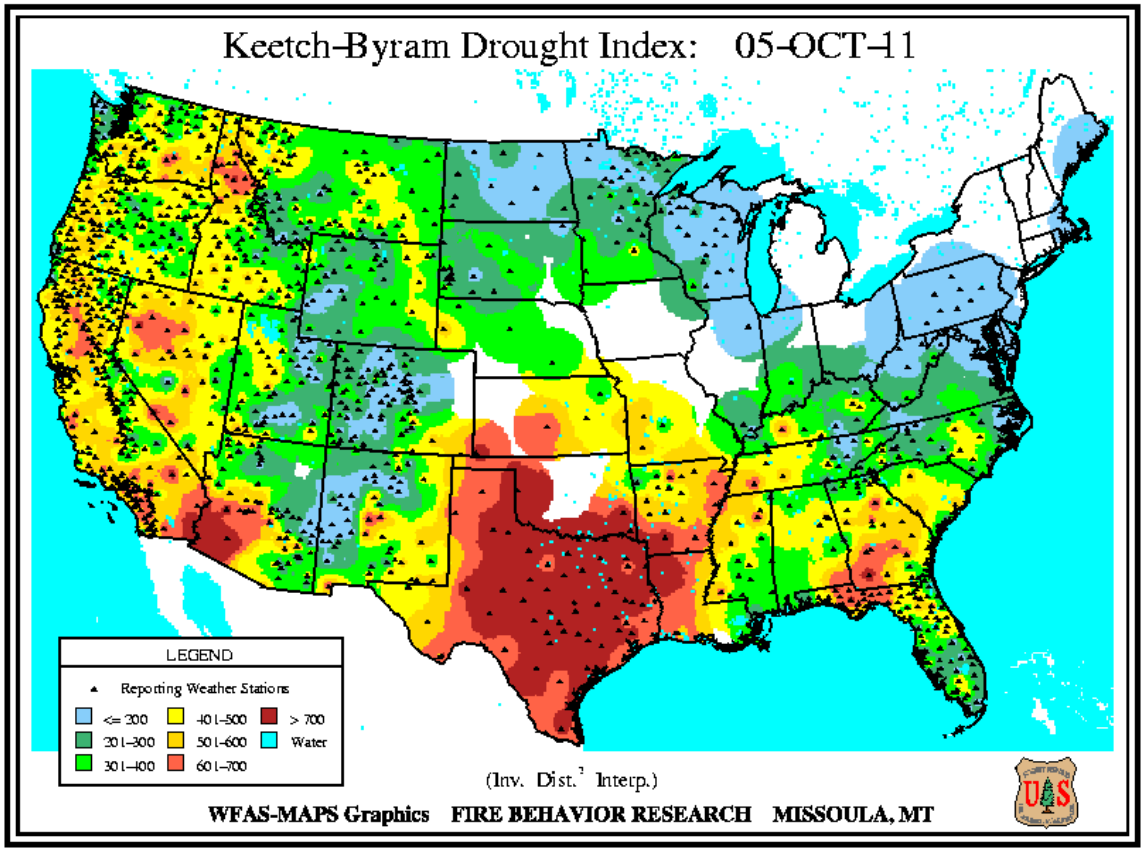
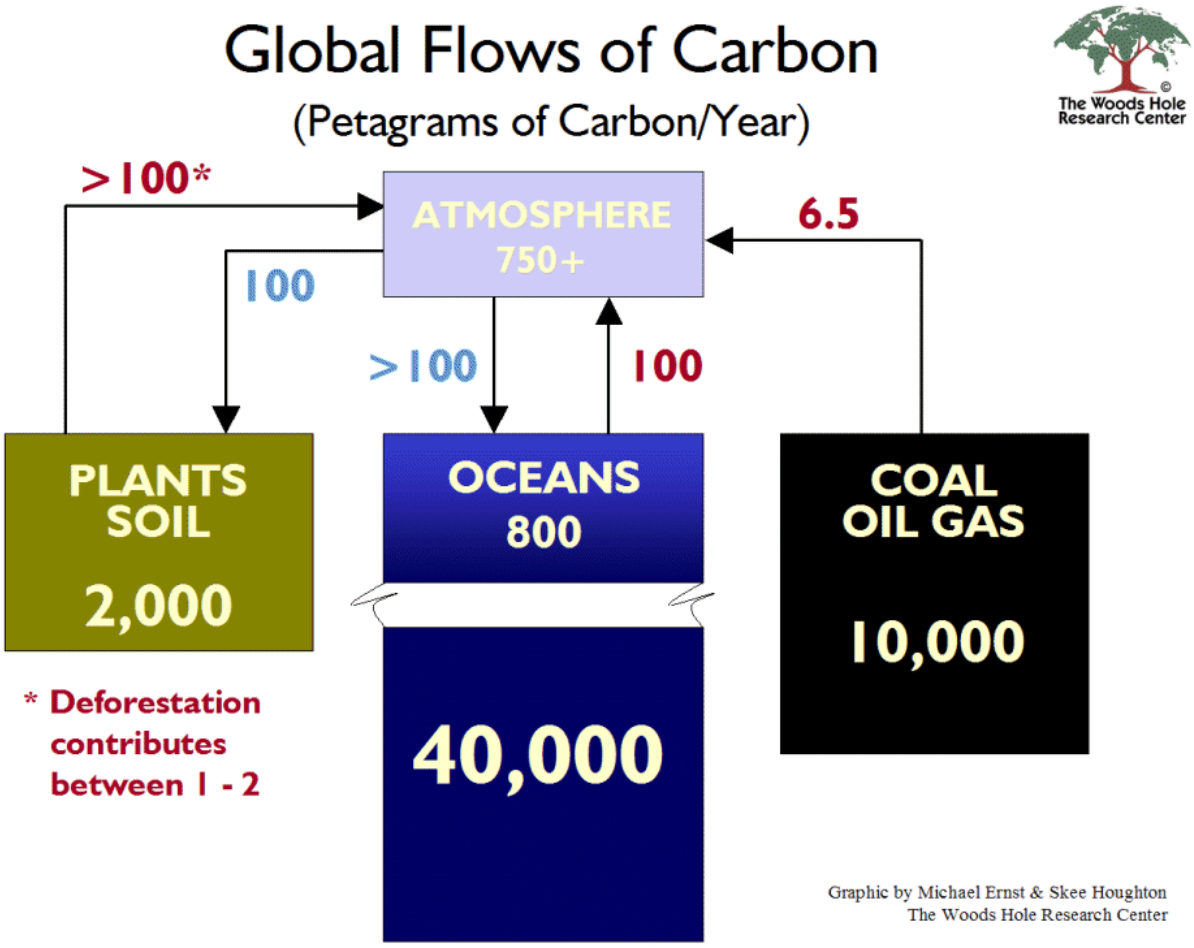
Forests in a Changing World

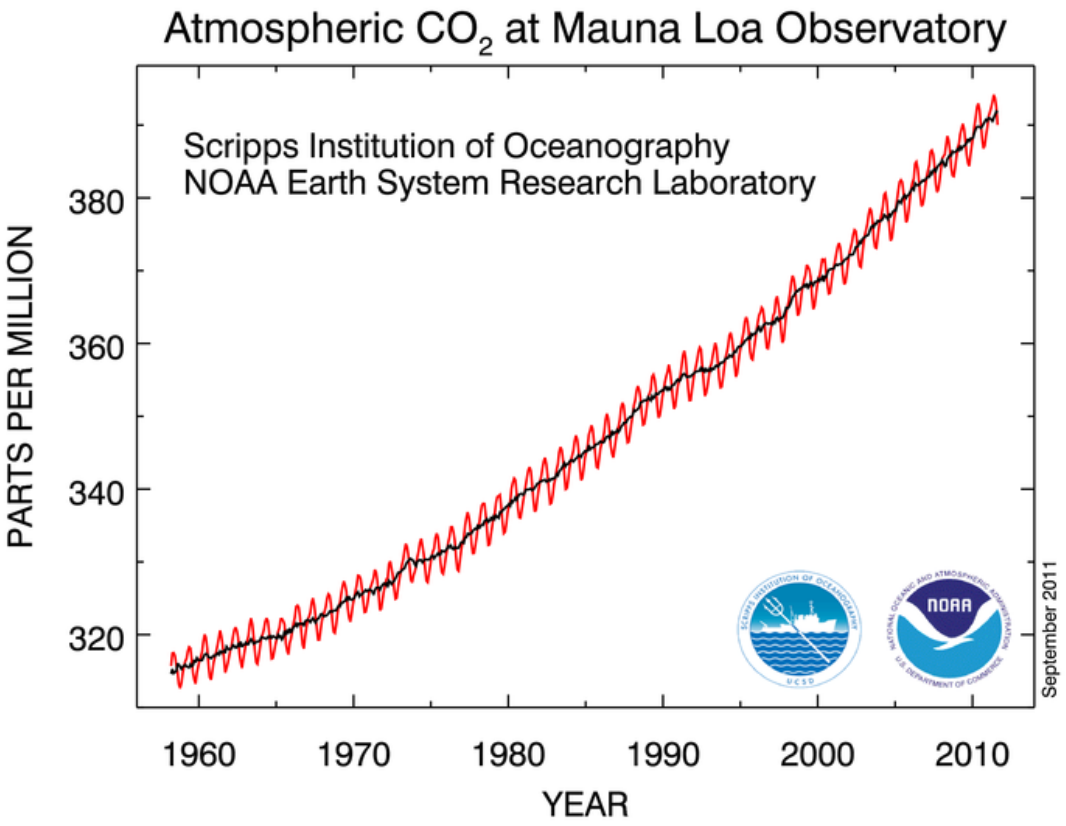
Tim Martin
School of Forest Resources and Conservation
University of Florida



Elevated Atmospheric CO_2 and Climate



Elevated Atmospheric CO_2 and Climate



Elevated Atmospheric CO_2 and Climate

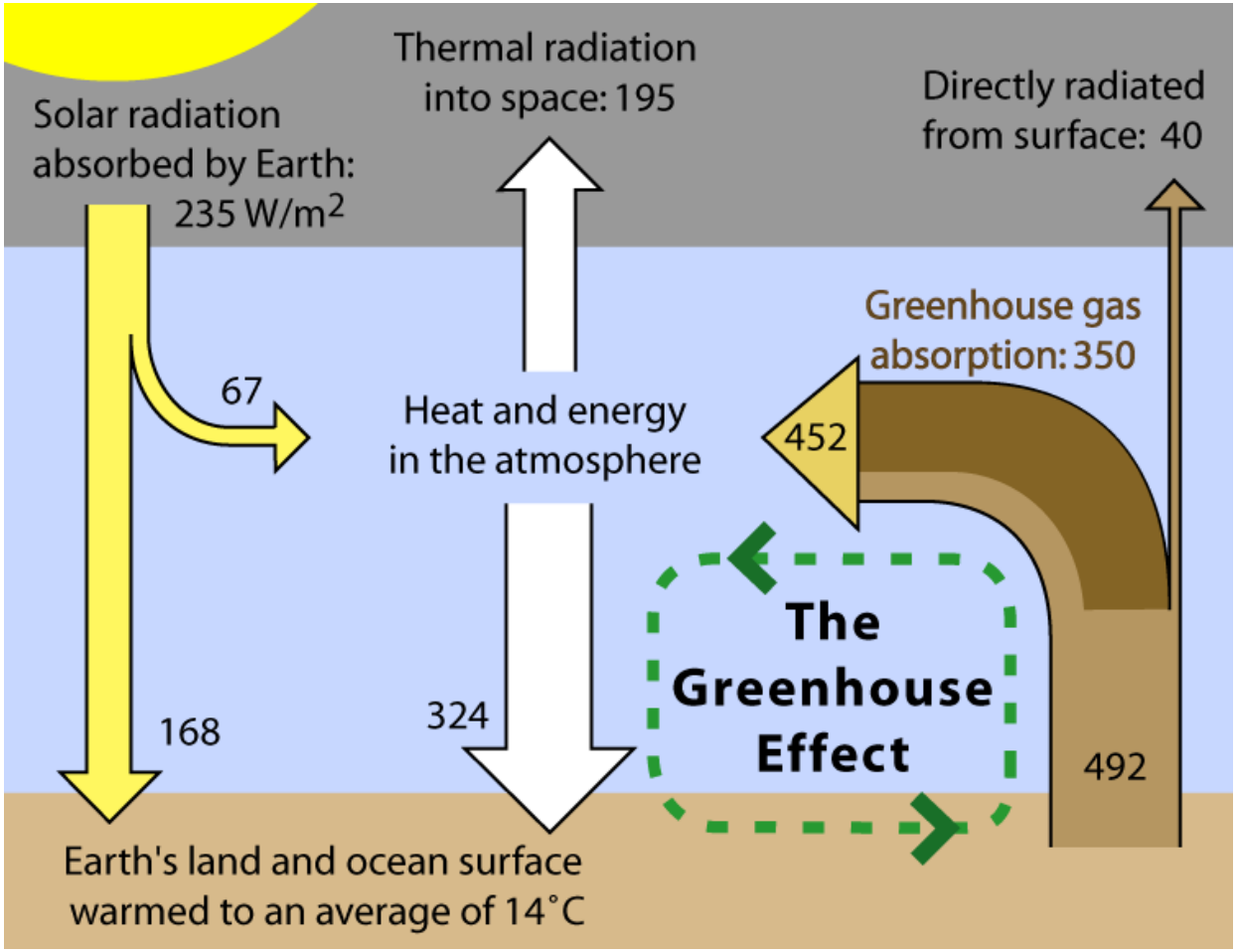
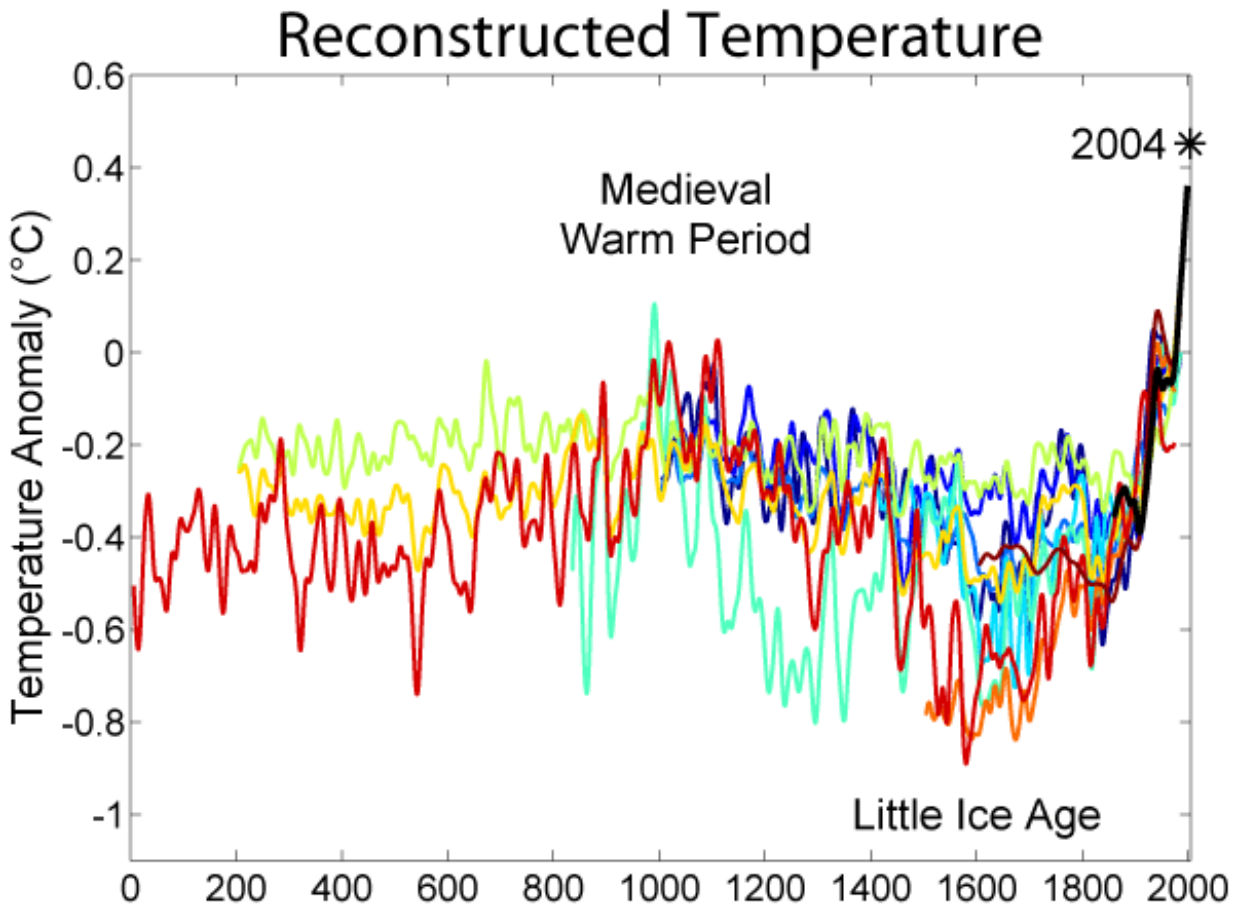


Image created by Robert A. Rohde / Global Warming Art
http://www.globalwarmingart.com/wiki/File:Greenhouse_Effect_png

Elevated Atmospheric CO_2 and Climate



Colored lines = temperature proxies like ice cores and tree rings

Black line = instrument temperature

Image created by Robert A. Rohde / Global Warming Art
http://www.globalwarmingart.com/wiki/File:2000_Year_Temperature_Comparison_png

What We Know

- Atmospheric CO_2 ***is*** rising due to human activity
- Average temperatures are rising, mostly due to the effects of atmospheric CO_2
  - Warmer and more frequent hot days and nights are ***virtually certain***
  - Warm spells and heat waves are ***very likely*** to increase
- Altered precipitation regimes are ***likely***, but effects will vary across the globe (and across regions) and are more difficult to predict and may include
  - ***Likely*** increased intensity of rainfall events
  - Increased/decreased rainfall depending on location
- Increased tropical cyclone activity ***likely***

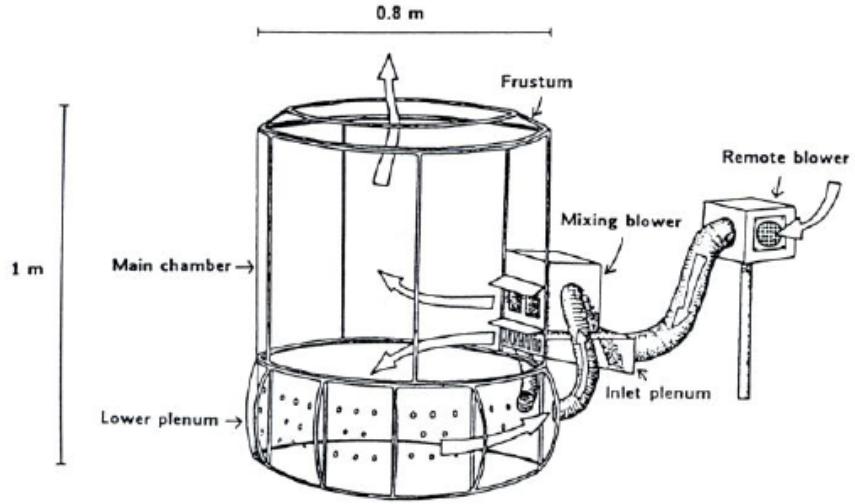
Effects on Trees and Forests

- Direct Effects of CO_2 on trees and forests
- Indirect effects through changes in environment
  - Elevated temperature
  - Altered precipitation regimes
  - Altered soil water balance
  - Altered storm frequency and/or severity
  - Alteration of other disturbance regimes
    - Wildfire
    - Insects and disease

Elevated CO_2 Studies - Chambers

Florida oak scrub
Kennedy Space Center / Smithsonian Inst.

Quercus alba and *Liriodendron tulipifera*
white oak and yellow-poplar seedlings
Oak Ridge National Lab



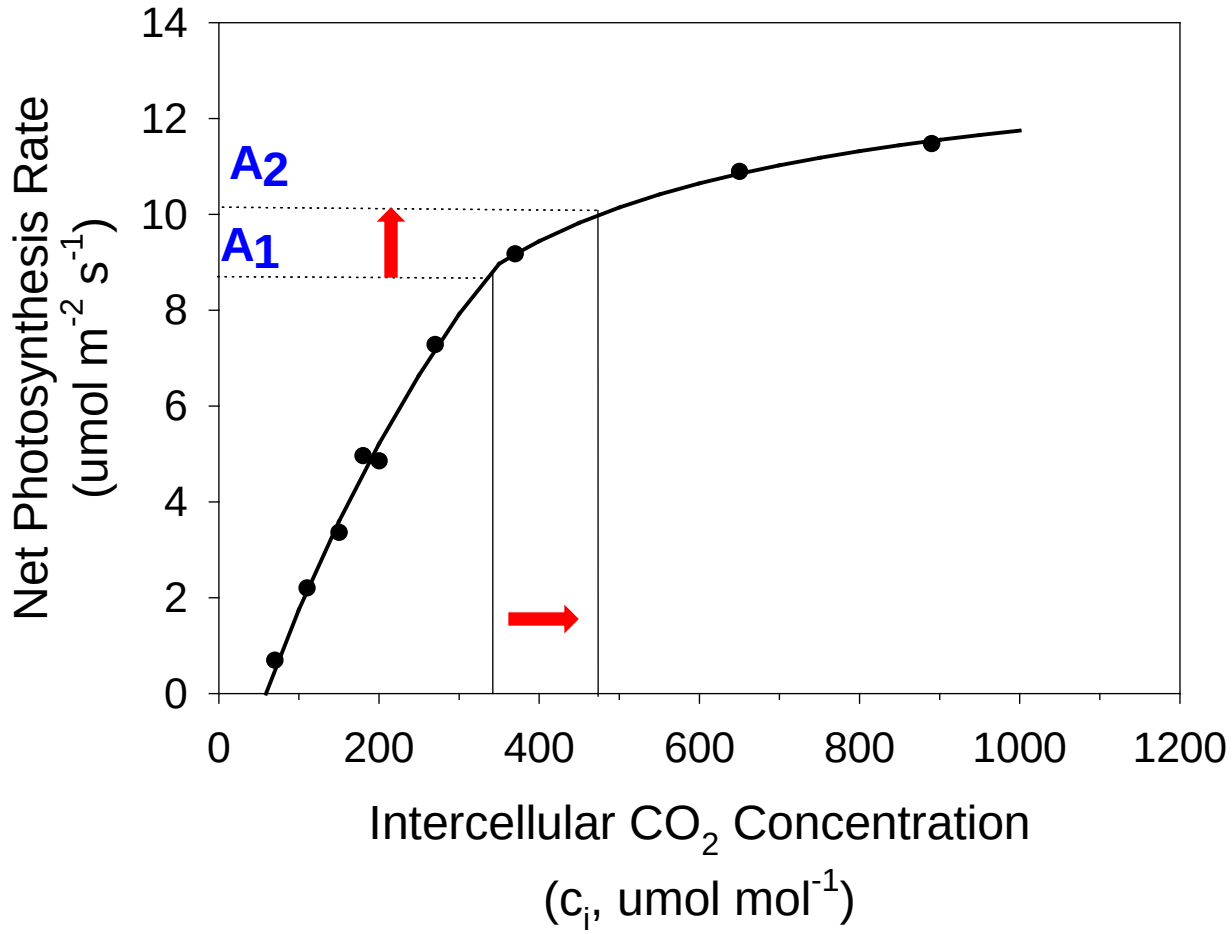
Allen et al. 1991. "SCOPE 45 Ecosystem Experiments", Chapter 15.

Forest Free-Air CO_2 Enrichment (FACE)

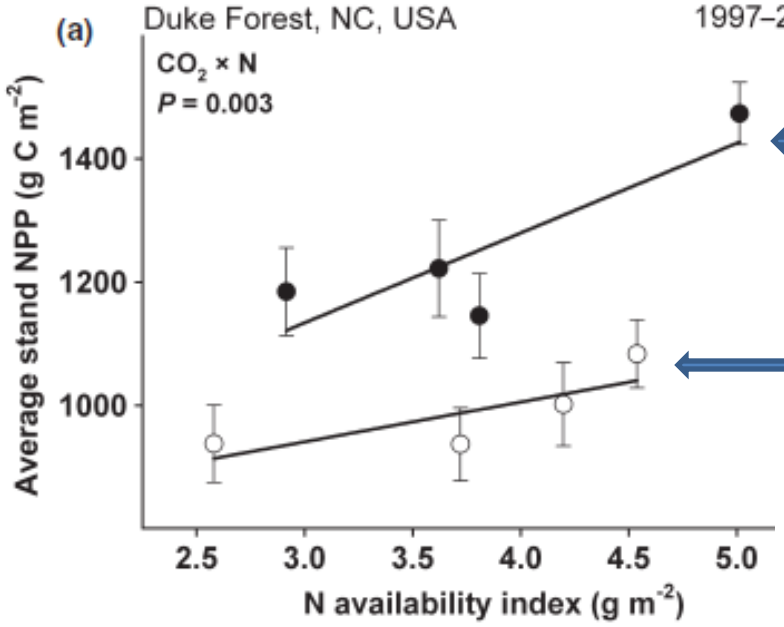
Pinus taeda
/ loblolly pine
Duke Forest, NC

Populus tremuloides
/ trembling aspen
Rhinelander, WI

Direct and Short Term Effects of CO_2 on Net Photosynthesis



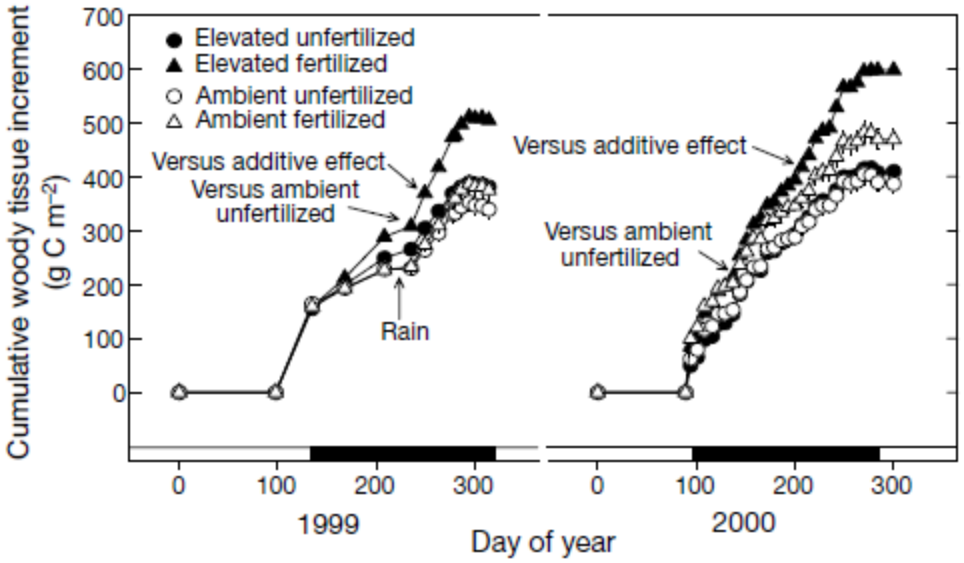
Long-Term Growth Response to Elevated CO_2 Depends on Availability of Other Resources



Elevated CO_2

Ambient CO_2

McCarthy *et al*. 2010. New Phytologist 185:514-528.



Oren *et al*. 2001. Nature 411:469-472.

Species Responses to CO_2 Vary

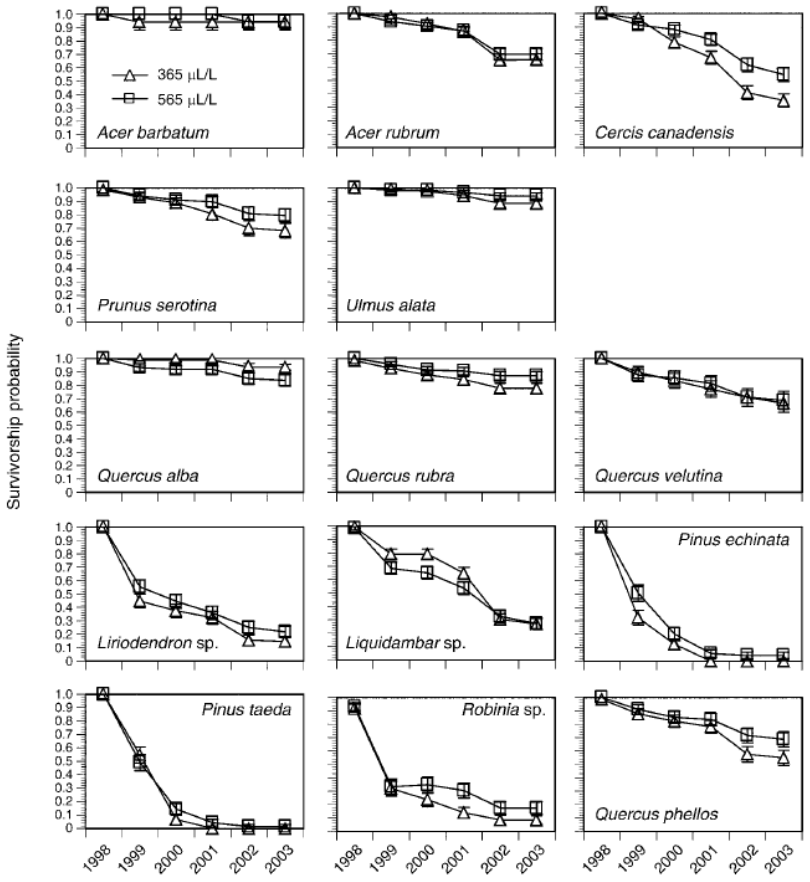
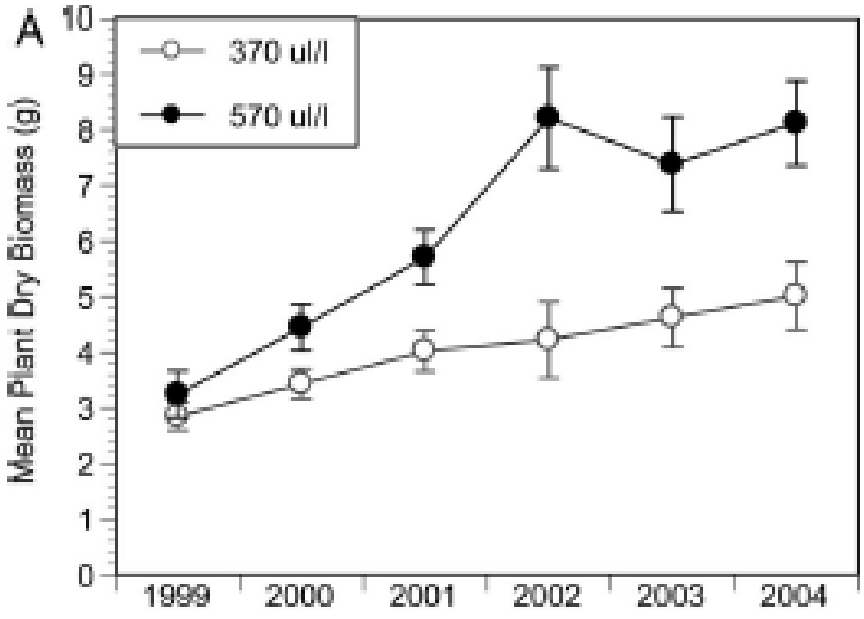


FIG. 4. Mean cumulative survivorship probabilities over six years for individual tree species growing under ambient (triangles) and elevated (squares) CO_2 treatments at FACE. Error bars represent ±SE.

- Understory tree growth and survivorship responses to CO_2 enrichment varied by species

Mohan *et al*. 2007. Ecological Applications 17:1198-1212.

Toxicodendron radicans response to elevated CO_2



Duke Forest, NC.
Mohan *et al*. 2006. PNAS 103:9086-9089.

Direct Effects of Temperature on Leaf-Level Carbon Balance

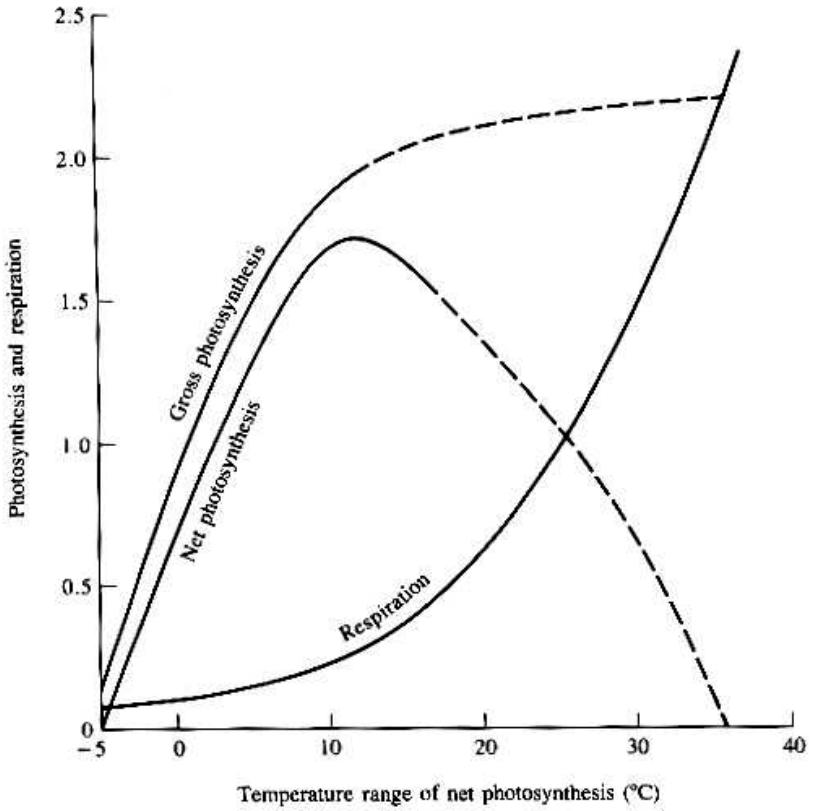
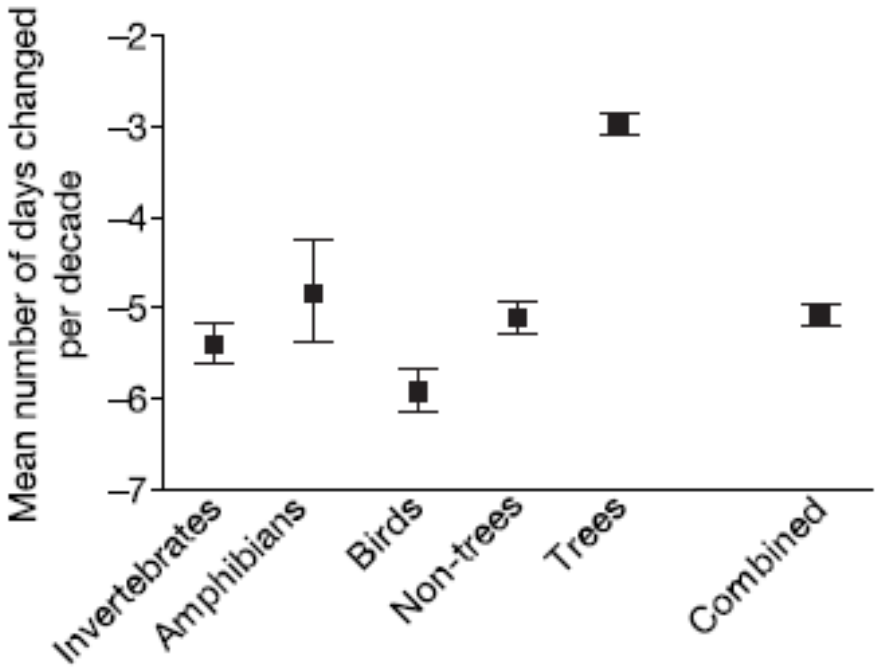


FIGURE 5.23. Effects of temperature on gross photosynthesis, respiration, and net photosynthesis of Swiss stone pine seedlings. Solid parts of lines are from actual measurements; dashed parts are estimated. From Tranquillini (1955) with permission of Springer-Verlag.

- Respiration increases faster with increasing temperature than does photosynthesis
- "Carbon starvation" is a possible outcome, especially in water-limited forests
- Reduced sugar availability can make trees more susceptible to other stresses
- In longer term, biochemical processes can acclimate to changing temperature, although not always enough to completely offset effects of change

Growing Season / Phenology Effects

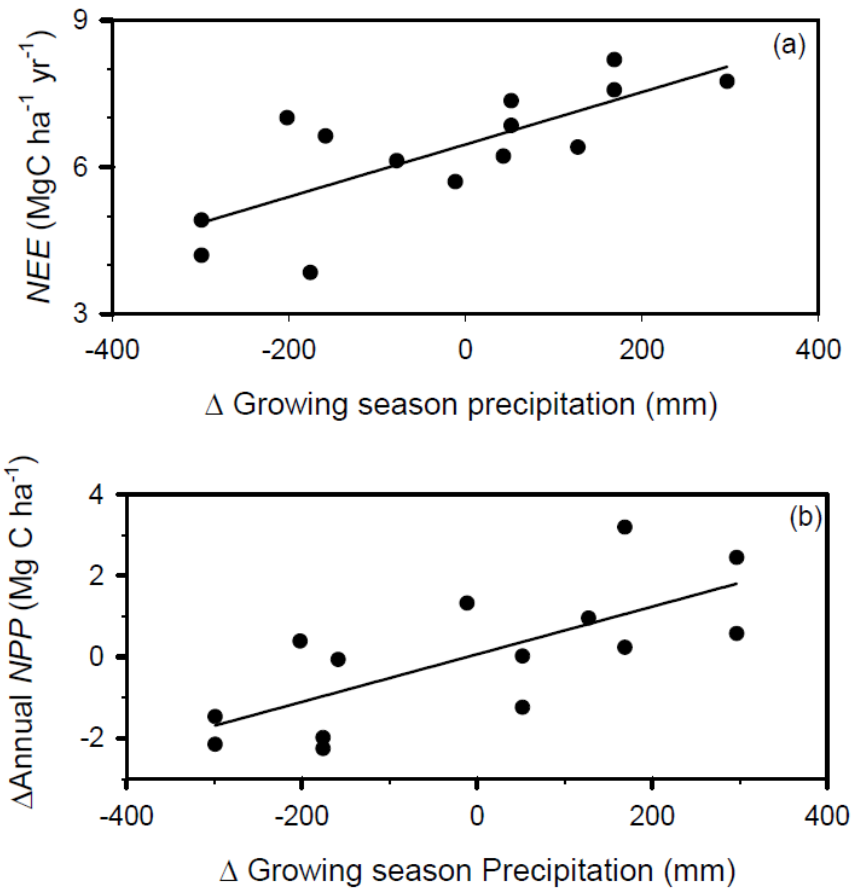


- Earlier spring flushing and breeding and migration behavior

Root *et al*. 2003. Nature 421:57-60.

Effects of Decreased Soil Moisture

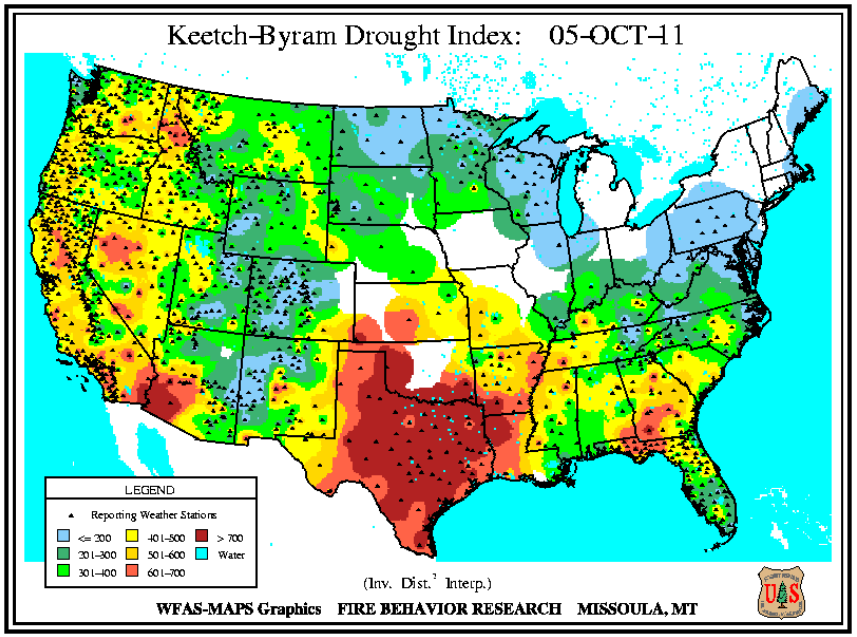
Pinus elliottii, north-central Florida



- Impacts on growth and carbon gain

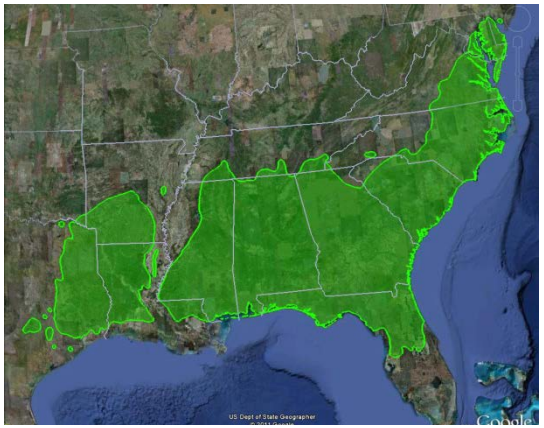
Bracho *et al.* 2011, Ecological Monographs .

Effects of Decreased Soil Moisture



- Impacts on growth and carbon gain
- Effects likely to be greater on edges of ranges where water balance may already be marginal

Pinus taeda / loblolly pine natural range



Potential moisture effects

Betula / birch drought mortality – Wisconsin
USFS

- Mortality, especially in
  - severe droughts
  - seedlings
  - forests where water balance is already marginal

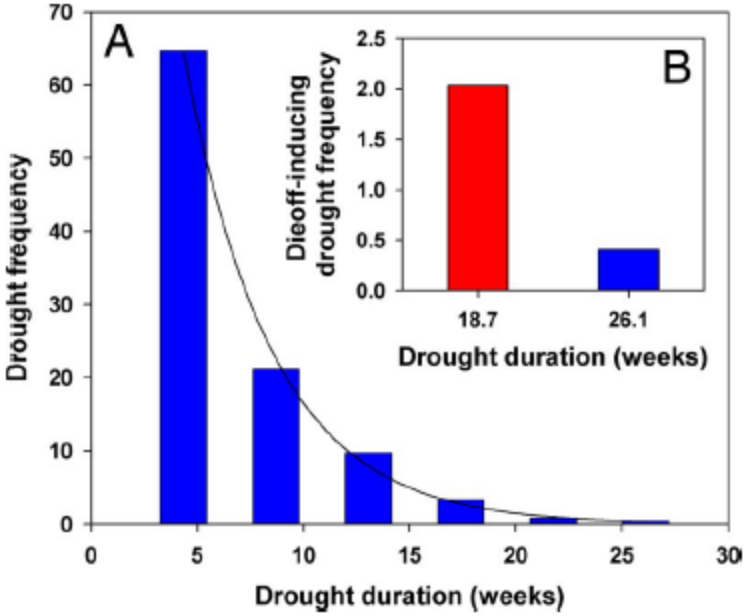
Potential moisture effects

Containerized Seedling

Bareroot Seedling

- Mortality, esp. in severe droughts, in seedlings, and in forests where water balance is already marginal
- Regeneration / seedling stage is most vulnerable stage

Interaction of Temperature and Drought



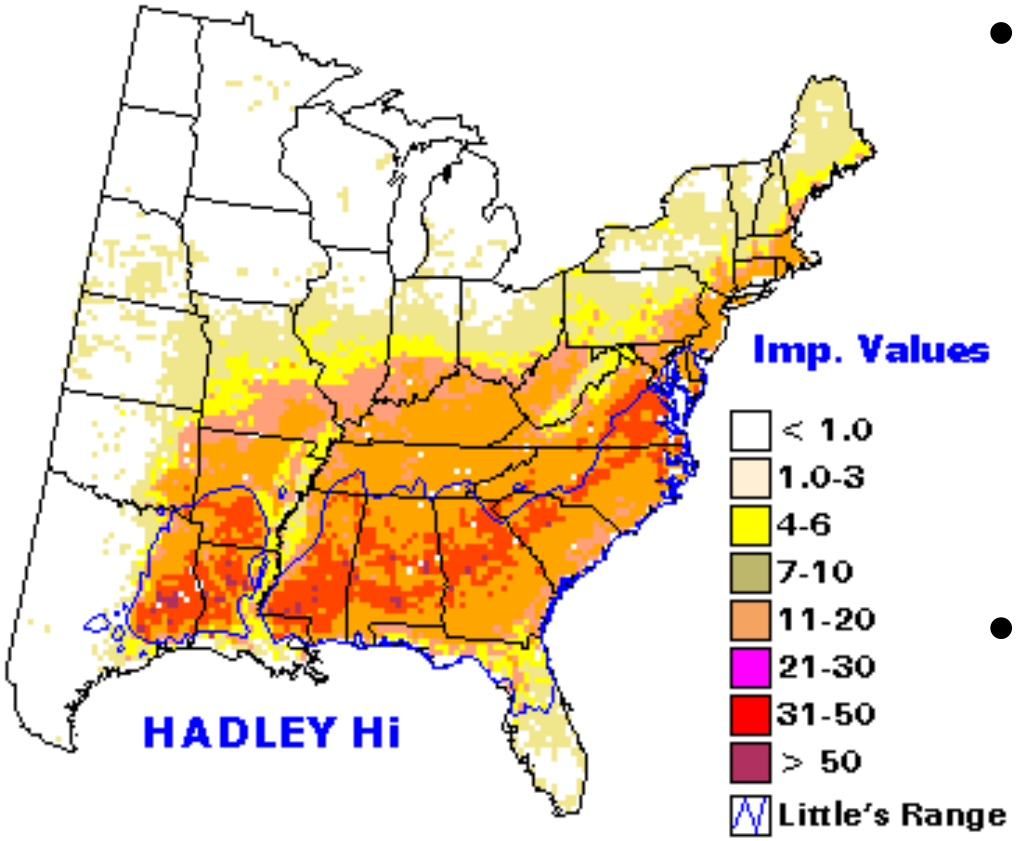
- Drought-associated pinyon pine dieoff events predicted to become five times more common under elevated temperature

Forestryimages.org

Adams *et al*. 2009. PNAS 106:7063-7066.

Range Shifts?

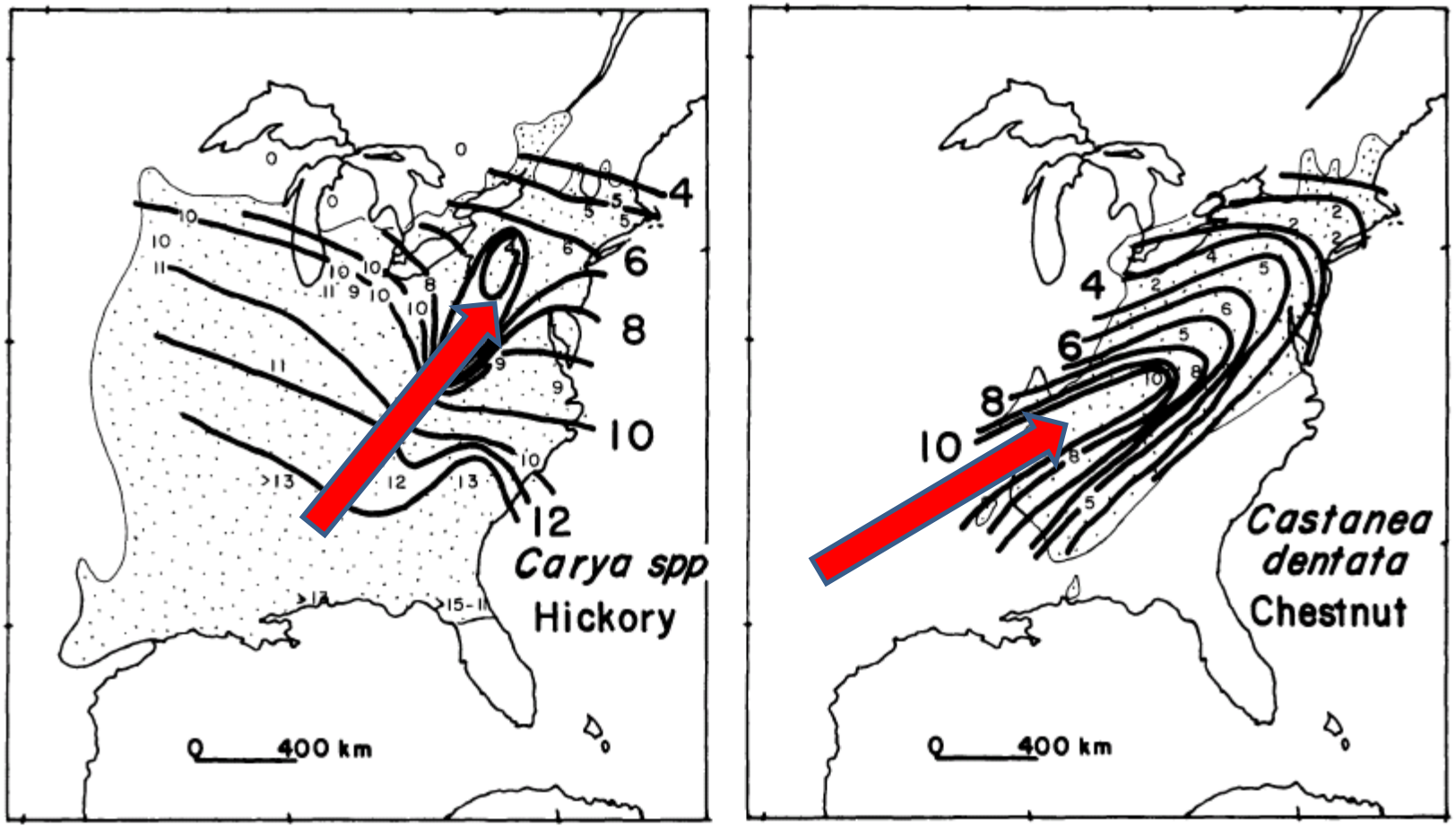
Pinus taeda



- USFS has predicted range shifts for many NA tree species based on climate scenarios and species autecology
- Results controversial but provide "food for thought"

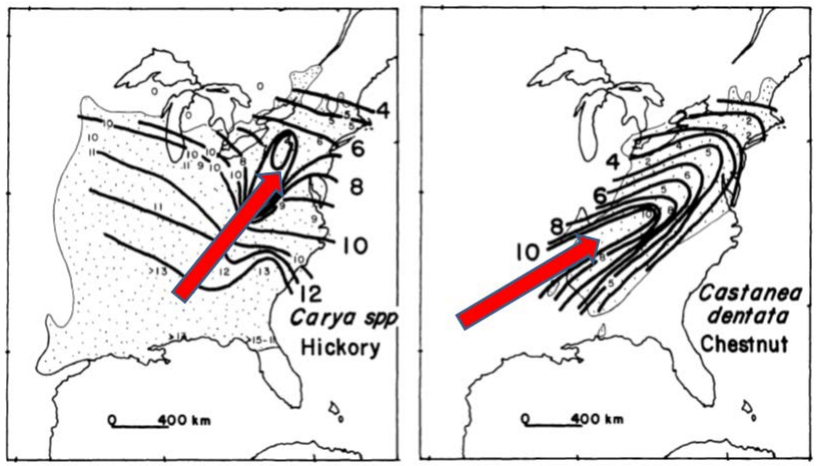
Prasad *et al.* 2007-ongoing. A Climate Change Atlas for 134 Forest Tree Species of the Eastern United States [database]. http://www.nrs.fs.fed.us/atlas/tree, Northern Research Station, USDA Forest Service, Delaware, Ohio.

Range Shifts?



Davis, M.B. 1983. *Annals of the Missouri Botanical Garden 70:550-563.*

Range Shifts?



- In the past, species have tended to move independently with changing climate
- Species composition may change

Forest Disturbance - Wildfire

2007 Georgia Wildfires
GA Forestry Commission

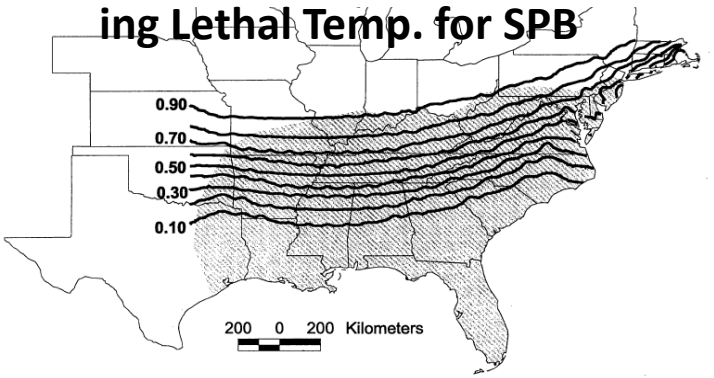
Forest Disturbance – Southern Pine Beetle

SPB Infestation, Sabine Nat'l Forest, TX
R. Billings

Southern Pine Beetle

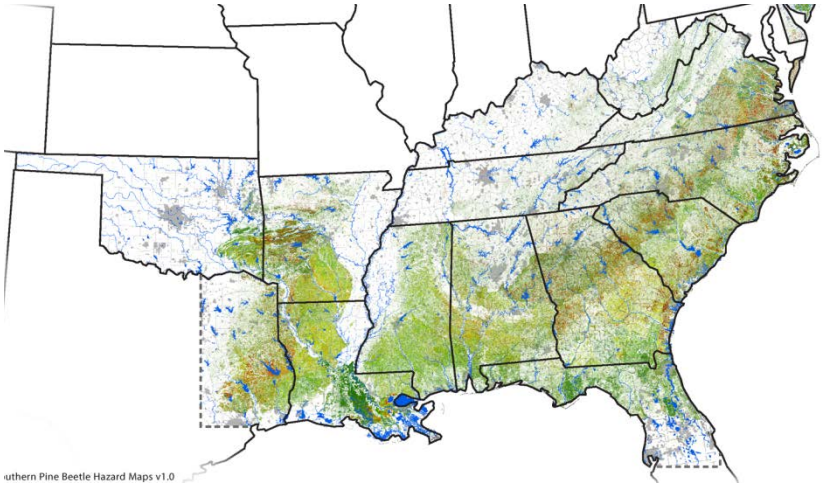
- Winter minimum temperature is a good predictor of the northern limit of the SPB range
- USFS has developed hazard maps for SPB using a multi-criteria framework
- Temperature changes may directly impact SPB population dynamics

Annual Probability of Reaching Lethal Temp. for SPB



Ungerer et al., 1999. J. Biogeography 26: 1133-45

USFS SPB HAZARD MAP

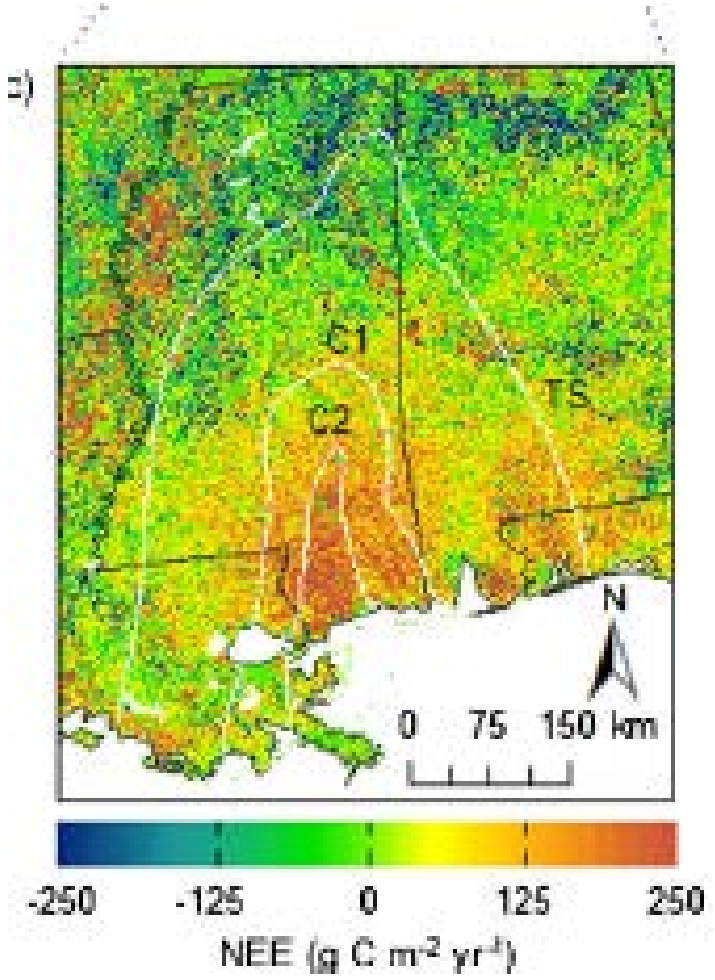


http://www.fs.fed.us/foresthealth/technology/nidrm_spb.shtml

Forest Disturbance – Windstorms and Hurricanes

Hurricane Hugo damage, A. Boone

Forest Disturbance

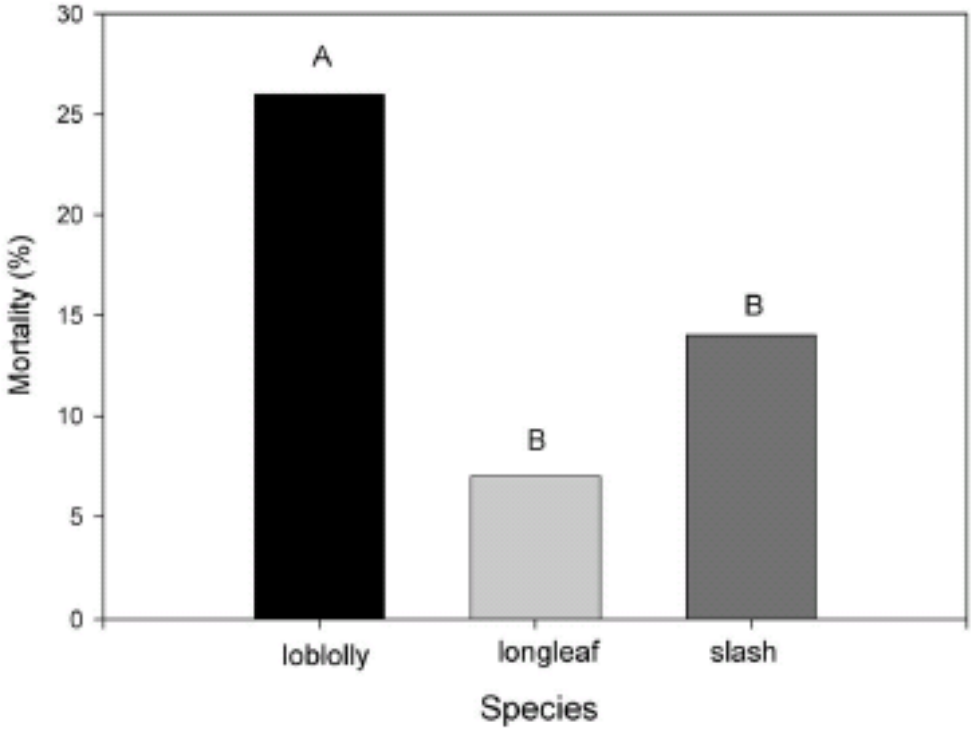


- Hurricane Katrina caused shifts of huge swaths of forest from C sink to C source

Xiao *et al.* 2011. *Agricultural and Forest Meteorology 151:60-69.*

Other Factors

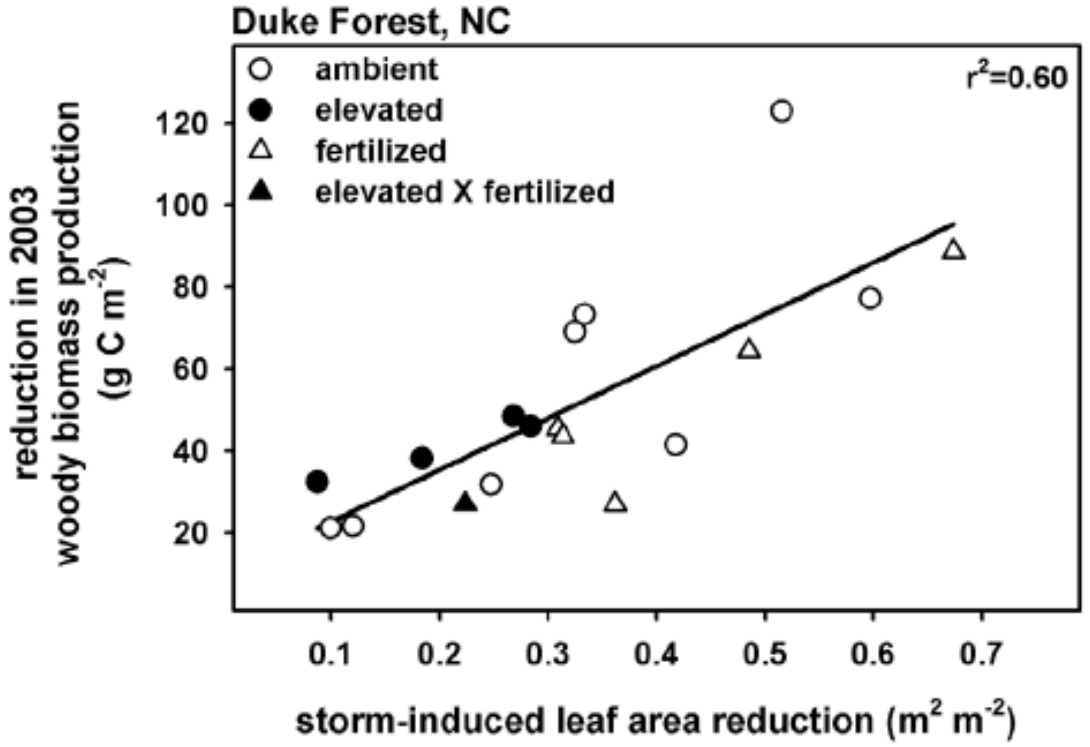
- Hurricane Katrina damage and mortality varied by species



Johnsen *et al.* 2009. Southern Journal of Applied Forestry 33:178-181.

Other Factors

- Elevated CO_2 decreased damage from 2003 ice storm



McCarthy *et al*. 2006. Journal of Geophysical Research 111:1-10.

Take Home Messages

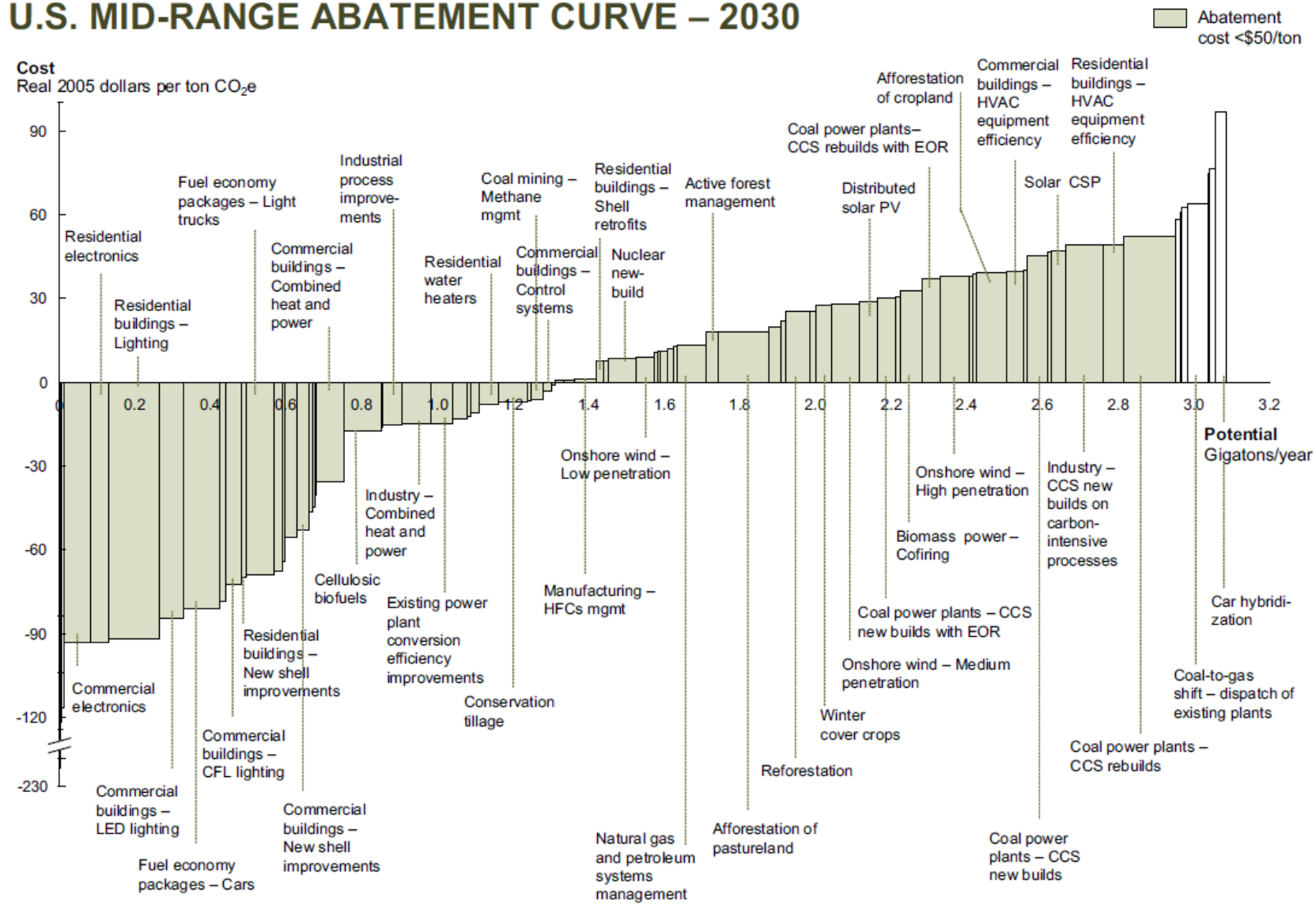
- Climate is changing
- Effects on forests are happening and are highly likely to continue
- Some effects may be positive; most are negative and will likely worsen
- Range shifts are possible but difficult to predict
- Physiological effects may be important, but impacts of disturbance may “swamp” biological effects

What Can Foresters Do?

- Much good thinking on how “natural” / non-plantation forests might be managed under changing climate, but economics limits action
- The best forestry response is to practice sound forest management to maintain robust, resilient stands
- Manage for carbon sequestration when possible, given multiple constraints
  - Ecological
  - Economic

Exhibit B

U.S. MID-RANGE ABATEMENT CURVE – 2030

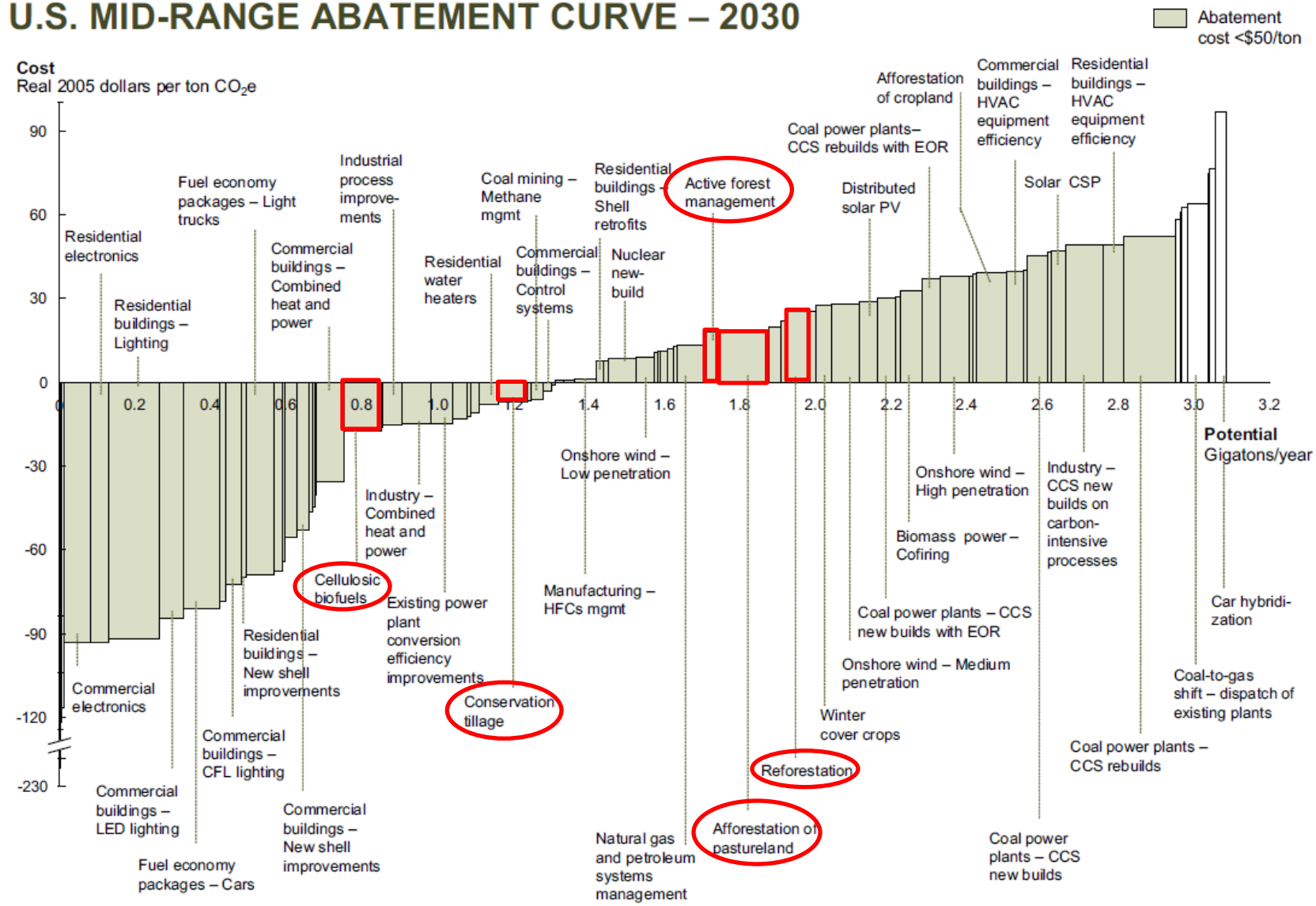


Source: McKinsey analysis

Creyts et al. 2007

Exhibit B

U.S. MID-RANGE ABATEMENT CURVE – 2030



Source: McKinsey analysis

Creyts et al. 2007

What Can All Citizens Do?

- Small actions
  - Are morally consistent: align actions with concerns
  - Provide examples to others
  - Often save $
  - Don’t make much difference on the margin (i.e. if everyone isn’t doing it)

What Can All Citizens Do?

- Think BIG
  - If you consider this an important moral issue for you and your children and their children, make that clear to your elected representatives
  - Contribute resources to organizations working for Big Change

What Can All Citizens Do?

- Think BIG
  - Support climate literacy for your fellow citizens (THANK-YOU!)