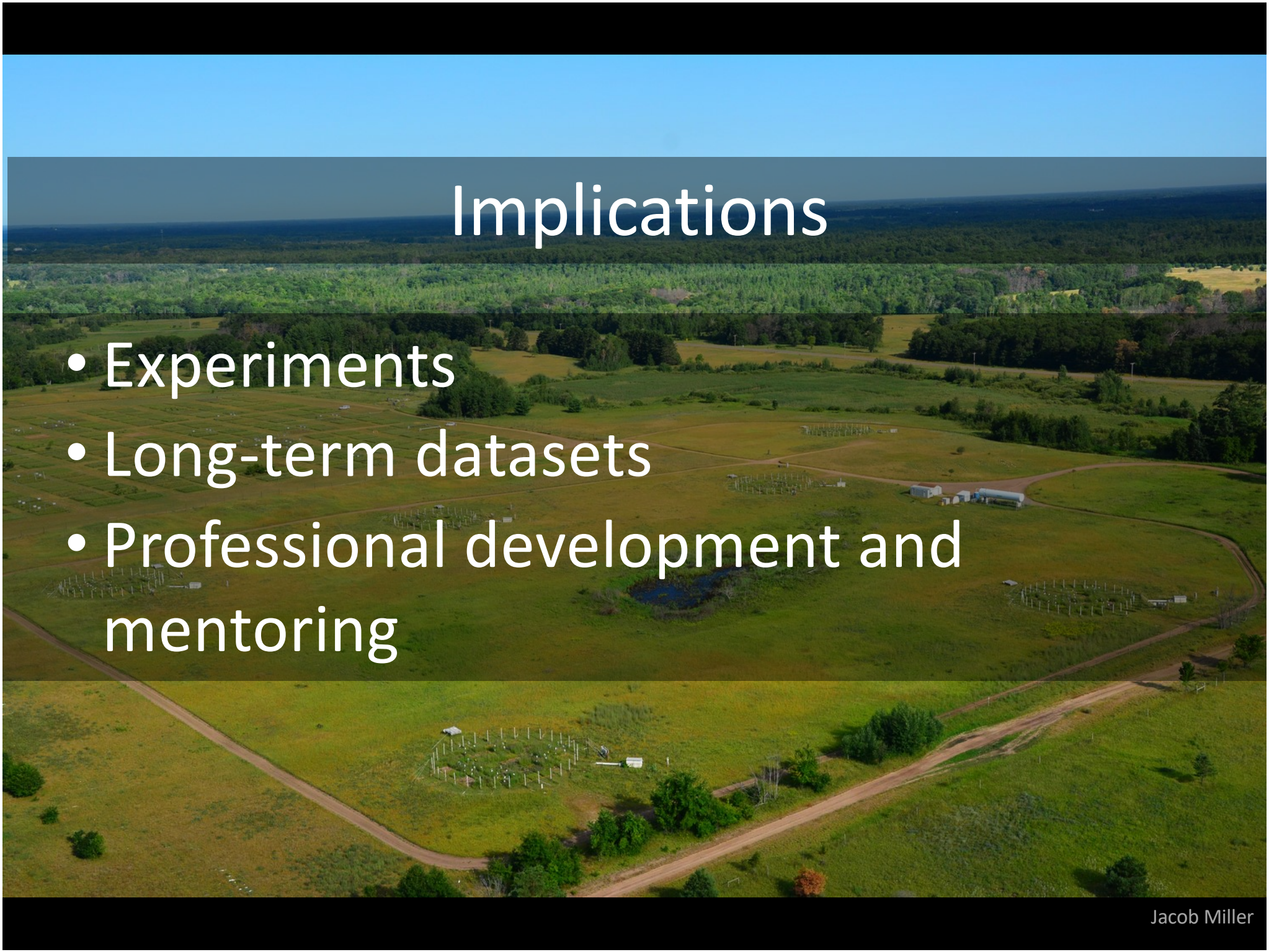

Implications

- Experiments
- Long-term datasets
- Professional development and mentoring

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