Ecosystem ecology: Theories, methods, lenses

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Ecosystem Ecology and Biogeochemistry

Pop Quiz

What is ecosystem ecology?

Ecosystem Ecology: the study of organisms, the abiotic environment, and their interactions in a defined area where the connections within the area are stronger than the connections across system boundaries

What is biogeochemistry?

Biogeochemistry: the study of the biological, chemical, physical, and geological processes and reactions that govern the environment

Where does the energy in ecosystems come from?

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What are the essential macronutrients for most life?

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Nitrogen (N), Phosphorus (P), Calcium (Ca), Magnesium (Mg), Potassium (K), and Sulfur (S)

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Carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4)

Can you give their 100 year global warming potentials?

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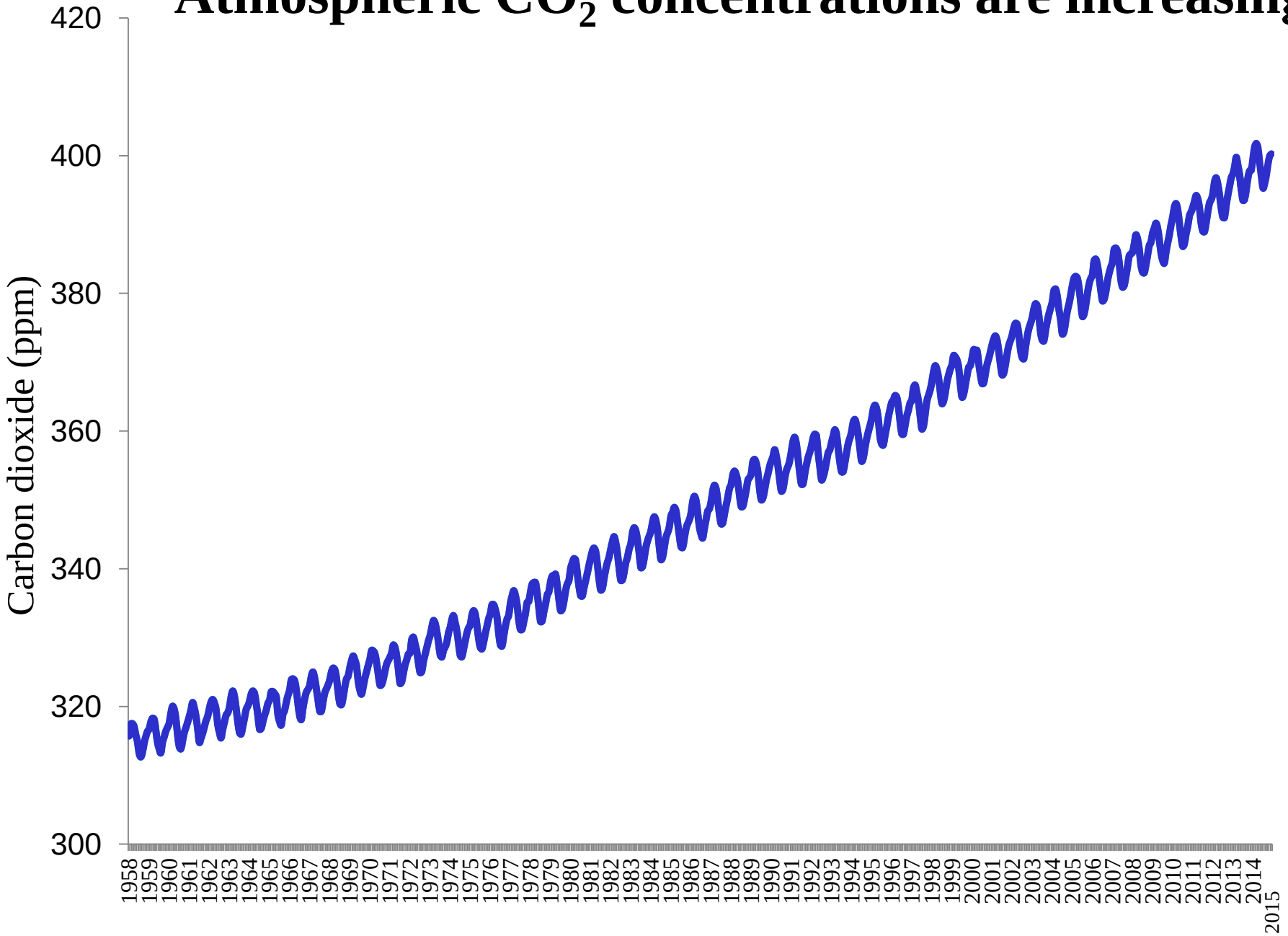
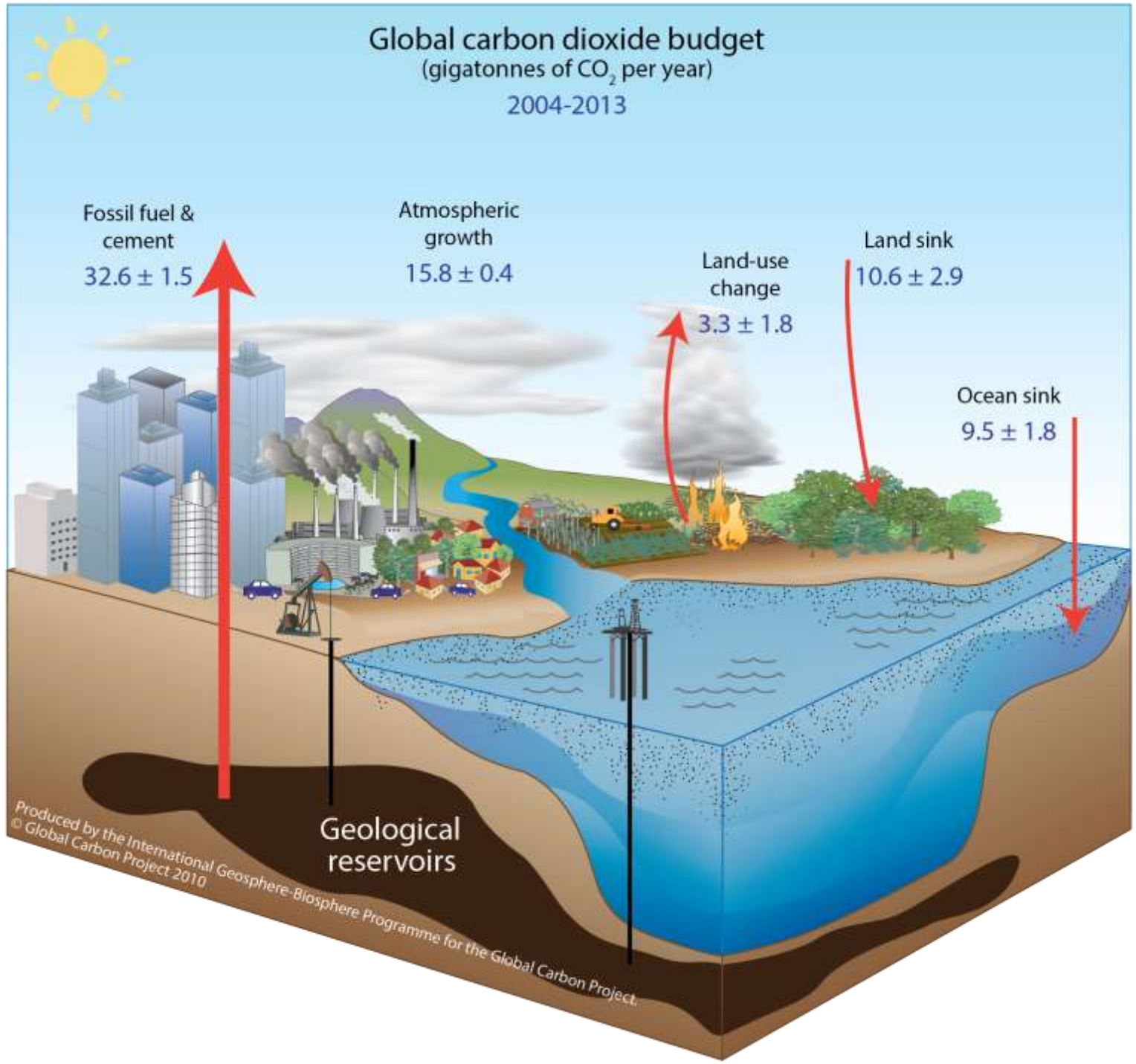
1, 298, 34

Ecosystem:
Definitions and Terminology

Atmospheric CO_2 concentrations are increasing



Data: Dr. Pieter Tans, NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends/) and Dr. Ralph Keeling, Scripts Institution of Oceanography


Global carbon dioxide budget
(gigatonnes of CO_2 per year)
2004-2013
Fossil fuel & cement
32.6 ± 1.5
Atmospheric growth
15.8 ± 0.4
Land-use change
3.3 ± 1.8
Land sink
10.6 ± 2.9
Ocean sink
9.5 ± 1.8
Geological reservoirs
Produced by the International Geosphere-Biosphere Programme for the Global Carbon Project.
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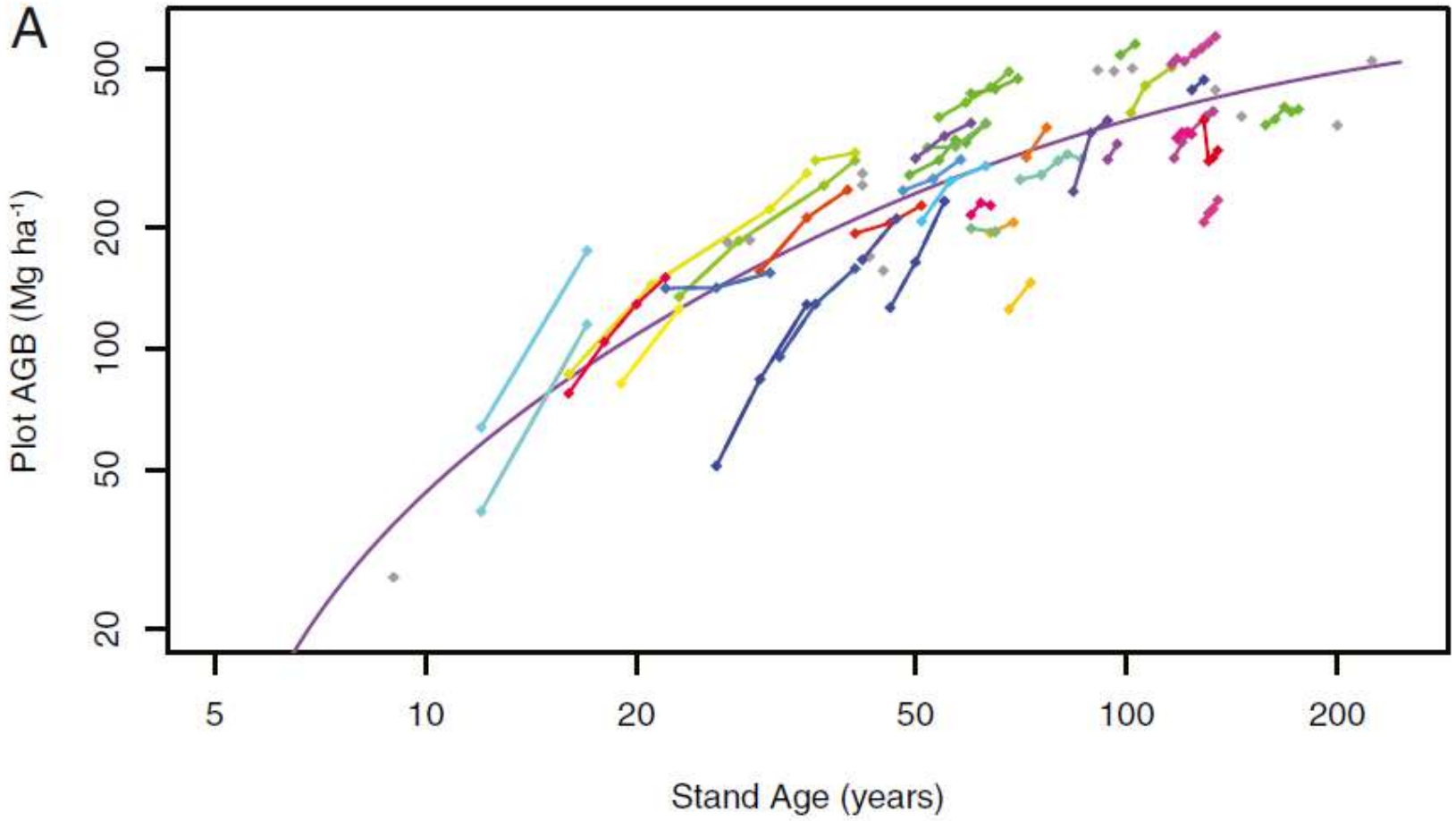
Accelerated Growth in Eastern Trees



McMahon et al PNAS 2010

Thesis statement: **Atmospheric carbon dioxide concentrations, through its role in photosynthesis, is the dominant controller of ecosystem carbon storage.**

Question: **What is the ecosystem response to elevated carbon dioxide?**

Hypothesis: **Carbon dioxide is a key resource for plant growth, thus increased concentrations will stimulate plant growth, and greater plant growth will lead to greater overall carbon storage in the ecosystem.**

Net carbon balance of an ecosystem

(net ecosystem production = NEP)

$$NEP = GPP - R_{auto} - R_{hetero}$$

Where: GPP is gross photosynthesis

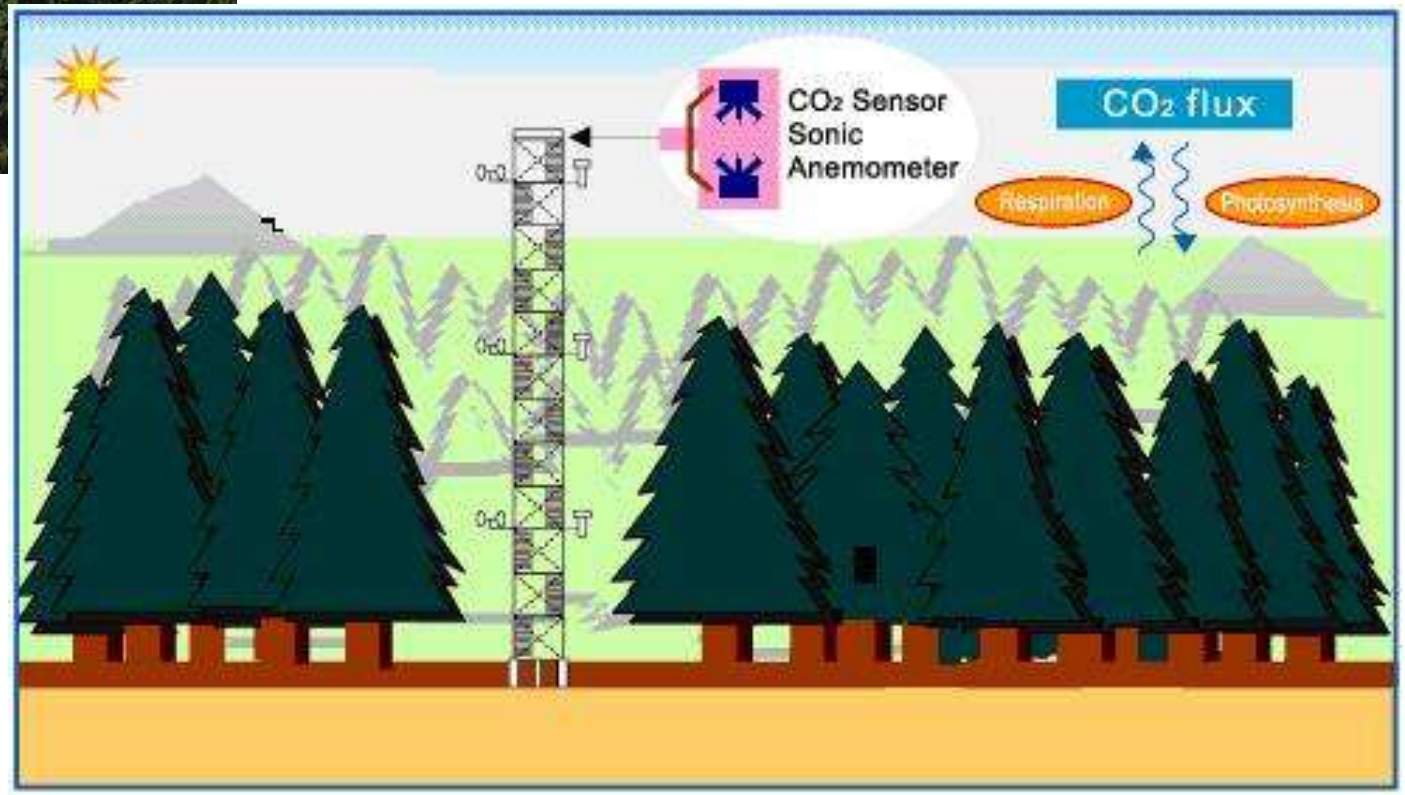
R_{auto} is plant respiration

R_{hetero} is the respiration of heterotrophs

How do you measure NEP?

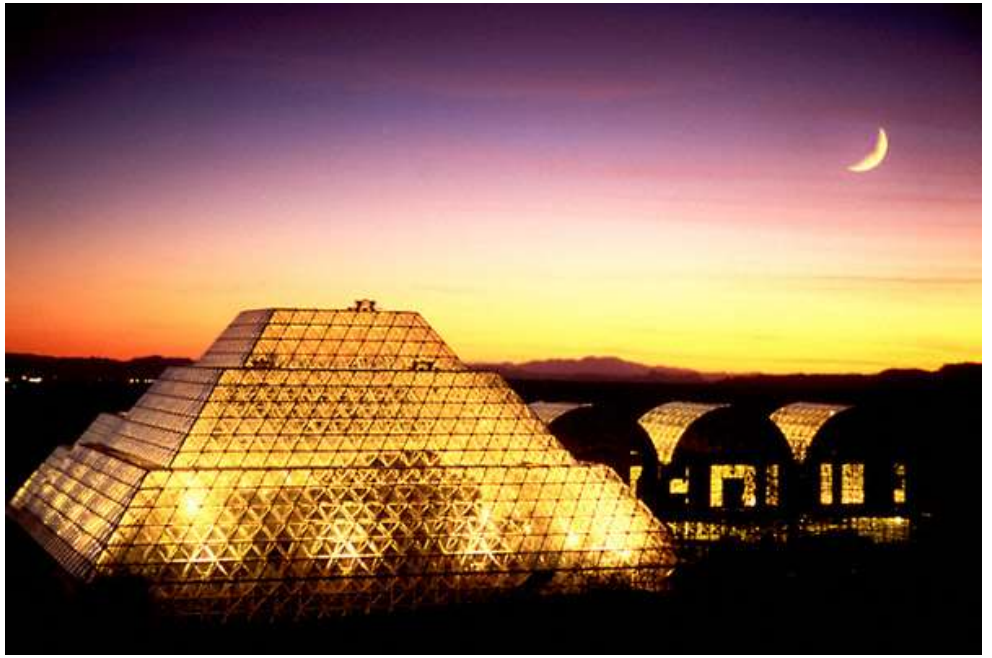
Eddy co-variance techniques measure CO_2 in and CO_2 out

- Good for net carbon balance
- Not good for discerning mechanisms
- Couple with round based measurements and models



Free Air CO_2 Enrichment (FACE) experiments

Other experimental approaches



CO_2 Exposure Methods: Pros and Cons

Pots

- Seedlings or saplings, not representative of mature trees
- Plants become root-bound
- No ecosystem interactions or competition

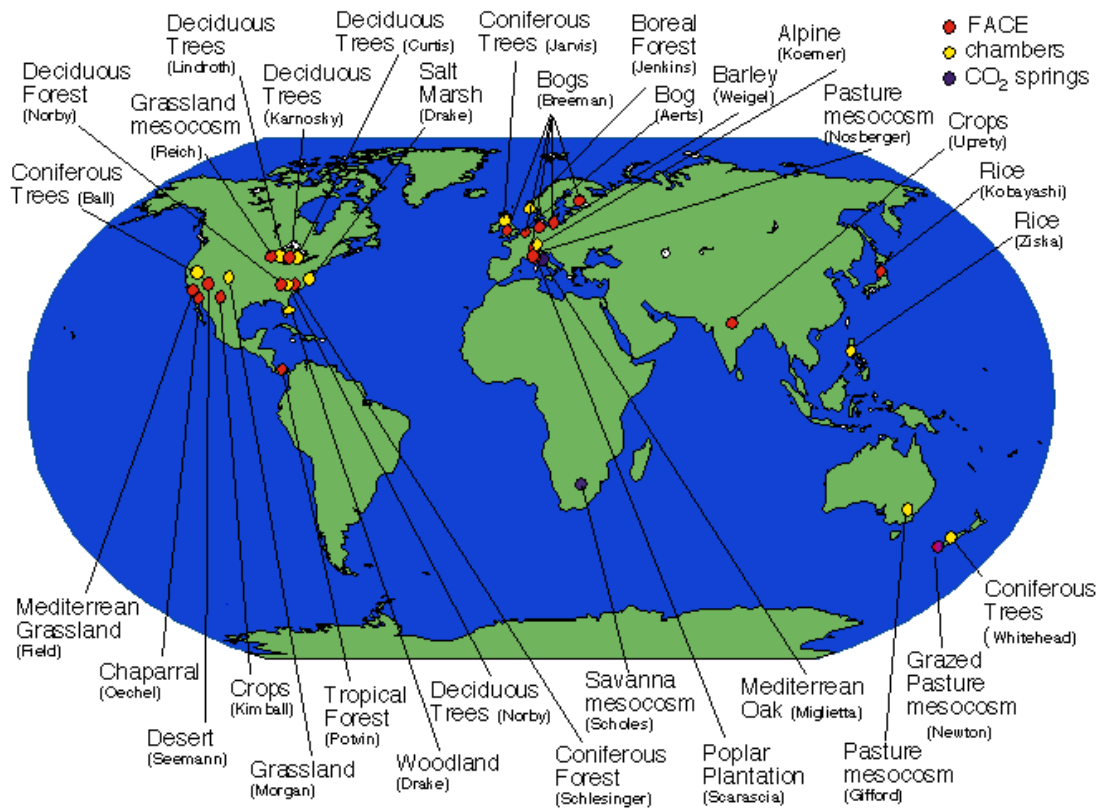
Chambers and Soil monoliths

- Artificial light, humidity and temperature levels in the chambers
- No ecosystem processes
- Limited to one or a few low stature plants

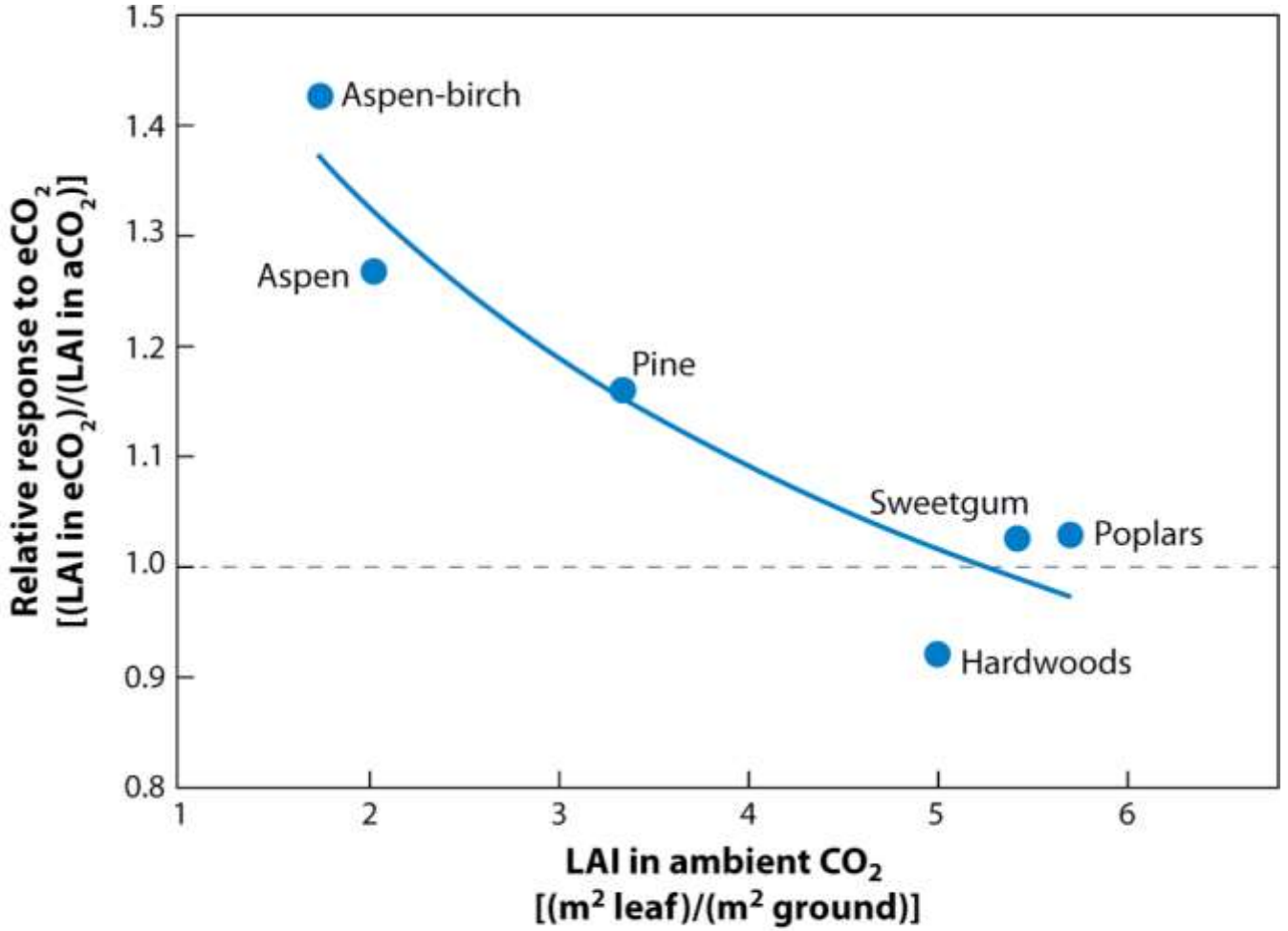
Free-Air Carbon Exposure Studies (FACE)

- Field conditions
- Plants compete for light, water and soil resources
- Expensive, much CO_2 is advected away.
- Control at set point varies by +/- 10 to 20%
- Expensive to replicate
- Sampling effects

Elevated CO_2 Studies

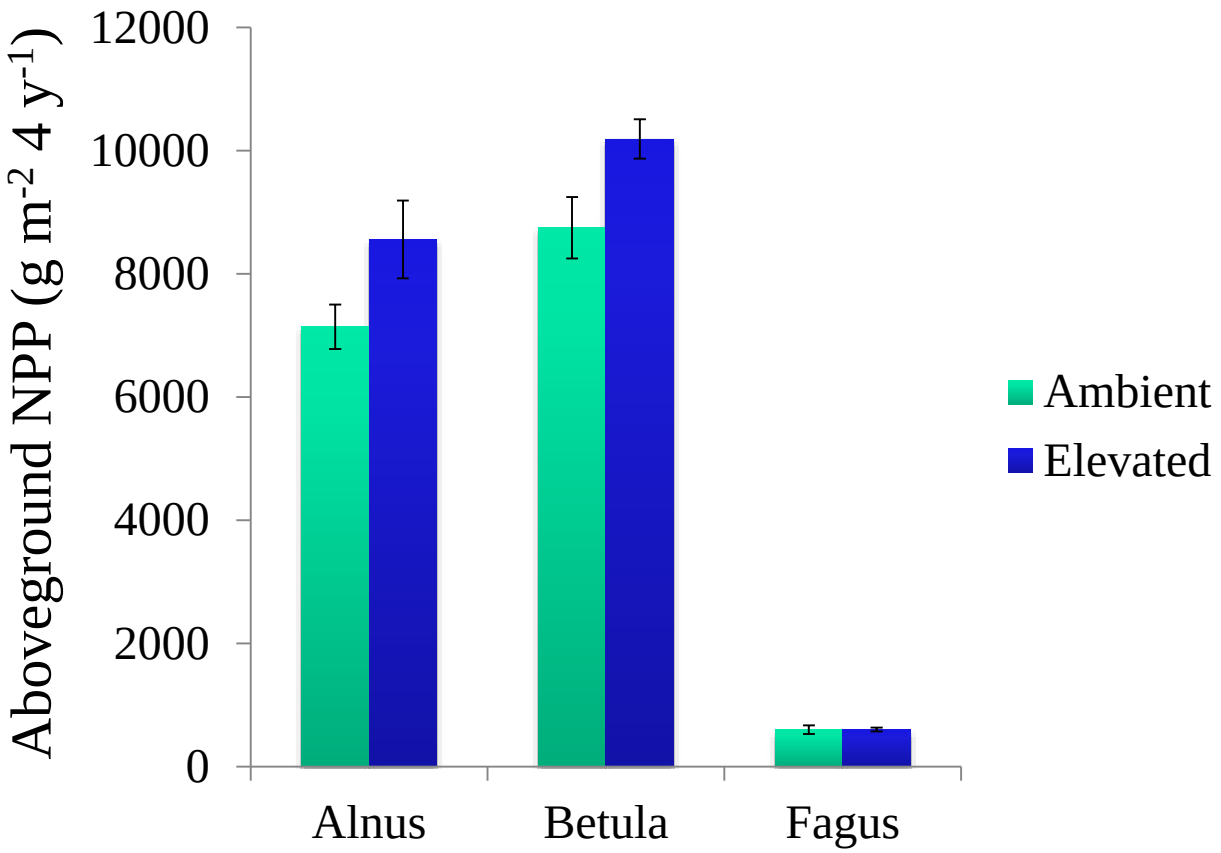


Plant growth (NPP) can be enhanced per unit of leaf area after canopy closure in some tree species, but not in others



Norby RJ, Zak DR. 2011.
Annu. Rev. Ecol. Evol. Syst. 42:181–203

Aboveground plant growth (NPP) can be enhanced in some tree species, but not in others



Hoosbeek et al. 2011