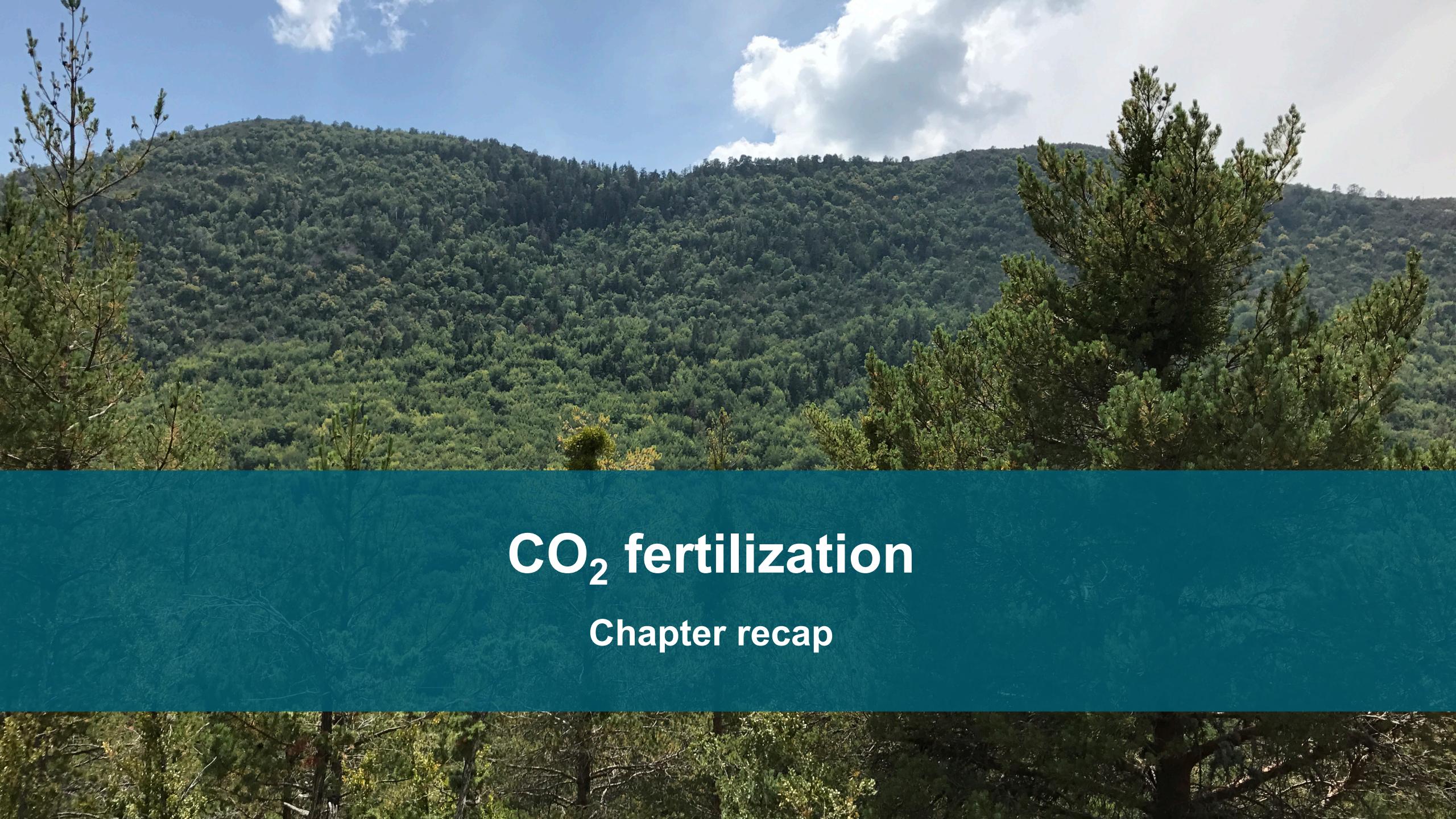


Session 02.12.2024

- Recap on the CO₂ Fertilization chapter
- Fun lecture on tree growth-forest biomass links
- Land Surface Greening chapter

The background of the slide is a photograph of a lush green forest covering a mountain. The sky is a clear blue with scattered white clouds. In the foreground, there's a dark teal semi-transparent rectangular overlay where the text is placed.

CO_2 fertilization

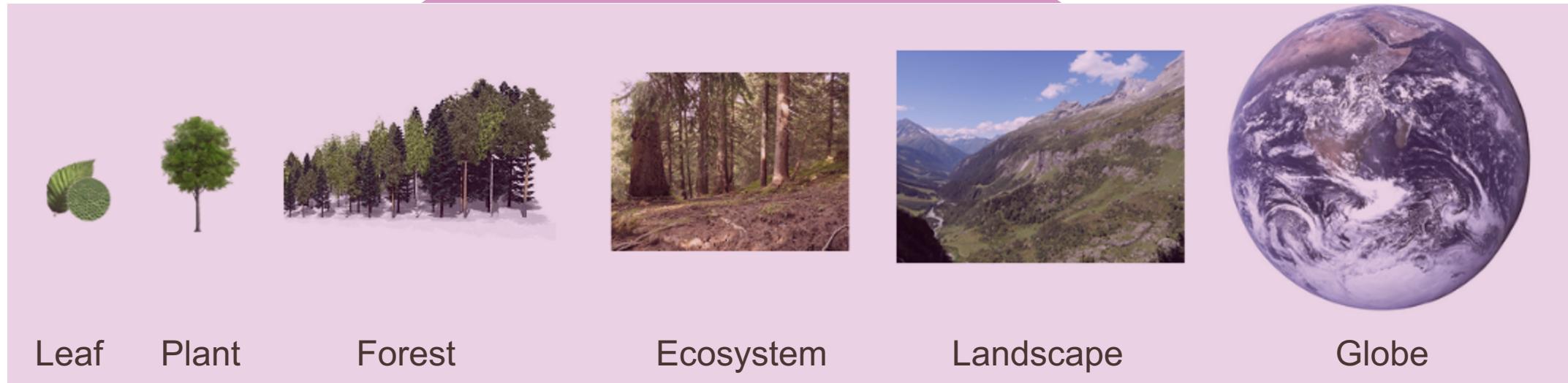
Chapter recap

1. What is CO₂ fertilization?

+ Atmospheric
CO₂



+ global C
stocks



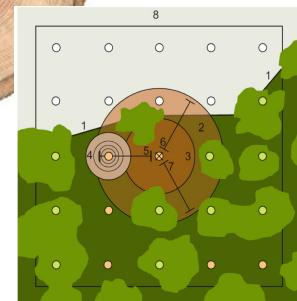
2. Measurements of CO₂ fertilization across scales



Lab experiments

Ecosystem experiments

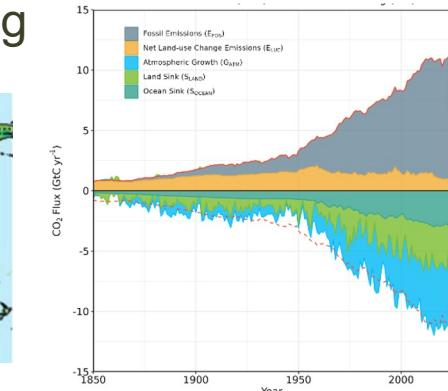
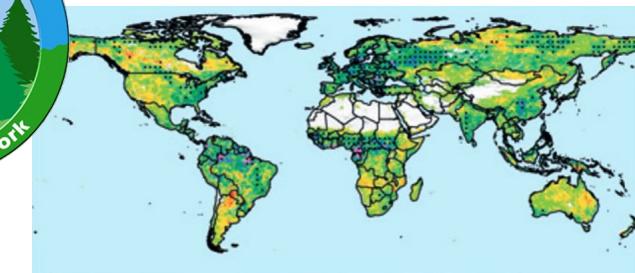
Tree-ring data
Forest inventories



Ecosystem experiments
Eddy-covariance measurements



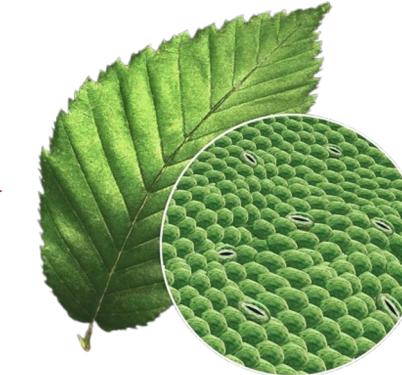
Satellite remote sensing



FACE experiments

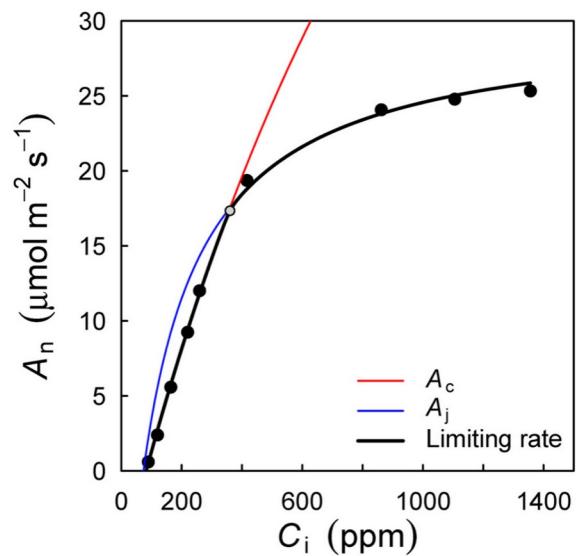
3. Leaf scale

Response and processes:



↔️ Ambient CO₂

↔️ Carbon Assimilation (A)



A - c_i curve

$$A = g_s(c_a - c_i)$$

↔️ Stomatal conductance

↔️ WUE

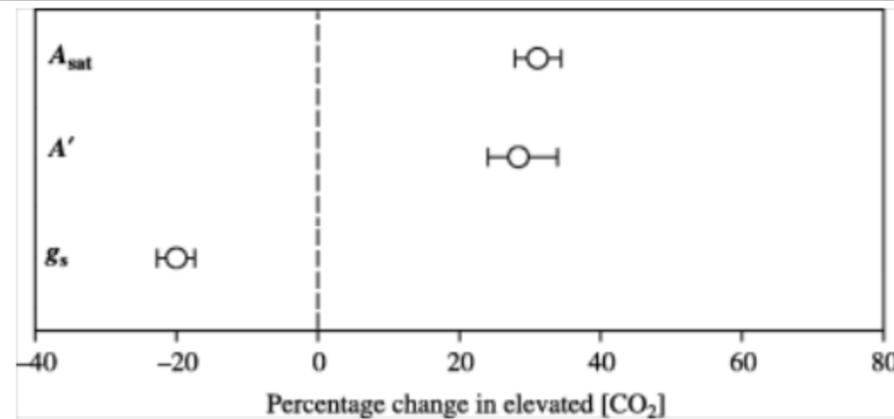


3. Leaf scale

Evidence:

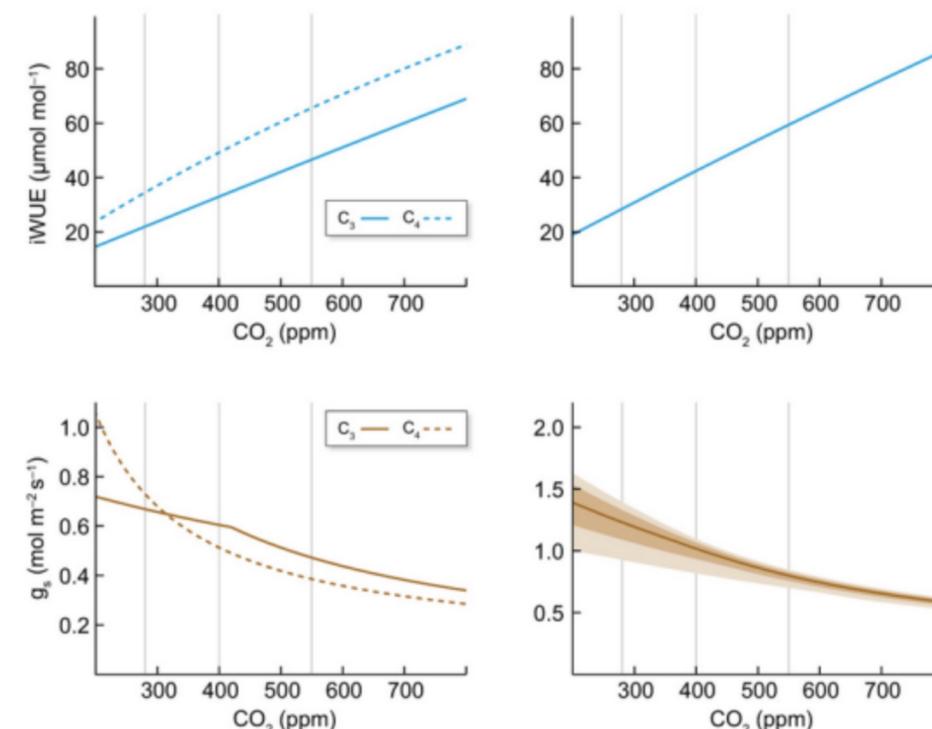
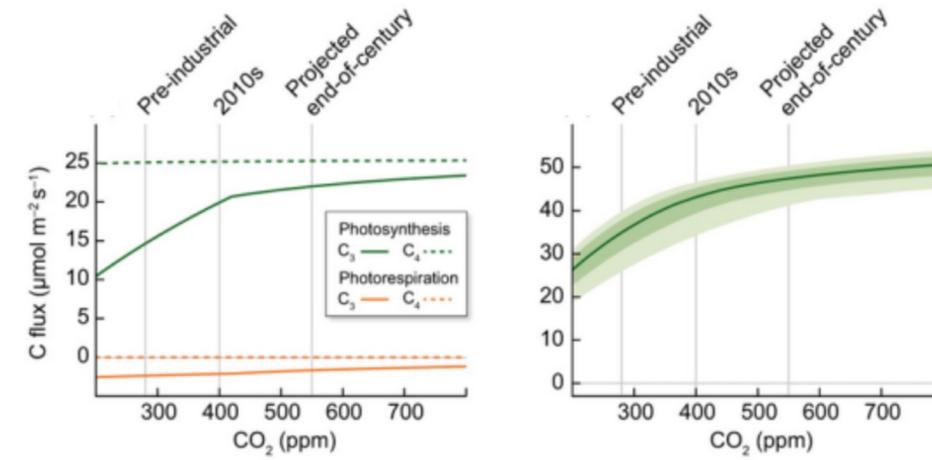


Increased light-saturated leaf photosynthetic rate (A_{sat}), diurnal carbon assimilation (A'), and stomatal conductance (g_s)



FACE experiment leaf responses to elevated CO_2 .
Ainsworth and Long 2005.

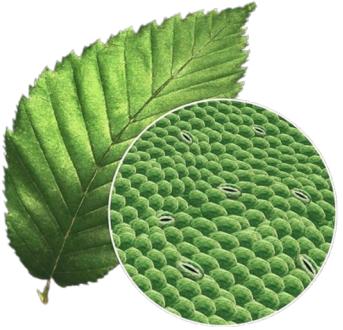
Increased net assimilation (A_n), iWUE and g_s



Modelled responses to atmospheric CO_2 concentration at the leaf (left column) and canopy (right column) levels. Walker et al. 2021.

4. Plant scale

Response and processes:



Carbon Assimilation (A)



Biomass production (BP)
i.e., Growth

Allocation



Photosynthetic rates



WUE

Resources availability

- Water
- Nutrients



Progressive Nitrogen
Limitation (PNL)
Luo et al. 2004.



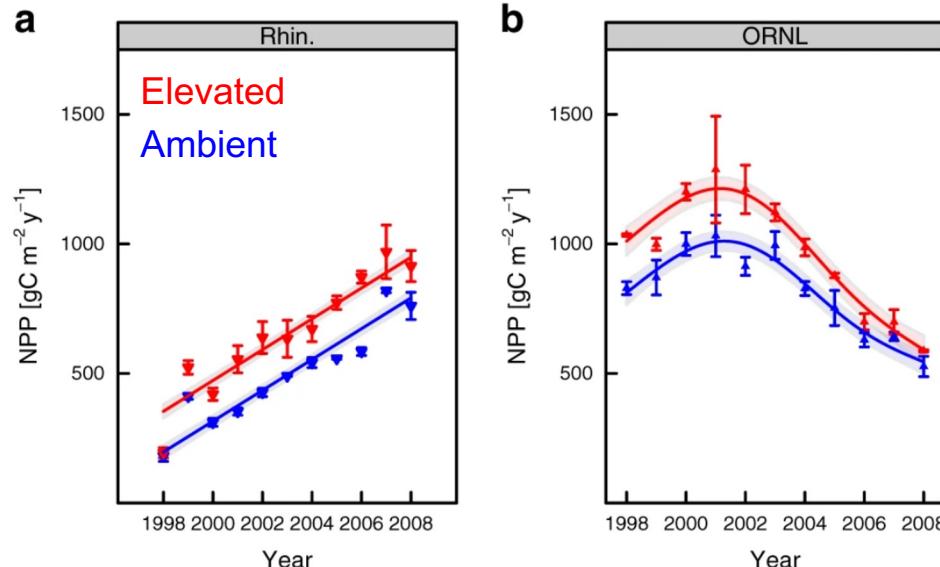
High confidence

4. Plant scale

Evidence:

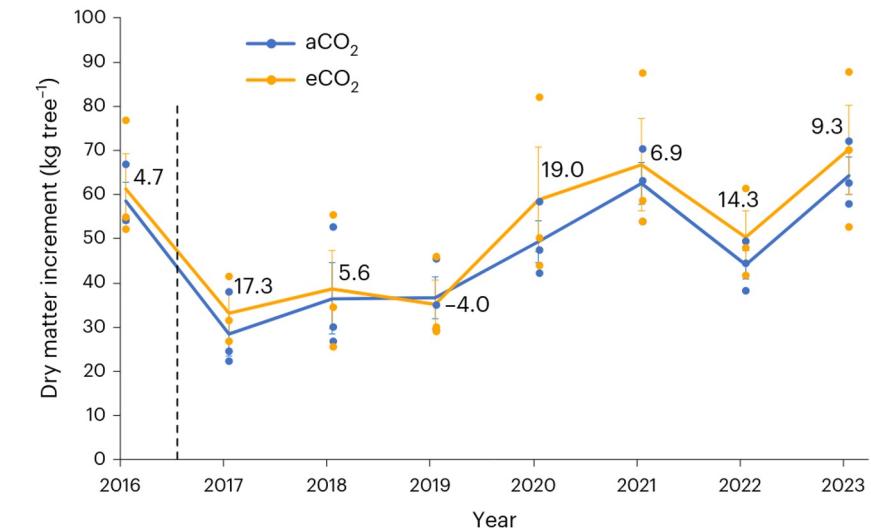


Growth increases under elevated CO₂ in young forests

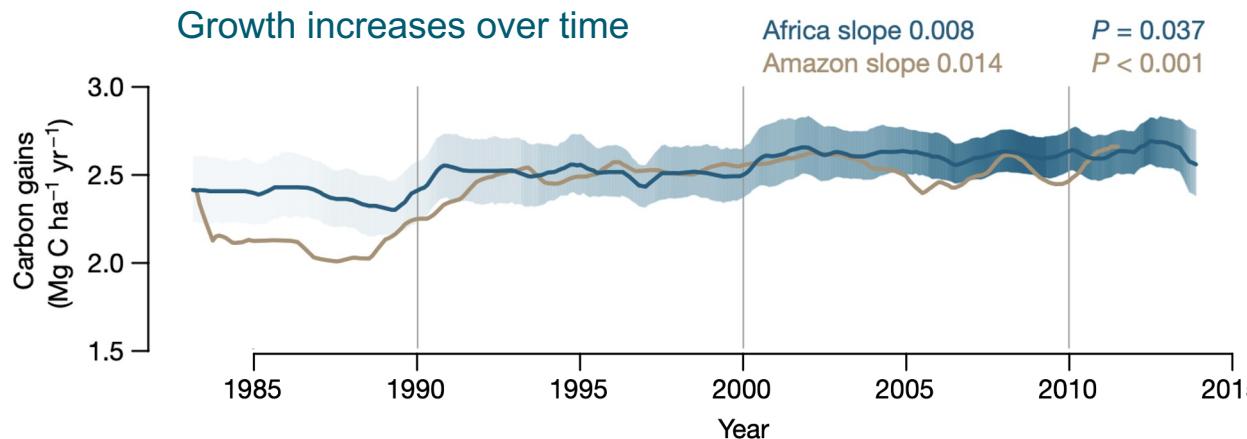


FACE experiment NPP responses to elevated CO₂ in young forests.
Walker *et al.* 2019.

... and mature forests



FACE experiment growth responses to elevated CO₂ in mature oak forest.
Norby *et al.* 2024.



Carbon gains in old-growth tropical forests from forest inventories.
Hubau *et al.* 2020.

5. Forest scale

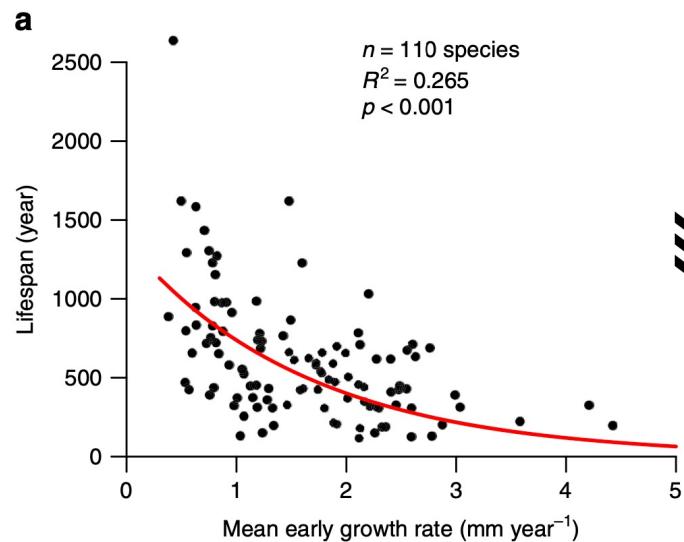
Response and processes:



Biomass production (BP)
i.e., Growth



Biomass accumulation



Tree mortality
- Competition
- Climate, droughts impacts

Tree longevity
Carbon residence time

Grow-fast-die-young (GFDY)

Bugmann & Bigler 2011
Körner 2017
Büntgen et al. 2019
Brienen et al. 2020

Growth-longevity trade-offs supporting the GFDY hypothesis. Results from tree-ring data. Brienen et al. 2015.



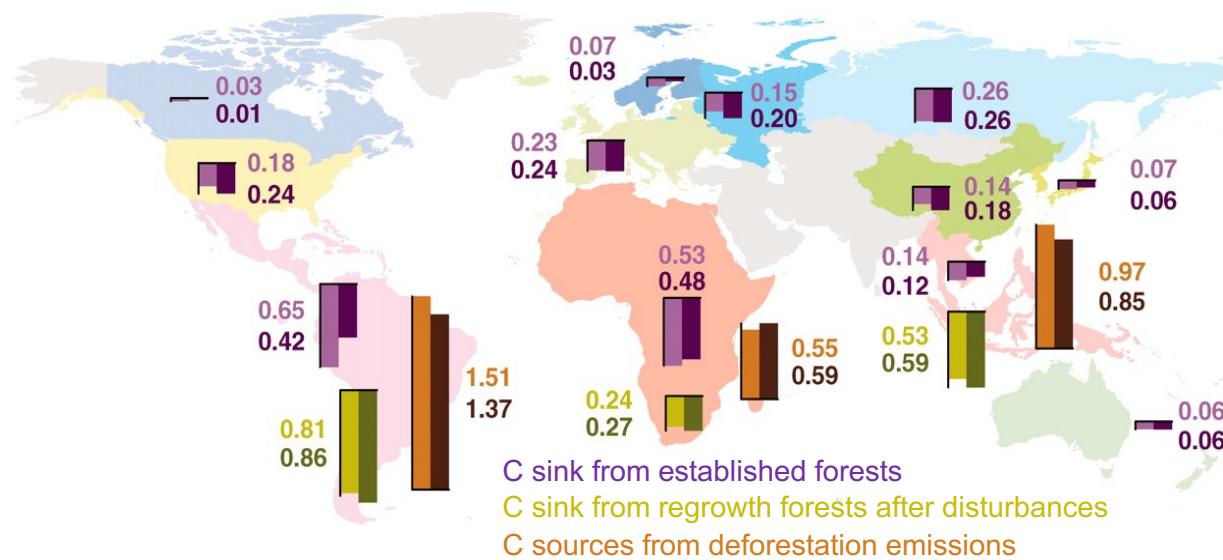
Conflicting evidence
Unclear direction

5. Forest scale

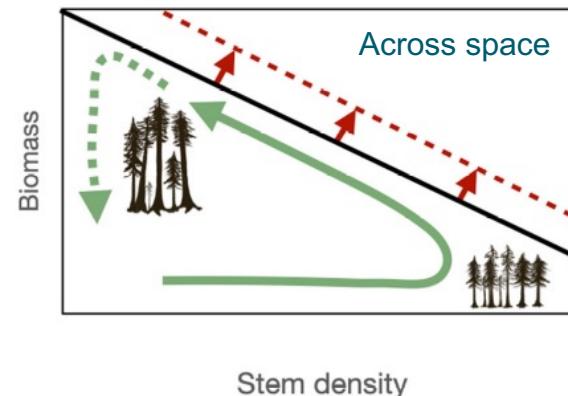
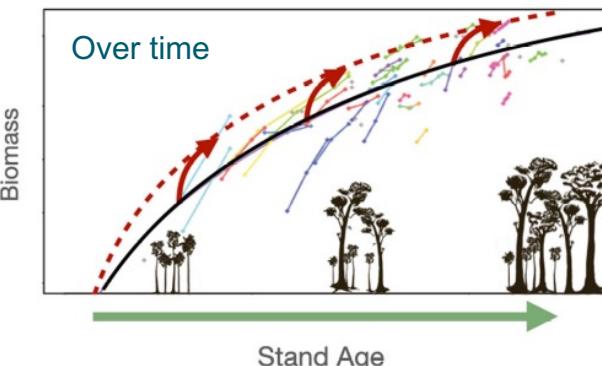
Evidence:



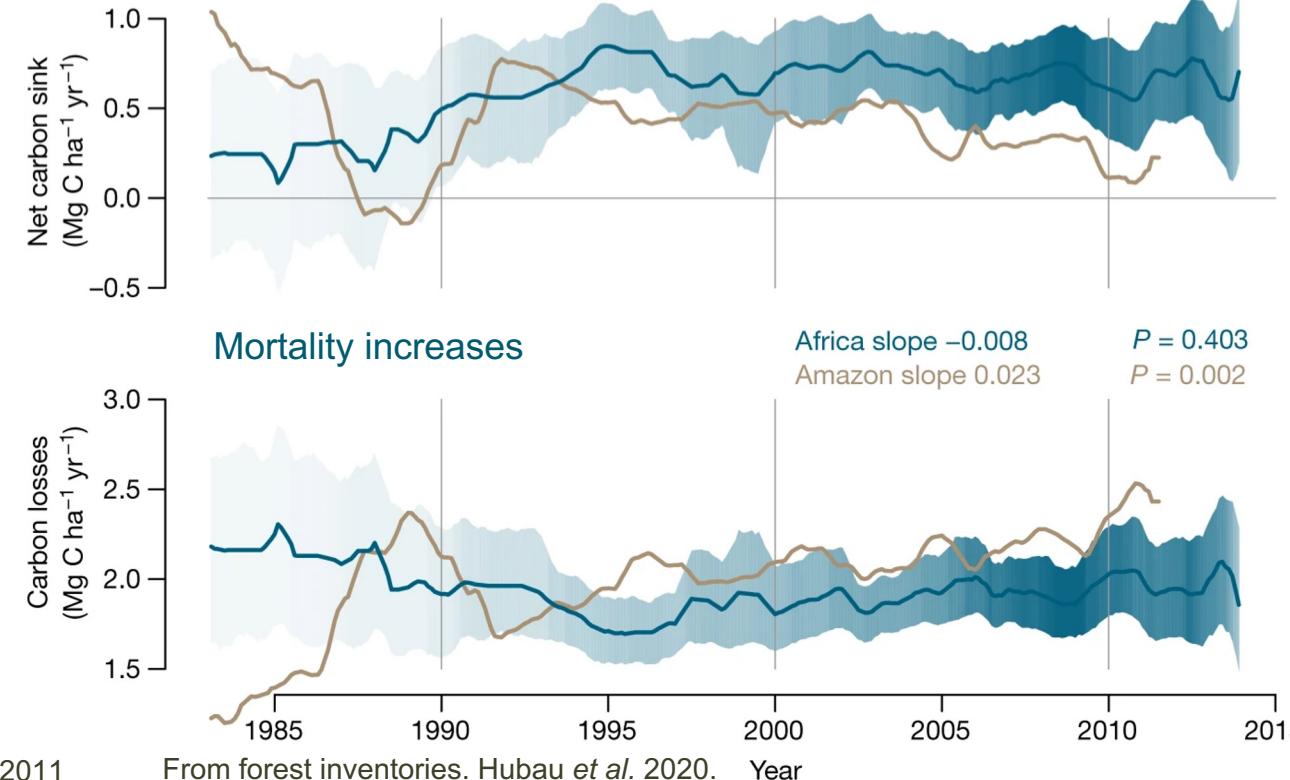
Increased carbon sink in forests around the globe



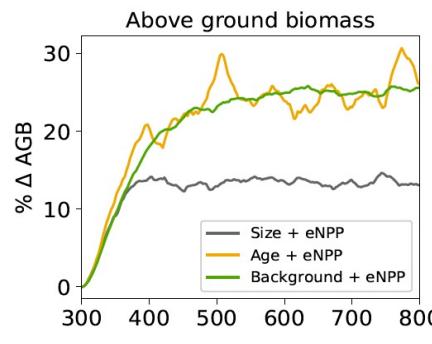
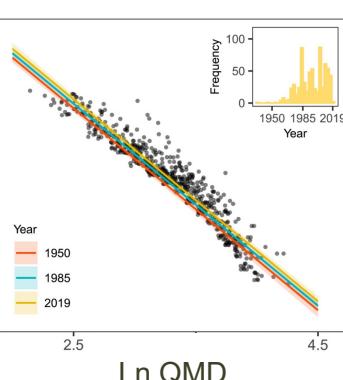
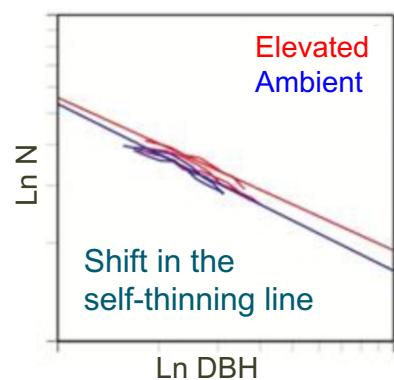
Increased biomass over time



Biomass decreases



From FACE experiments.
Kubiske et al. 2019.



6. Ecosystem scale

Response and processes:



Biomass accumulation

Net Ecosystem Production
(NEP)

Soil C dynamics

- SOM decomposition
- Soil respiration rates
- Nutrient availability



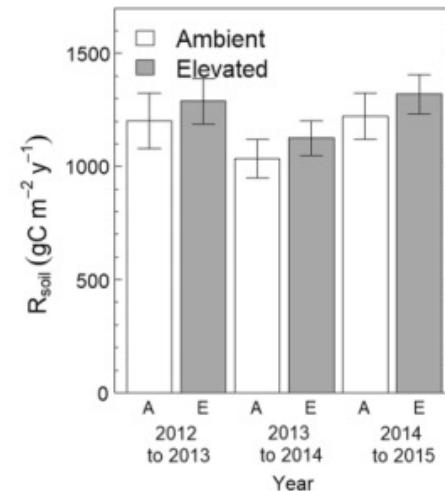
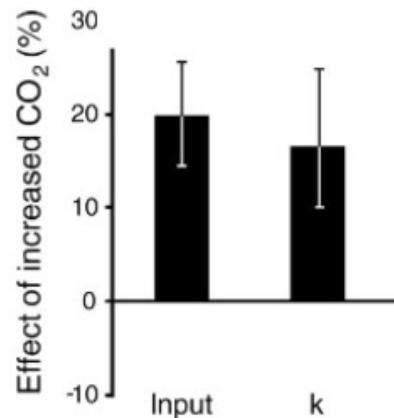
Medium
confidence

6. Ecosystem scale

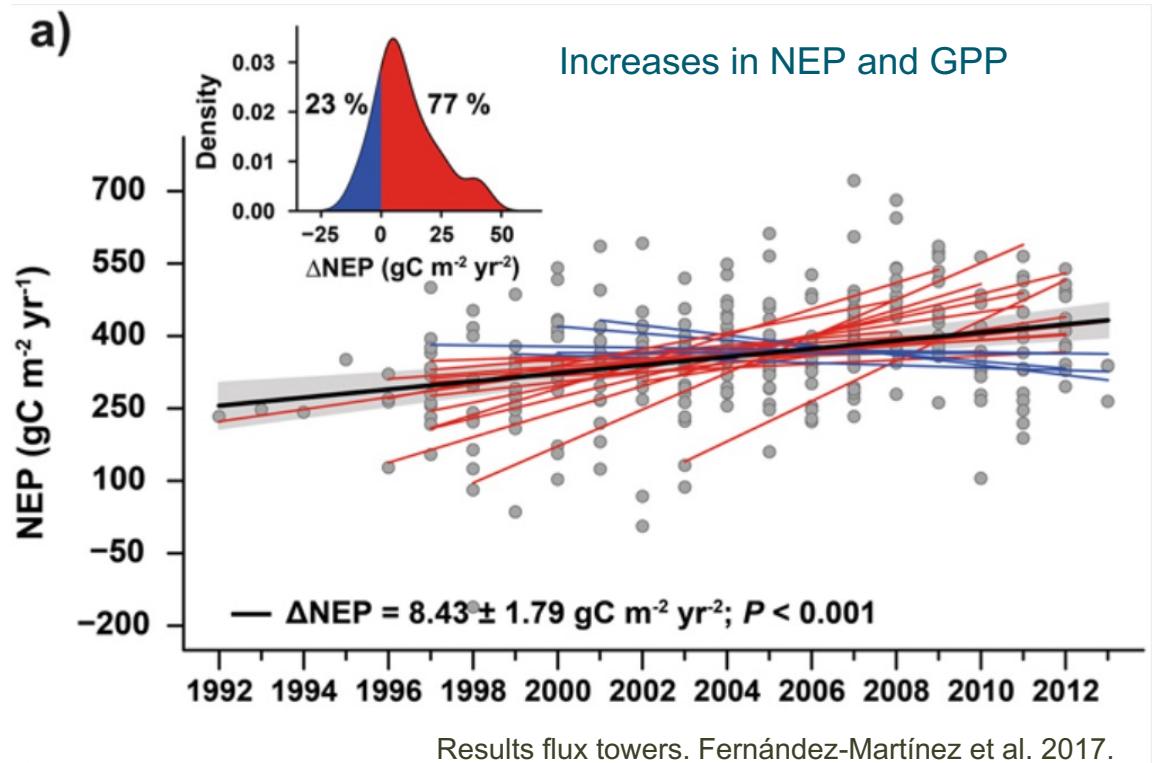
Evidence:



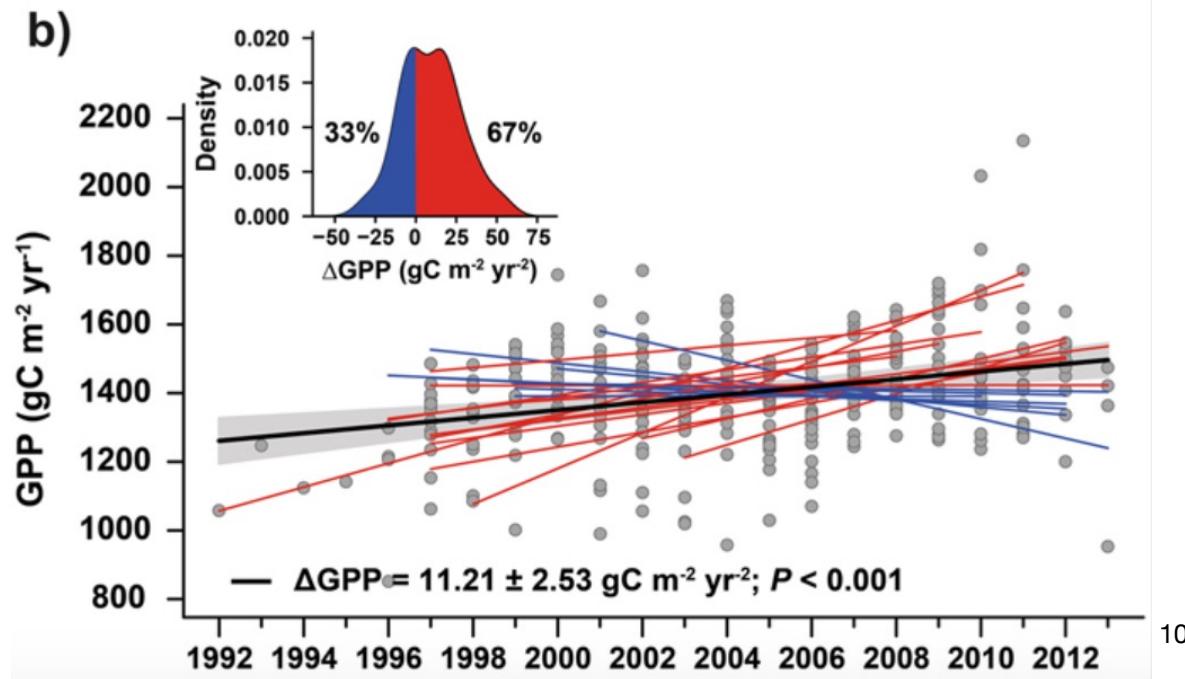
Changes in C inputs, decomposition rate (k) , and soil respiration (R_{soil})



Results from FACE experiments. Van Groenigen et al. 2014 and Drake et al. 2018.



Results flux towers. Fernández-Martínez et al. 2017.



7. Landscape to Global scales

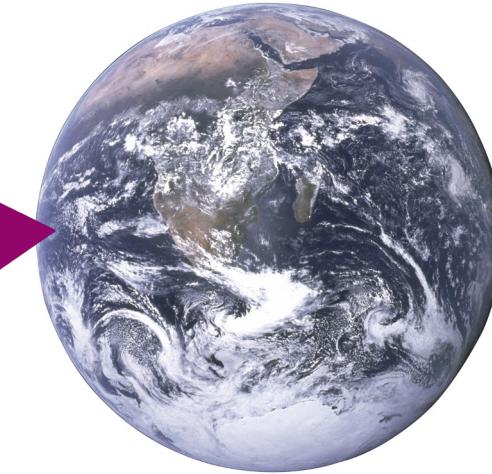
Response and processes:



Ecosystem C stocks



Landscape C stocks



Global C stocks

Net Biome Production (NBP)

Ecosystem variability
Land-use changes, soil erosion
Dissolved Organic Carbon dynamics
...
...

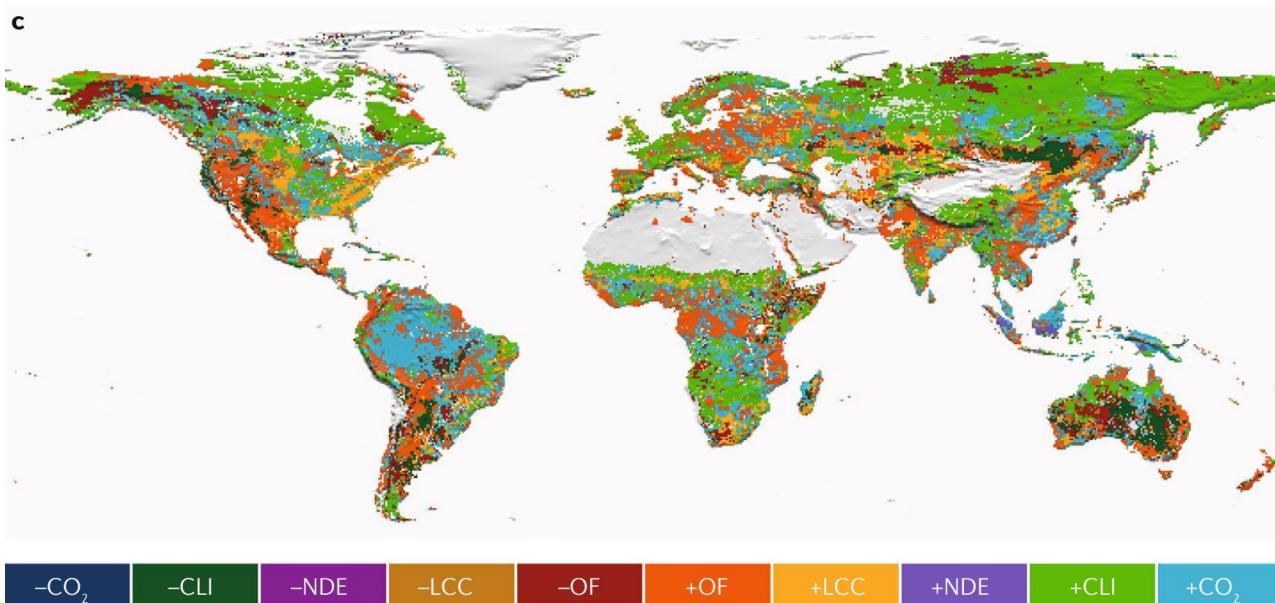


7. Landscape to Global scales

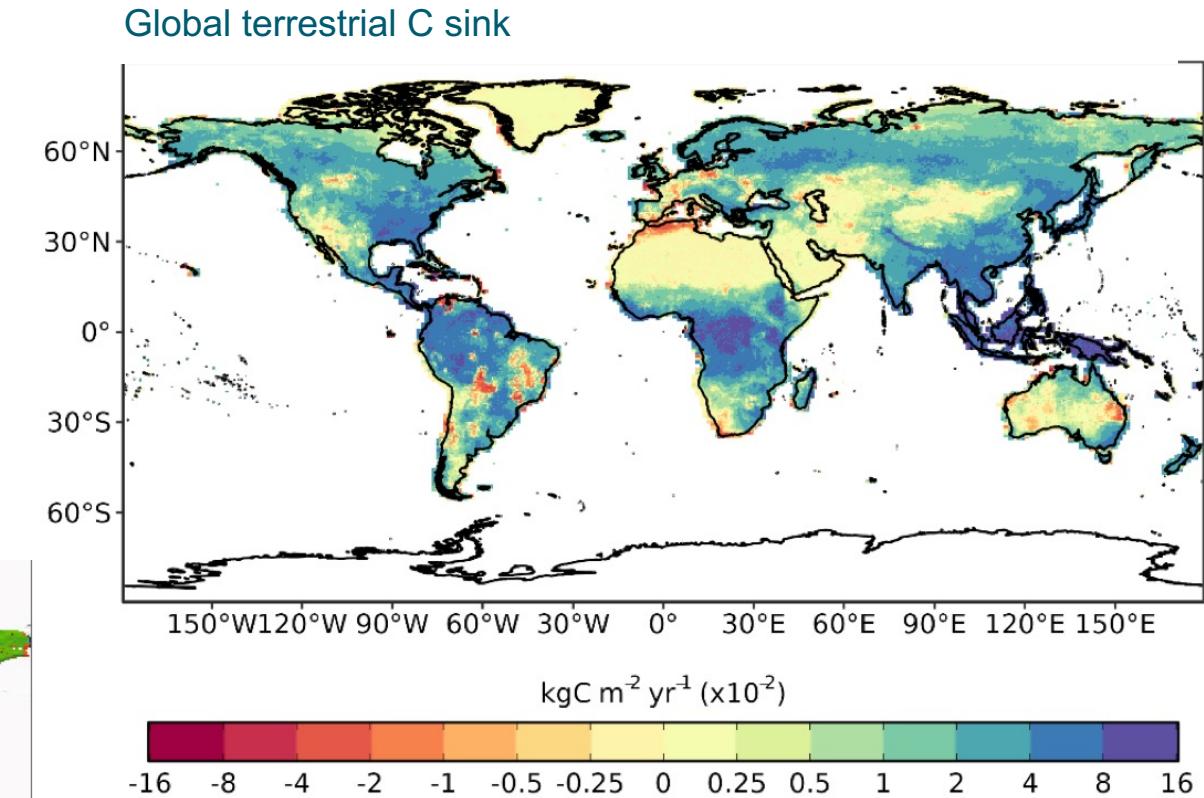
Evidence:



Trends in LAI and spatial distribution of dominant drivers



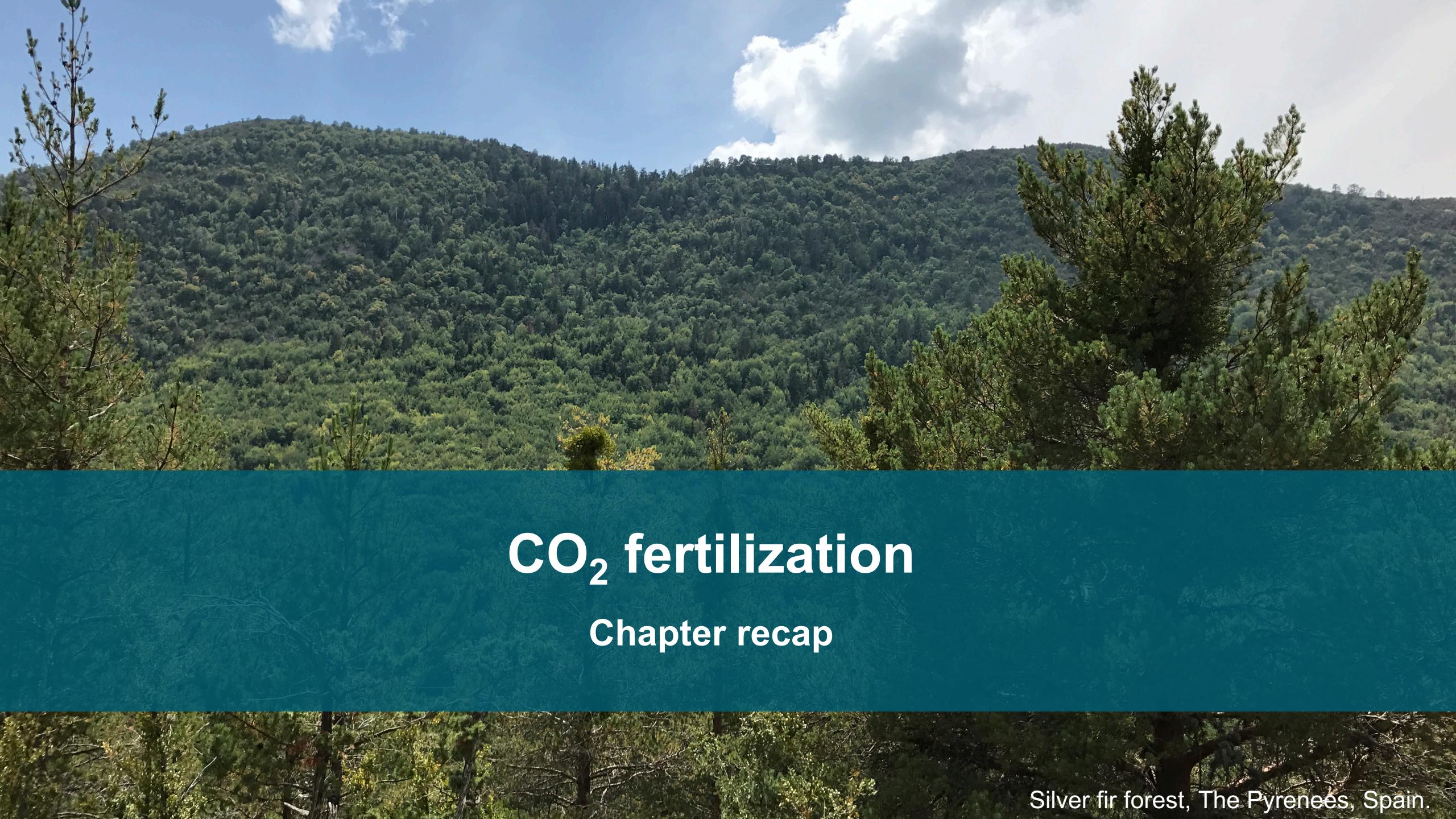
Results from remote-sensing observations. Piao et al. 2020.



Results from the Global Carbon Budget 2024. Positive values represent a flux from the atmosphere to the land (carbon sink). Friedlingstein et al. 2024.

8. Summary

	Response (R)	Processes (P)	Data sources	Evidence
	 Carbon Assimilation	Stomatal conductance WUE	Lab experiments FACE experiments	High confidence for R and P
	 Biomass production, i.e., plant growth	Allocation Resource availability Water and nutrients; PNL	FACE experiments Tree-ring data Forest inventories	High confidence for R and P
	 Biomass accumulation	Carbon turnover time Mortality, Forest dynamics GFDY	Tree-ring data Forest inventories FACE experiments Vegetation models	Unclear direction for R and P
	 Ecosystem C stocks	SOM decomposition Soil respiration Nutrient availability	FACE experiments Eddy-covariance obs.	Medium confidence for R and P
	 Landscape/Global C stocks	Ecosystem variability Land-use changes DOC dynamics	Remote sensing Global models Global Carbon Budget	Medium confidence for R and P



CO_2 fertilization

Chapter recap

Silver fir forest, The Pyrenees, Spain.