Impacts of climate change on agricultural and forestry plants

What do we know from empirical studies? What don't we know?

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Overview

How do changes in

- *temperature*
- *precipitation/water availability*
- *atmospheric CO_2 concentrations*

impact major crop and forestry plant species?

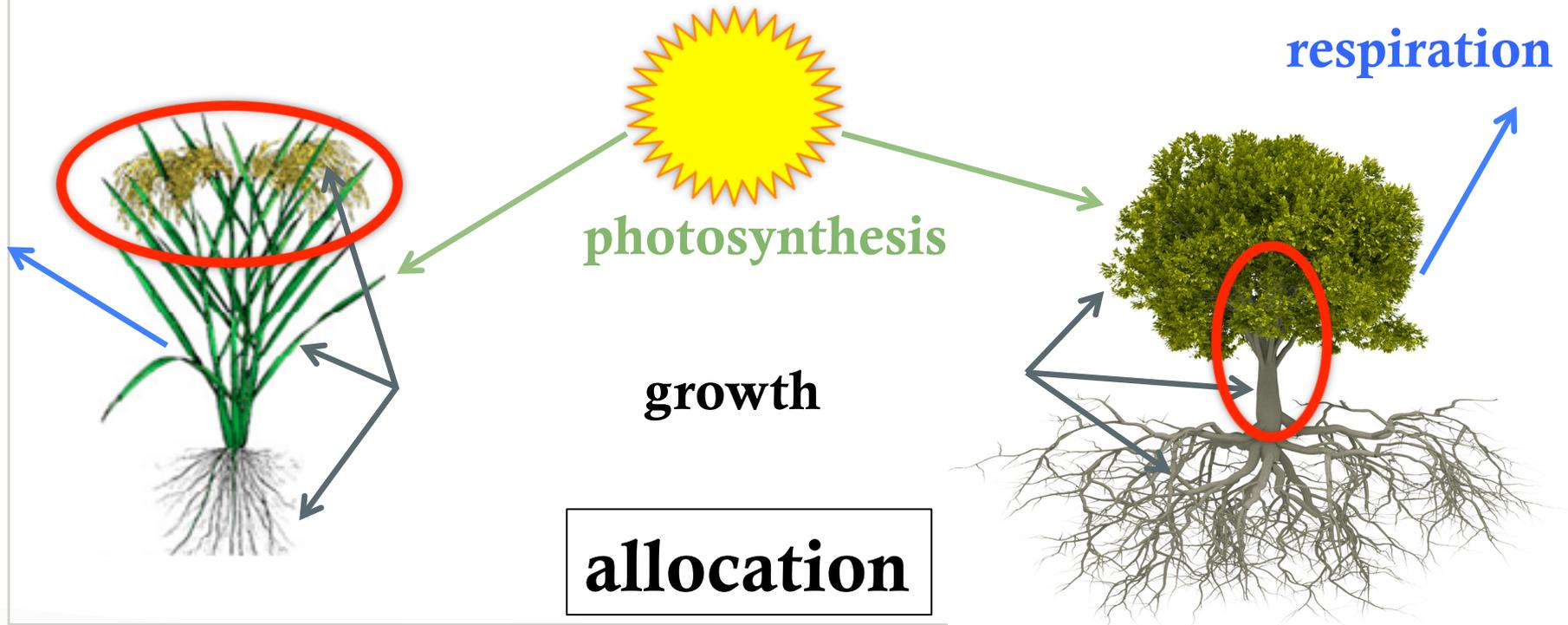# Data availability

Historical data/long term observations
Climate change experiments

photo credit: K. Stepnitz, MSU

As we parse the experimental results we have to remember that impacts on

photosynthesis ≠ productivity ≠ yield

respiration

photosynthesis

growth

allocation

What do we know?

Agriculture

Key Messages:

- Many crops show positive responses to elevated carbon dioxide and low levels of warming, but higher levels of warming often negatively affect growth and yields.
- Extreme events such as heavy downpours and droughts are likely to reduce crop yields because excesses or deficits of water have negative impacts on plant growth.

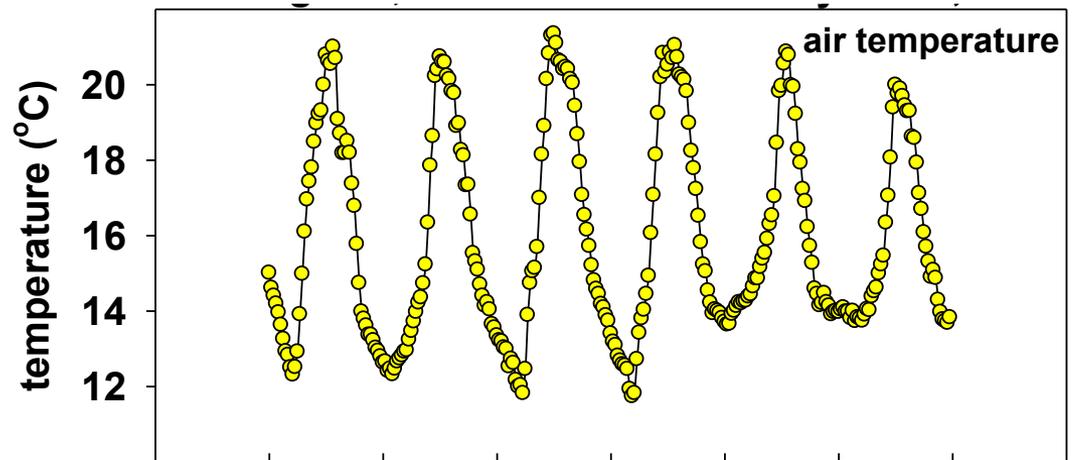**Global Climate Change Impacts in the United States**

A State of Knowledge Report from the U.S. Global Change Research Program

Temperature affects plant:

- respiration
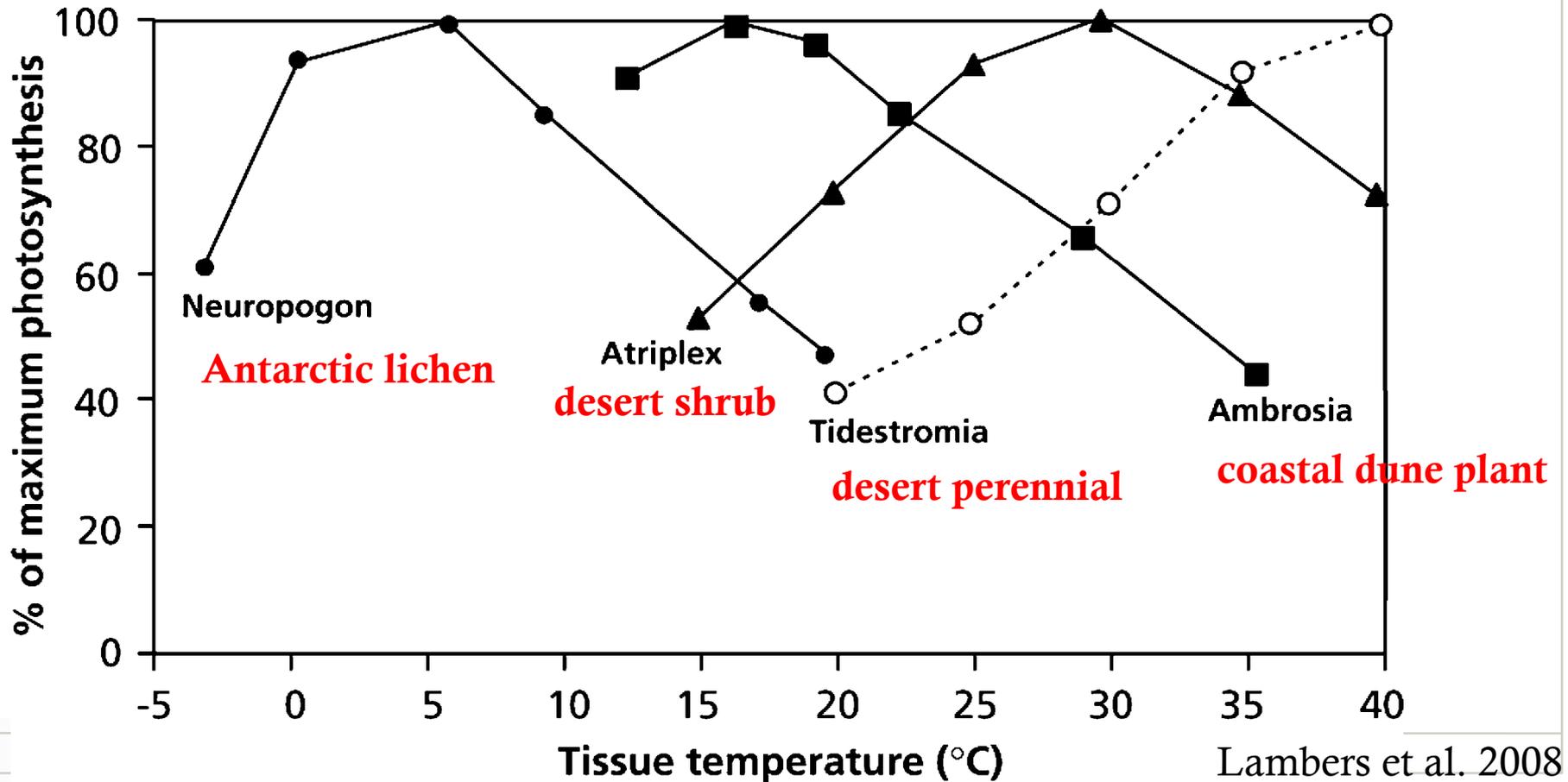- photosynthesis
- growth
- phenology

Many different temperature metrics are important

- maximums
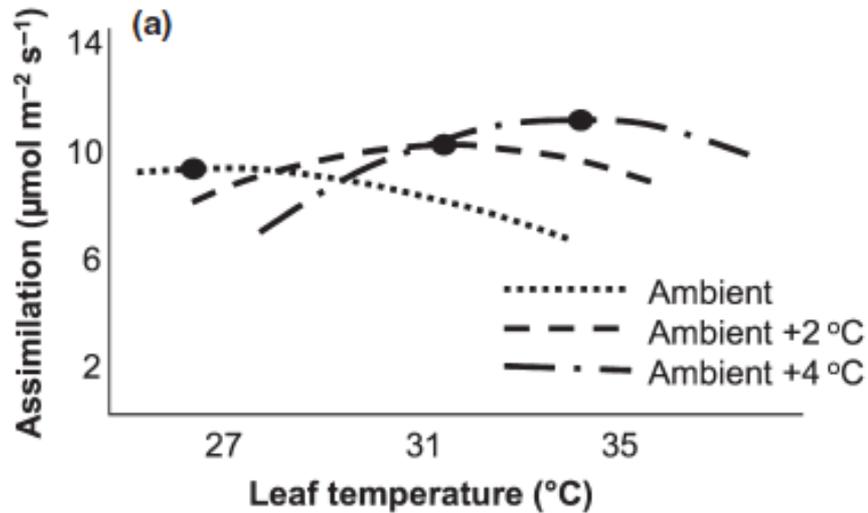- minimums
- daytime
- nighttime

As temperatures increase…

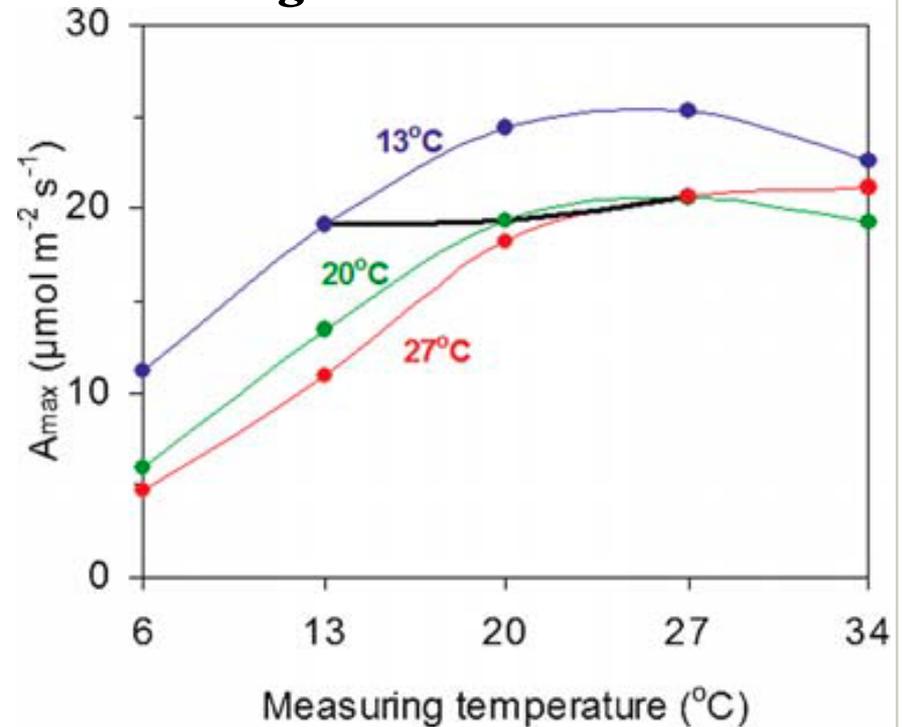plants may be operating beyond their photosynthetic optimum temperature

Lambers et al. 2008

As temperatures increase…

But, some acclimation can occur
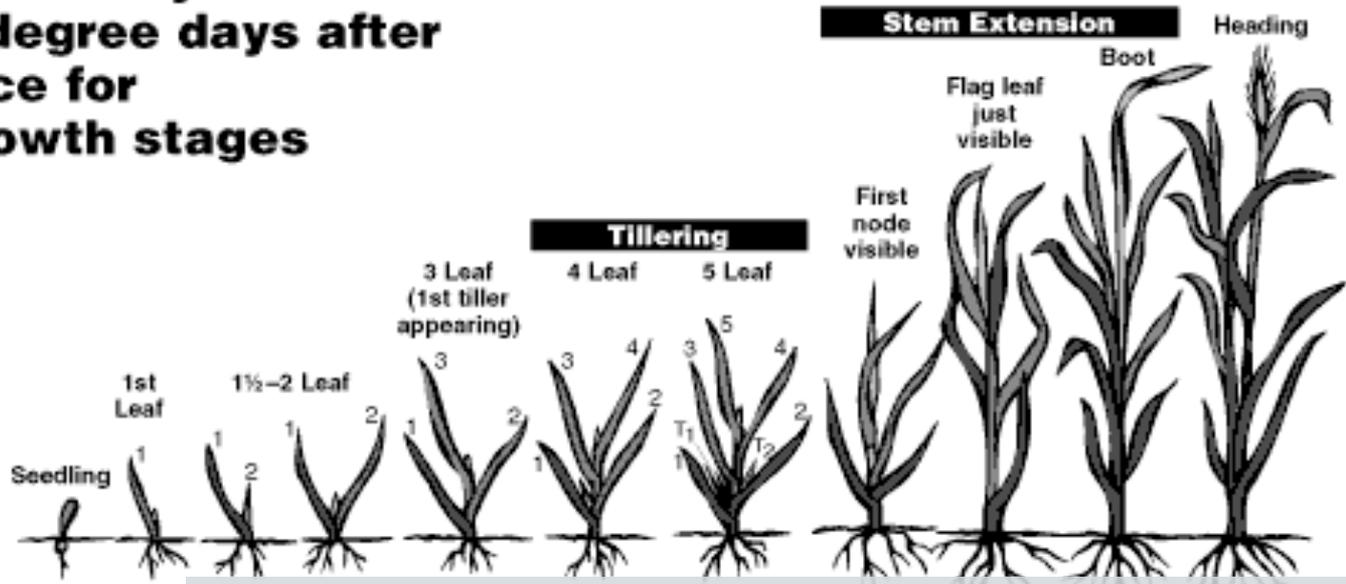
Plantago

Quercus

Smith and Dukes, 2013

Lambers et al. 2008

As temperatures increase…

developmental stages occur earlier

Approximate days or growing degree days after emergence for wheat growth stages

Seedling — 1st Leaf — 1½–2 Leaf — 3 Leaf (1st tiller appearing) — **Tillering** 4 Leaf, 5 Leaf — **Stem Extension** First node visible, Flag leaf just visible, Boot — Heading

Early Planting (days)	7-8						53	58
Late Planting (days)	6-7	11-13	16-18	21-23	25-27	28-31	45	49
Growing Degree Day* (units)	72							

The lettering on the drawing represents the following: 1=1st leaf on the main stem of the plant; 2=2nd leaf on the main stem; 3=3rd leaf on the main stem; 4=4th leaf on the main stem. [The coleoptile is not counted as a leaf when determining leaf stages.]

*Growing Degree Day Units = $\frac{(\text{Maximum Day Temperature} + \text{Minimum Day Temperature})}{2} - 32$

See extension circular EB-37, Use of Growing Degree Days to Determine Spring Wheat Growth Stages, for details about what development and use of growing degree day units.

For plants with chilling requirements, some stages may not be able to occur

Changes in precipitation amount…

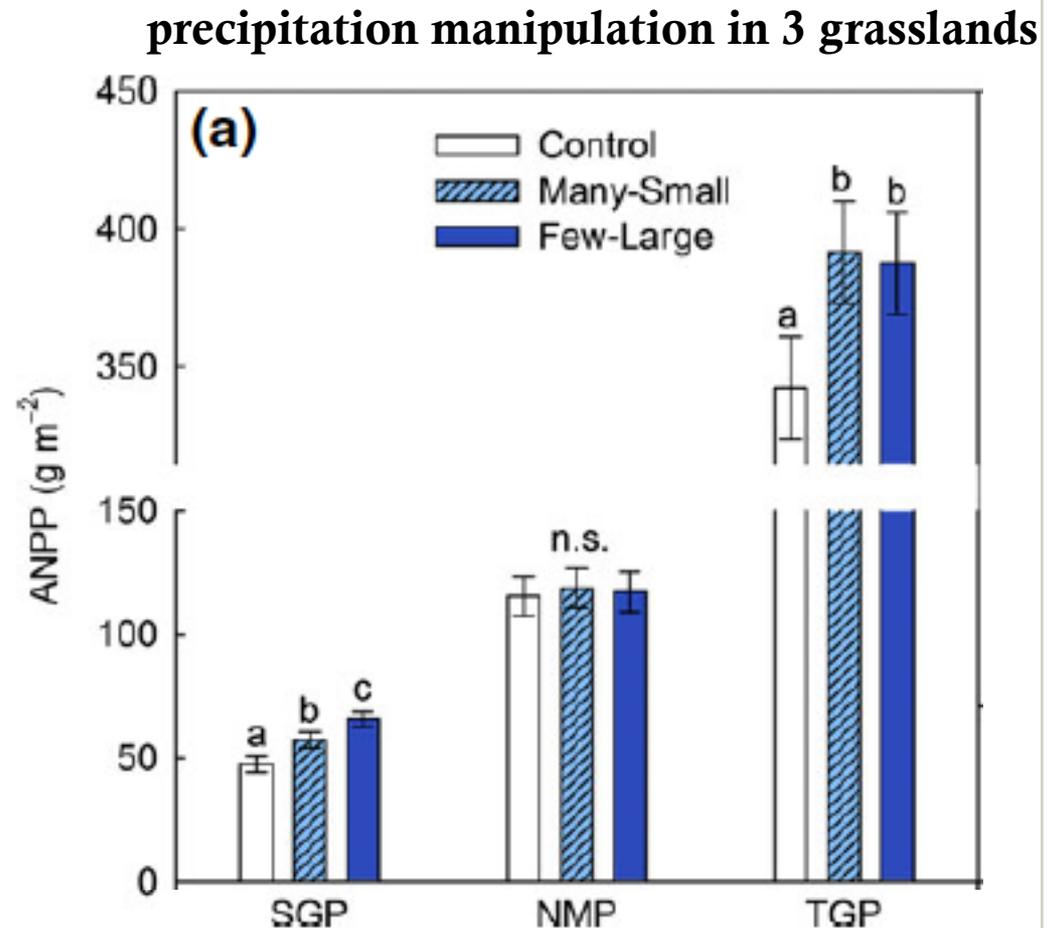Plants vary in drought tolerance, but less water is bad for plants!

Drought tolerance = slow growth and greater belowground allocation.

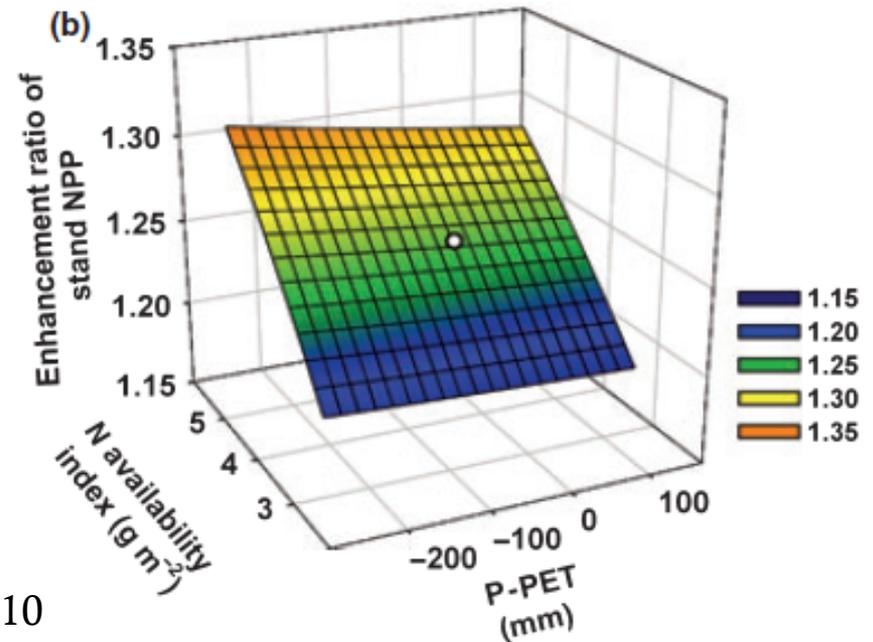# Changes in precipitation timing…

Can impact productivity

But much more work needs to be done in this area

precipitation manipulation in 3 grasslands

Wilcox et al 2015

Elevated atmospheric CO_2

Can growth enhancement by elevated CO_2 offset detrimental effects of other climate changes?
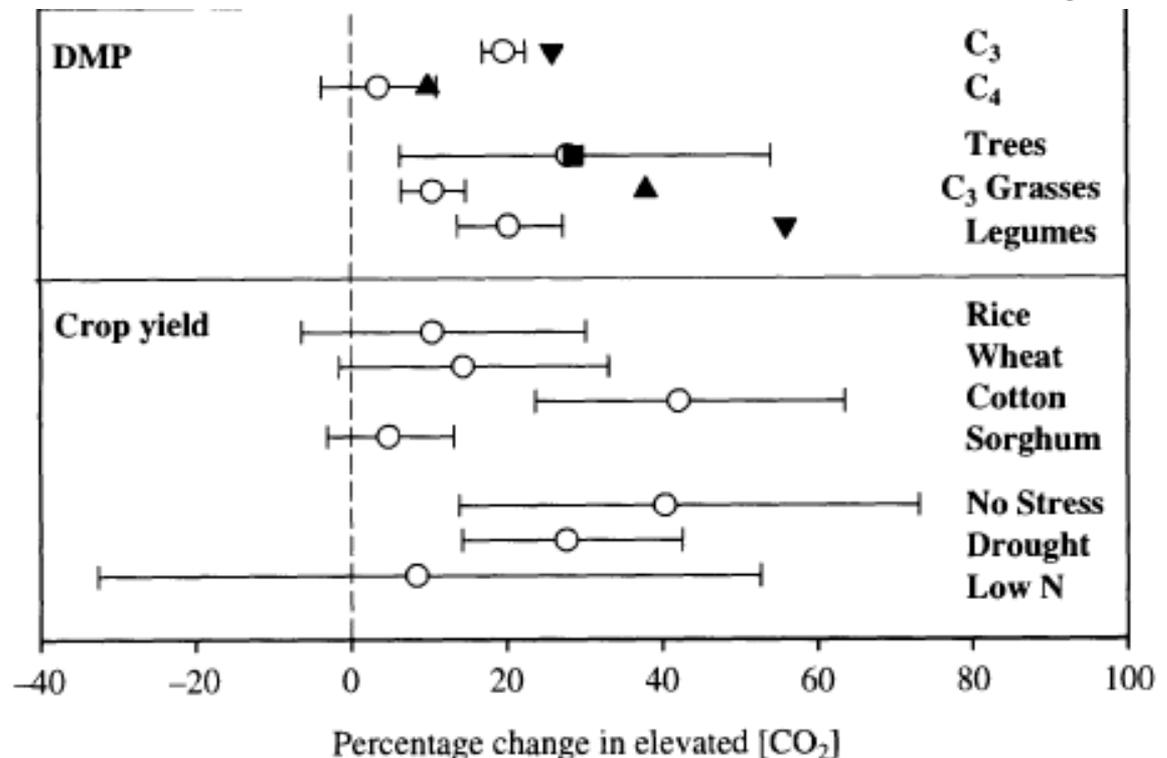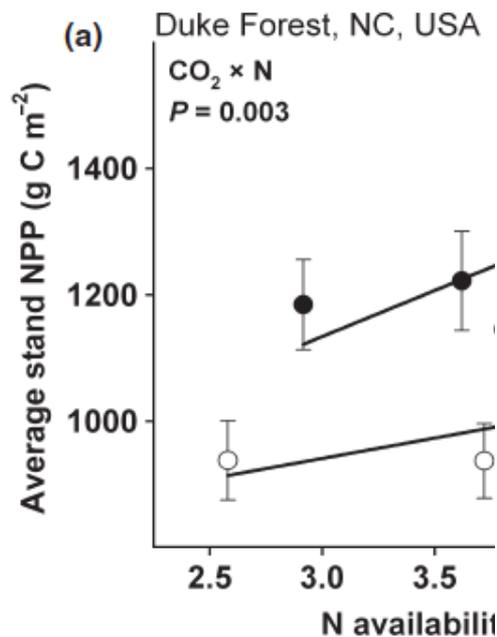

McCarthy et al. 2010

As atmospheric CO$_2$ increases…

many plants grow more, but the magnitude depends on nutrient and water availability and photosynthetic pathway
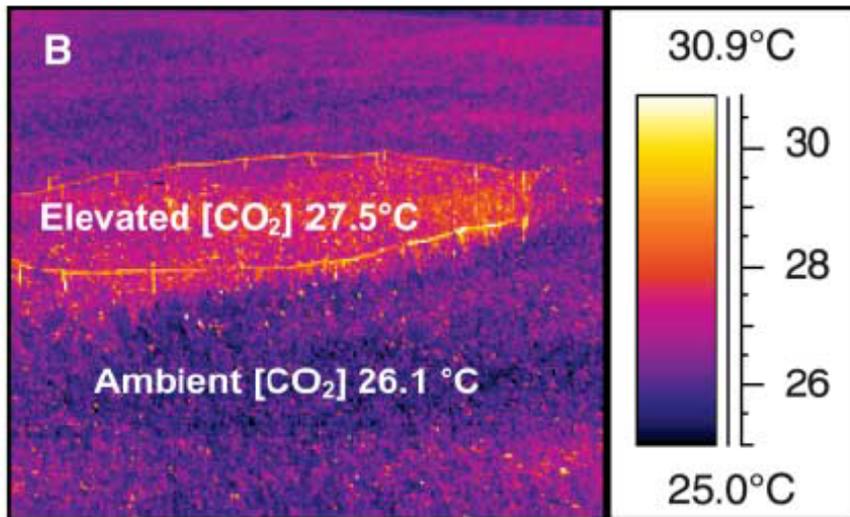
Ainsworth and Long, 2005
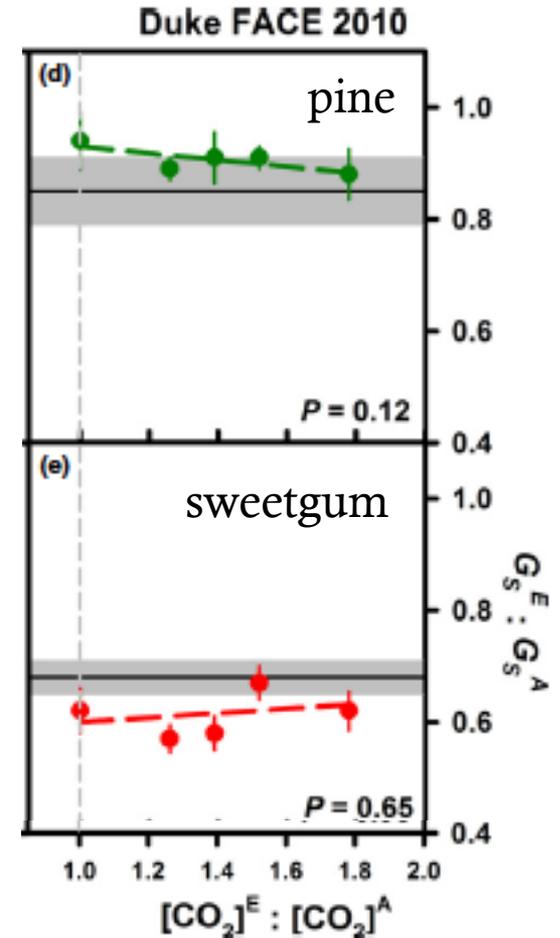

McCarthy et al. 2010

As atmospheric CO_2 increases…

stomatal conductance may be reduced

soybean

Long et al, 2006

Tor-ngern et al, 2014

What don't we know (very well)?

- Allocation – how it is affected by temperature, CO_2, nutrient availability?
- Can water use efficiency improve without decreases to yield?

- How much acclimation (in photosynthesis, respiration, growth)?
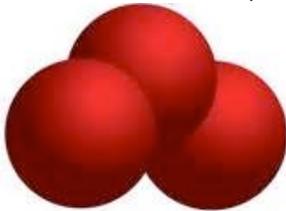- How do multiple (3+) global change factors interact?

The results of many studies suggest that temperature and increased CO_2 have less of an impact than predicted

How to address what we don't know?

Increase:
- systematic data sharing
- multifactor global change experiments
- extreme event experiments

O_3

CO_2