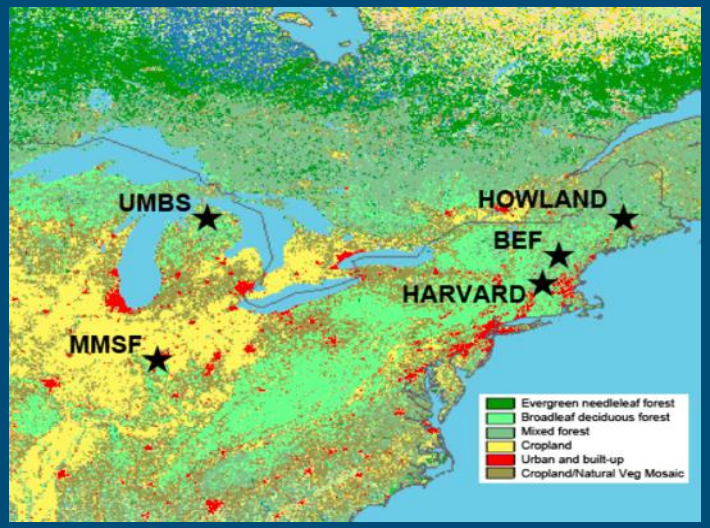
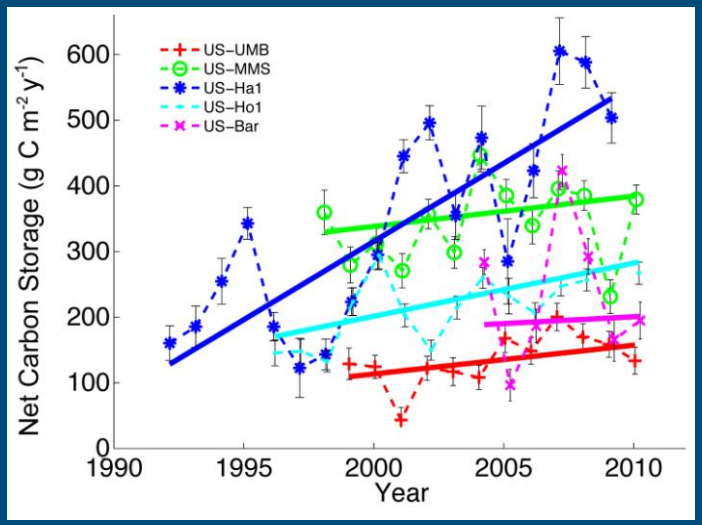
Increasing water use efficiency in northern hemisphere forests

Keenan TF, Hollinger DY, Bohrer G, Dragoni D, Munger JW, Schmid HP, Richardson AD.

Long-term changes in forest carbon uptake

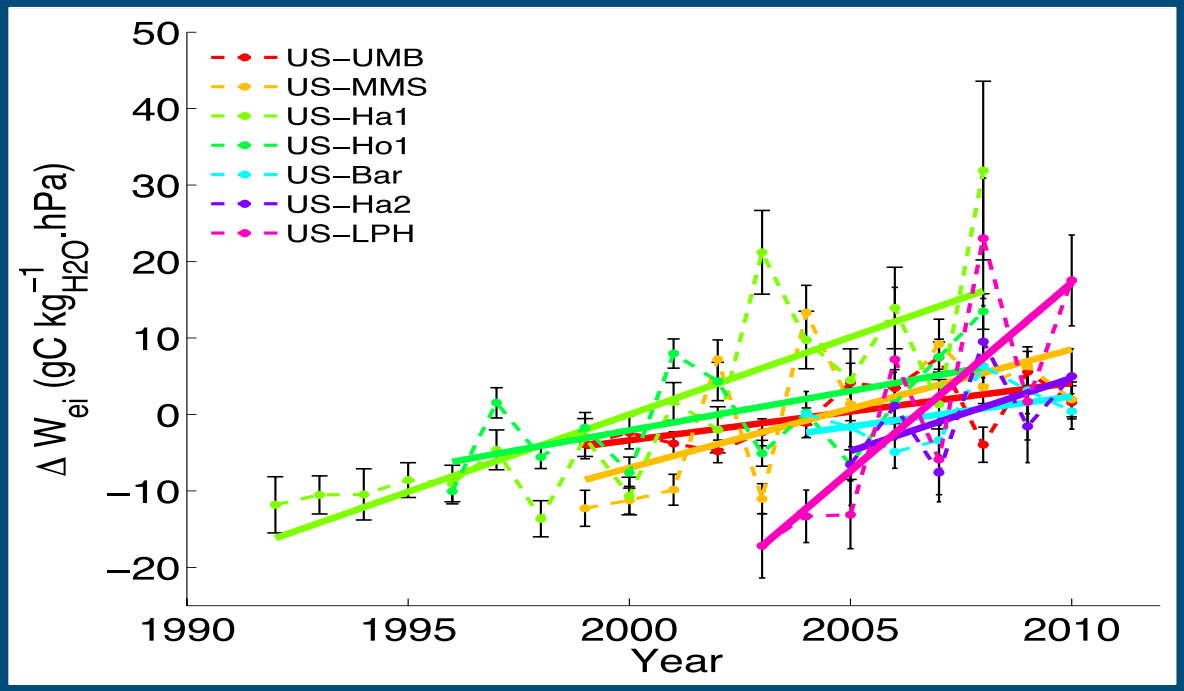




Increasing annual net C storage across the north-eastern and north-central US

Long-term changes in water use efficiency

$$\text{Water use efficiency} = \left(\frac{CO_2 \text{ taken up through Photosynthesis}}{H_2O \text{ lost through Transpiration}} \right)$$



La Thuile 2007 dataset

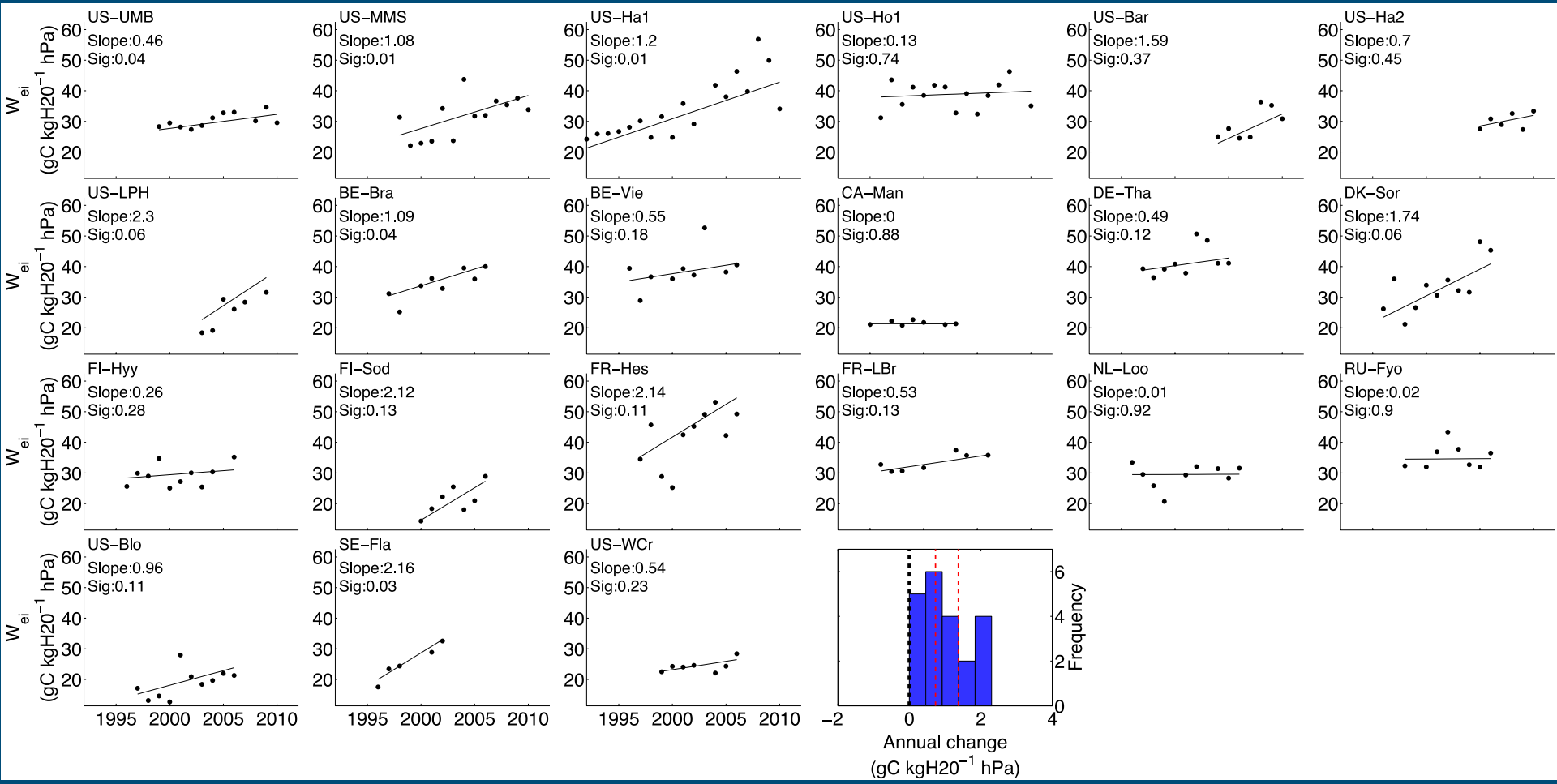
- 251 sites from around the world
- 153 sites with freely available data
- Data up to end 2006

Select: Forests with 7+ years or data (31)

Exclude:

- Young forests
- Mediterranean forests
- Savannas
- Forests with known issues (1)

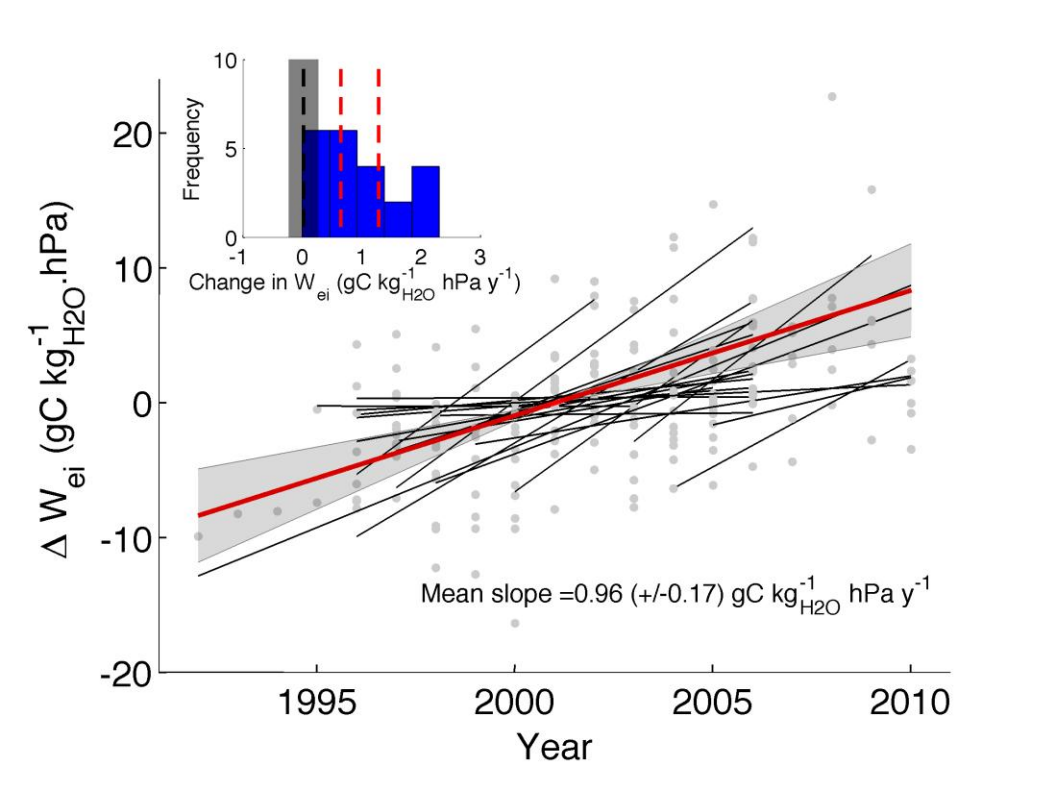
Long-term changes in water use efficiency in northern hemisphere forests



Keenan et al., 2013 Nature

Trends in forest water use efficiency

22 globally distributed temperate and boreal forests



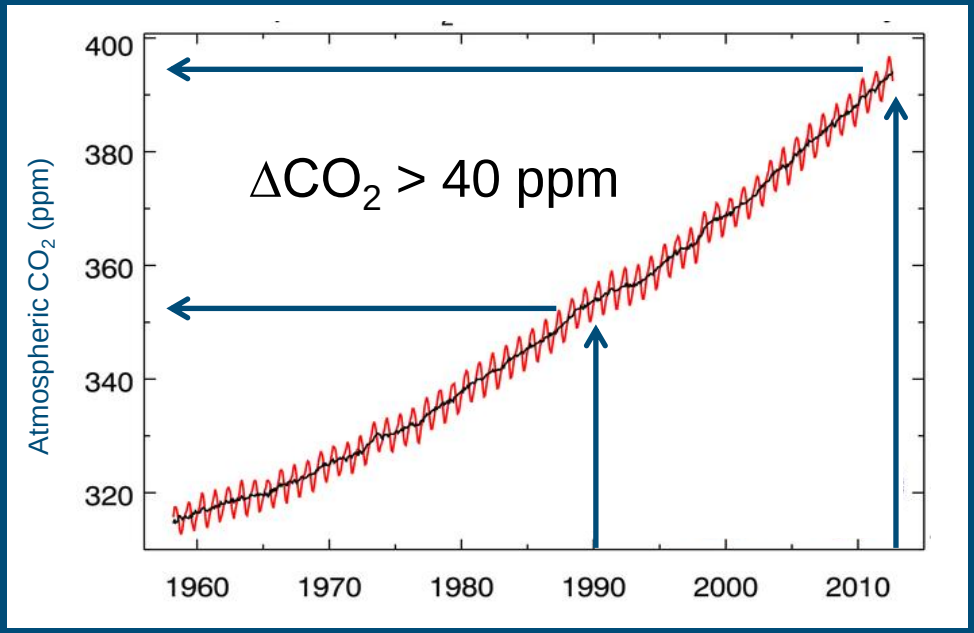
Keenan et al., 2013 Nature

What is driving the trend?

Hypotheses:

1. Long term change in climate (temperature, PAR, wind)
2. Extension of growing season length
3. Changes in nutrient deposition
4. Instrument degradation
5. Changes in LAI
6. Changes in canopy height and/or surface roughness
7. CO_2 fertilization

CO_2 fertilization of photosynthesis



Courtesy of NOAA/Scripps

Hetherington & Woodward, Nature 2003

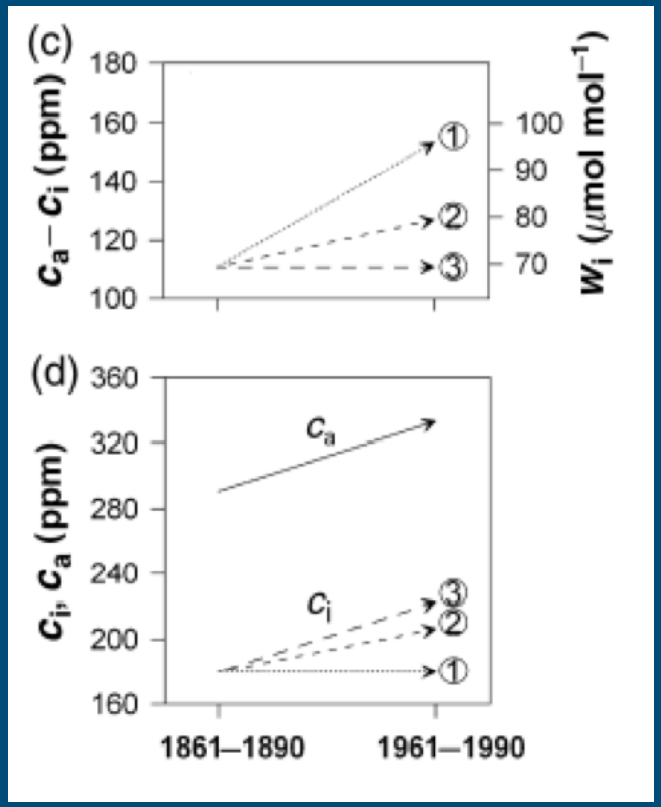
Theory: Increased atmospheric CO_2 enables

- → Higher rates of photosynthesis
- → Reduced stomatal conductance
- → Reduced transpiration
- → Increased water use efficiency of photosynthesis

How is W_{ei} related to c_i?

Water Use Effeciency = $(c_a - c_i)/1.6$

$\Rightarrow c_i = c_a - (W_{ei})/1.6$



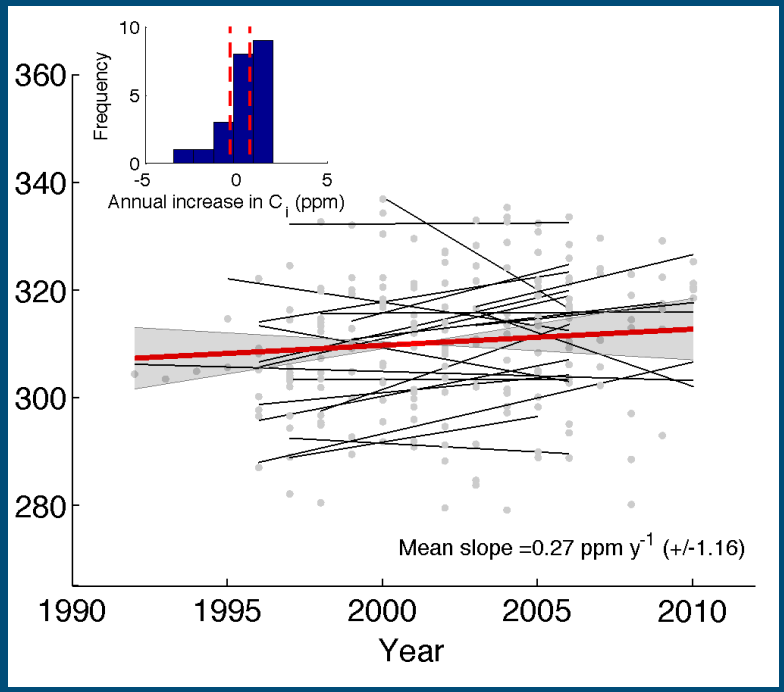
1. C_i constant. Big increase in W_{ei}.
2. C_i/C_a constant. Some increase in W_{ei}.
3. C_a-C_i constant. No increase in W_{ei}.

Saurer et al., 2004

Trends in leaf intercellular CO_2

Results support scenario 1:

C_i remains relatively constant, despite rising atmospheric CO_2.



Keenan et al., 2013 Nature

Conclusion

Clear evidence for strong increases in water use efficiency of temperate and boreal trees

Implications

1. A large shift in the carbon and water based economics of terrestrial plant photosynthesis.
2. If a response to CO_2, results likely hold more generally because of the global nature of the C3 photosynthetic pathway.

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Thank you!