Tropical Forests and Atmospheric Carbon Dioxide: Current Knowledge and Potential Future Scenarios

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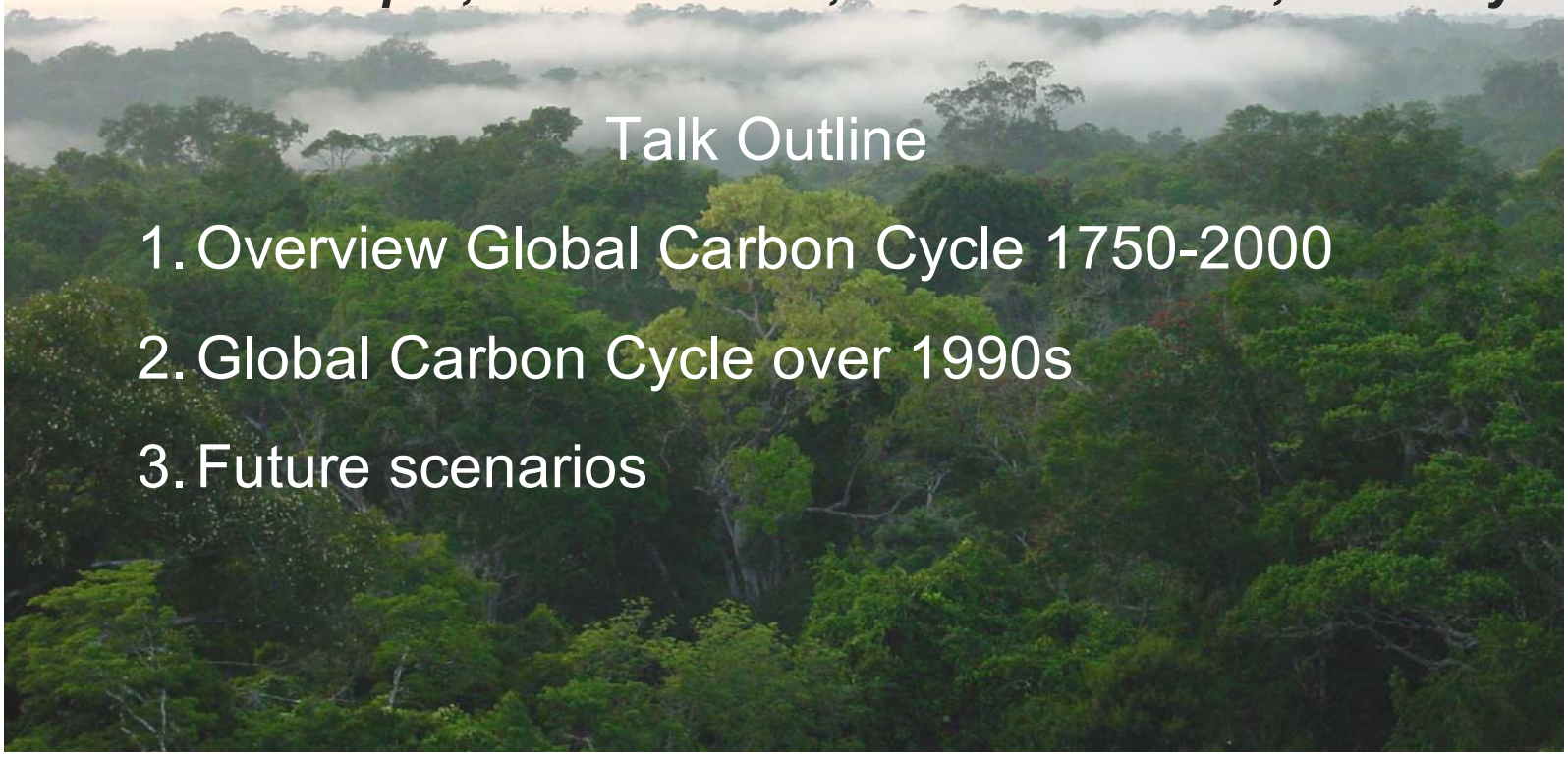


Talk Outline

1. Overview Global Carbon Cycle 1750-2000
2. Global Carbon Cycle over 1990s
3. Future scenarios

Tropical Forests: why are they important?

- Tropical forests cover ~10 % Earth's land surface
- BUT, contain ~40% of the globe's biomass carbon
- They are very productive systems, cycling large quantities of carbon with the atmosphere via photosynthesis and respiration
- Tropical forests contain 50-70% of Earth's species.

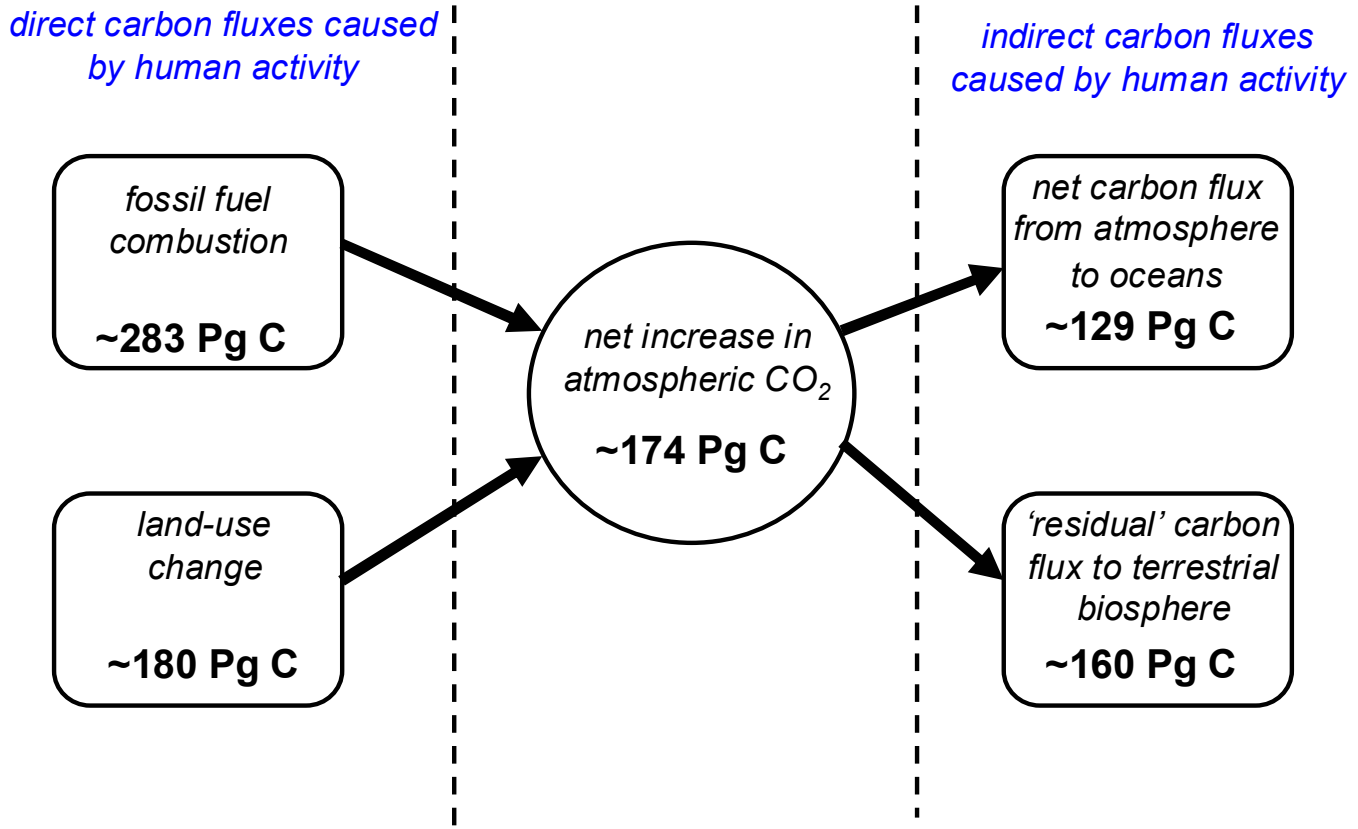
Therefore,

- Relatively small changes across the tropical forest biome may have large effects on the global carbon cycle, and hence the rate and magnitude of climate change.

and

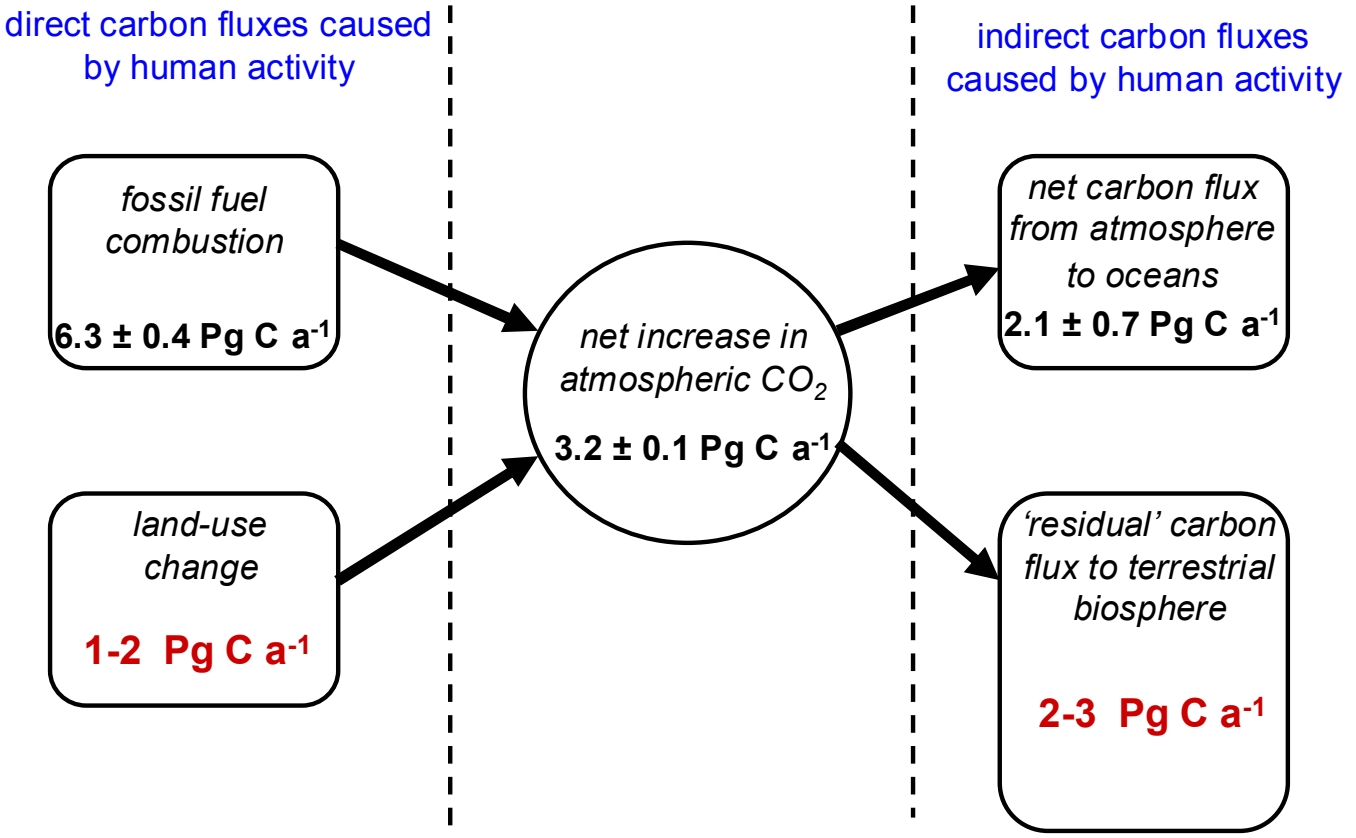
- Global environmental changes that alter tropical forests may have large effects on Earth's biodiversity.

Overview: Human-induced Global Carbon Cycle, 1750-2000



Cumulative totals, 1 Pg = 1 x10^{15}g = 1 Giga-tonne = 1 billion metric tonnes

Overview: Annual Carbon fluxes over the 1990s



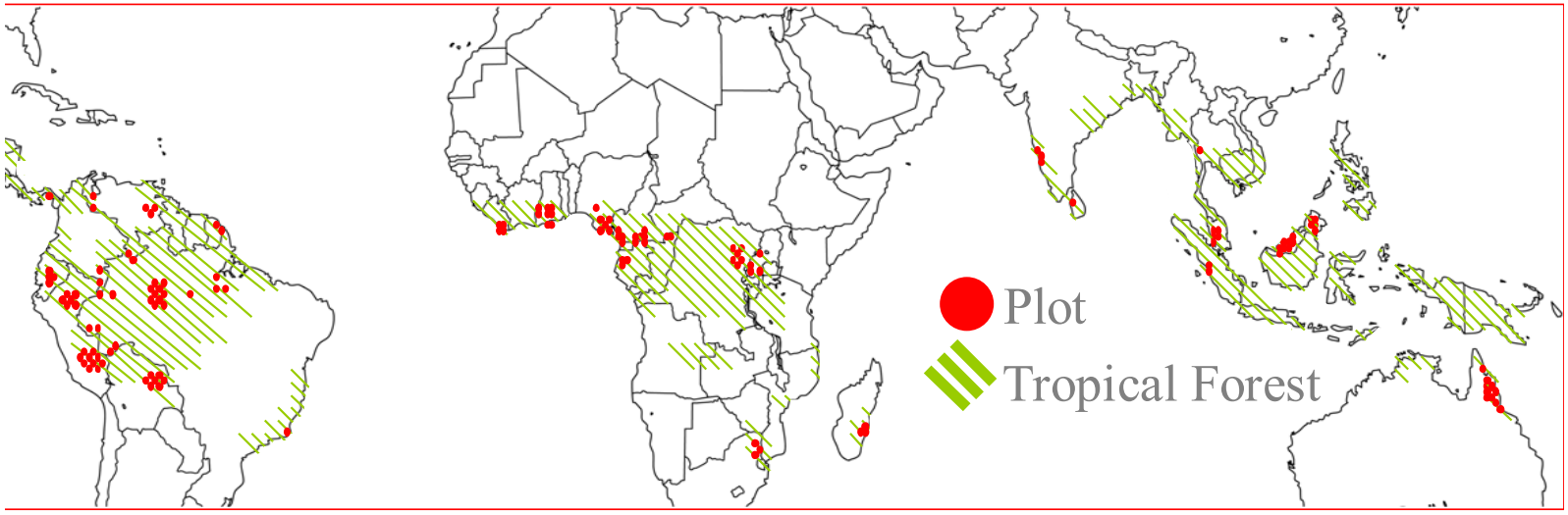
Annual totals, Pg = 1 x10^{15}g

How big was the tropical Carbon sink in the 1990s ?

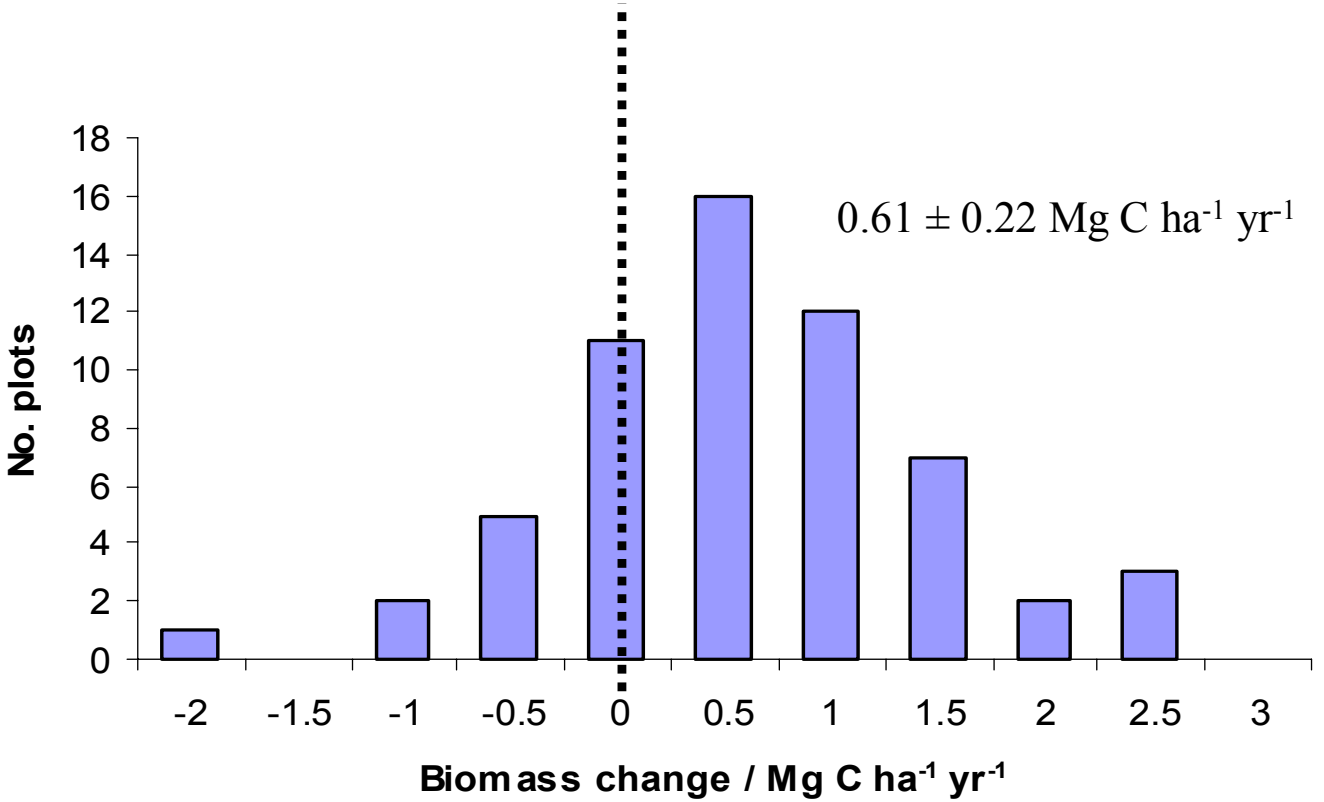
- Atmospheric CO_2 measurements and atmospheric transport models show the tropics, as a whole, to be neutral or a net source of C

- Therefore, as
  - Land-use change - tropical deforestation - contributes 1-2 Pg C a^{-1}
  - **"Natural" sink in terrestrial tropics thought to be 0-2 Pg C a^{-1}**

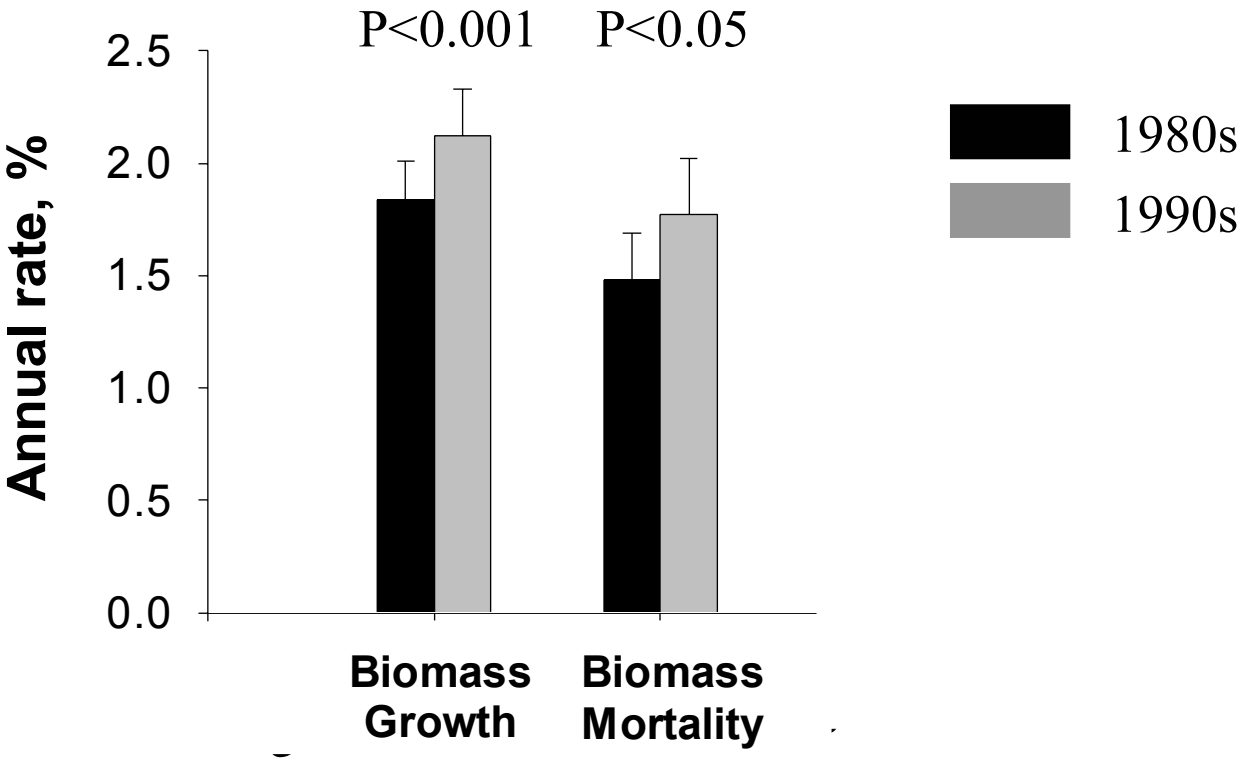
Long-term monitoring plots



Distribution of change in total vegetation biomass carbon from 59 plots across South America over late 20th century.

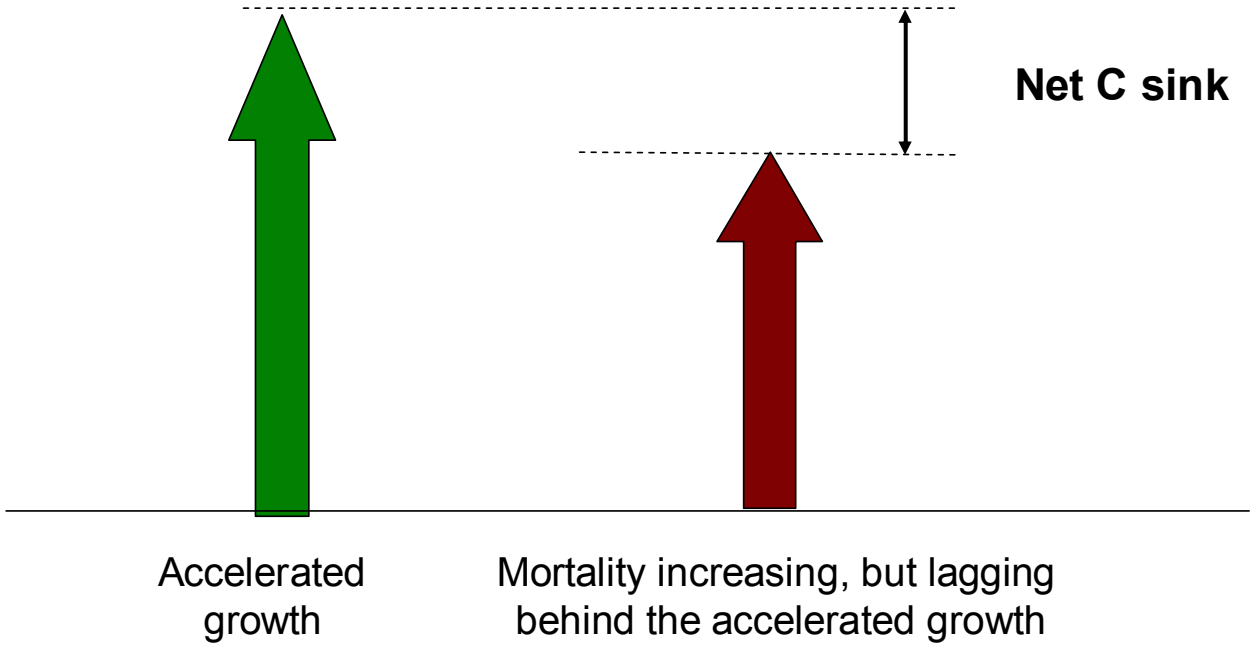


Changes *within* 50 South American plots

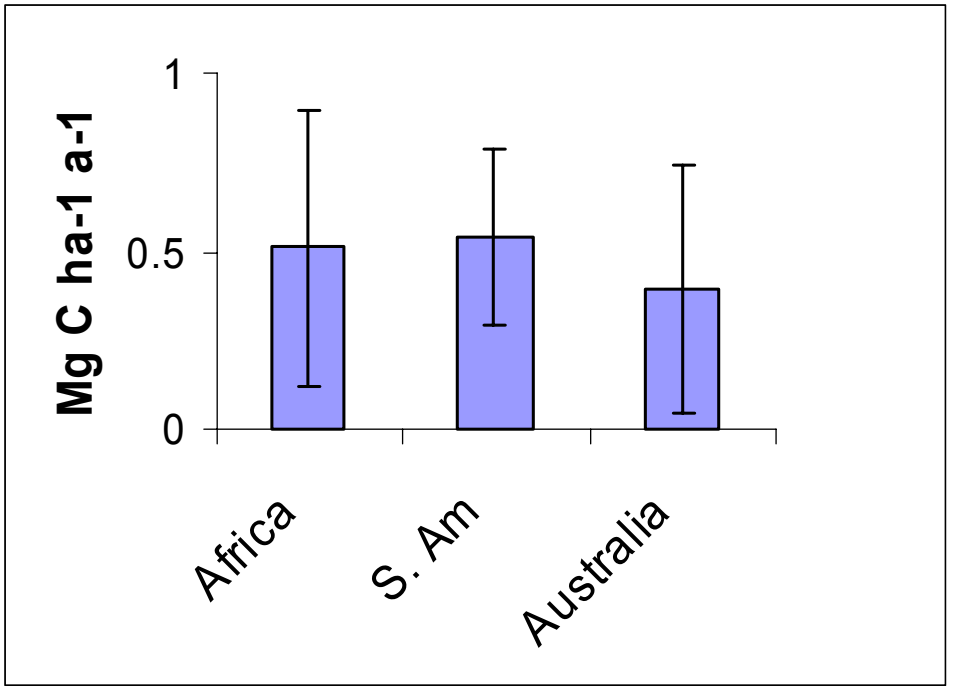


Relative increase = 2 to 5 % a^{-1}

The most parsimonious explanation is that an increase in plant resource availability (CO_2?) is increasing net primary productivity



Change in biomass carbon across forest plots across three continents over the late 20th century.



0.5 % a^{-1} increase in biomass carbon.

If tropical Asia is acting similarly, total tropical forest sink of 1 Pg C a^{-1}

The Future

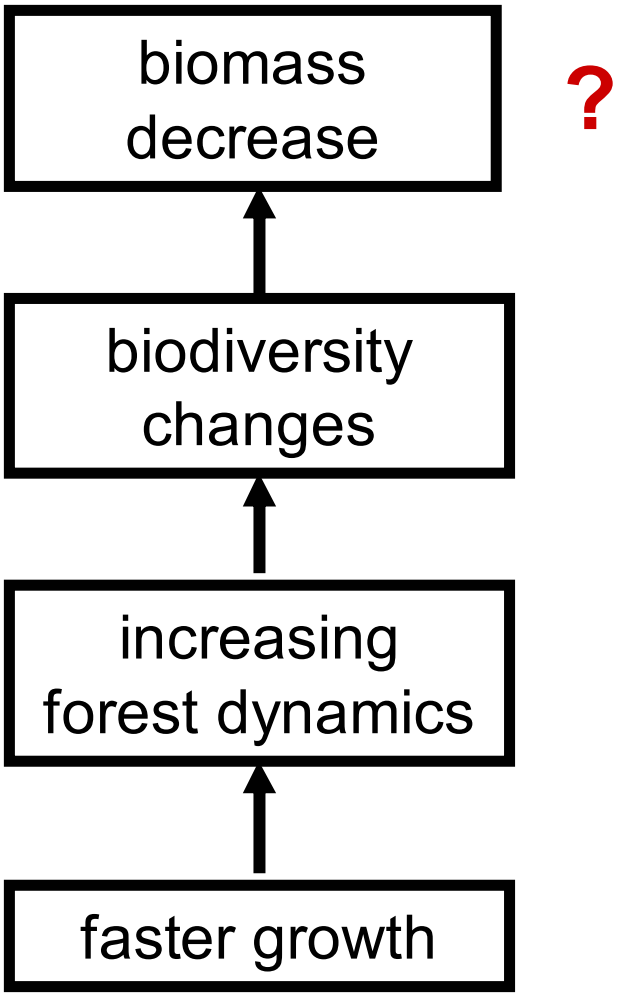
- Will remaining tropical forest become a C source in the future?
  - Balance between photosynthesis and respiration
  - Biodiversity change
- Will large-scale tropical forest collapse occur?
  - The drought route
  - The fire route

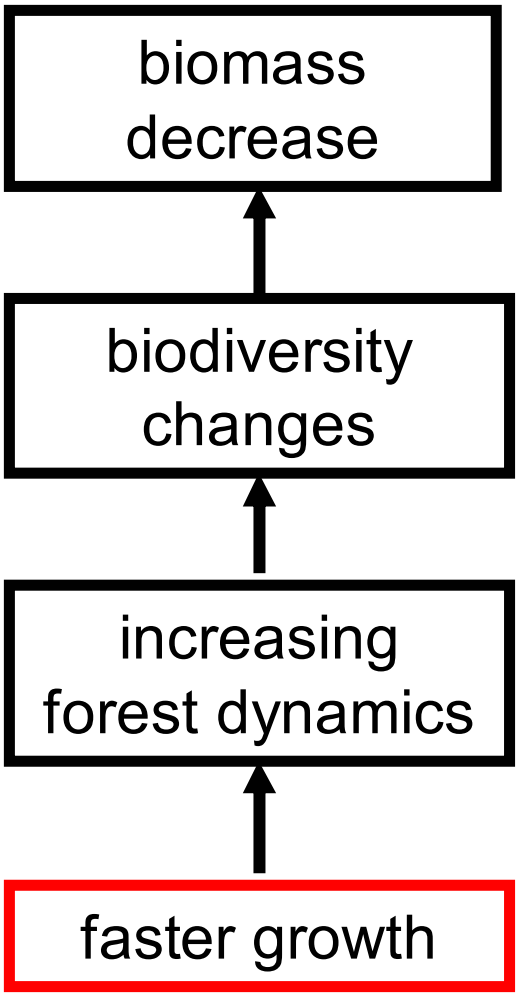
Will remaining forest become a C source?

- If higher atmospheric CO_2 concentrations are increasing forest growth causing the sink, this cannot continue indefinitely, as other factors will limit growth

- Rising temperatures may increase respiration costs and will eventually decrease photosynthesis rates

- Biodiversity changes may reduce, shut down, or reverse the sink.


biomass
decrease
?
biodiversity
changes
increasing
forest dynamics
faster growth


biomass decrease
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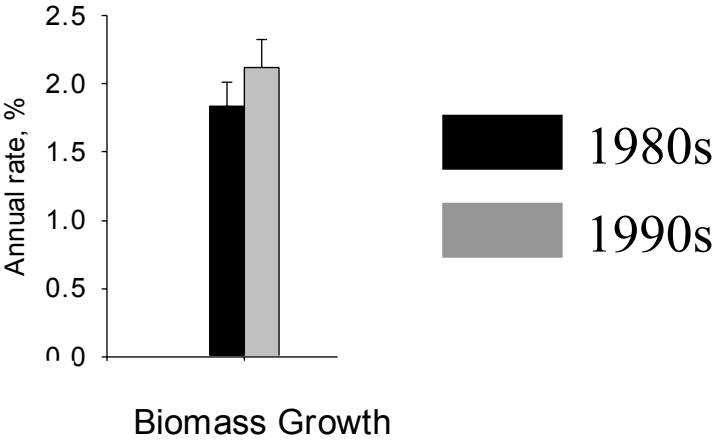
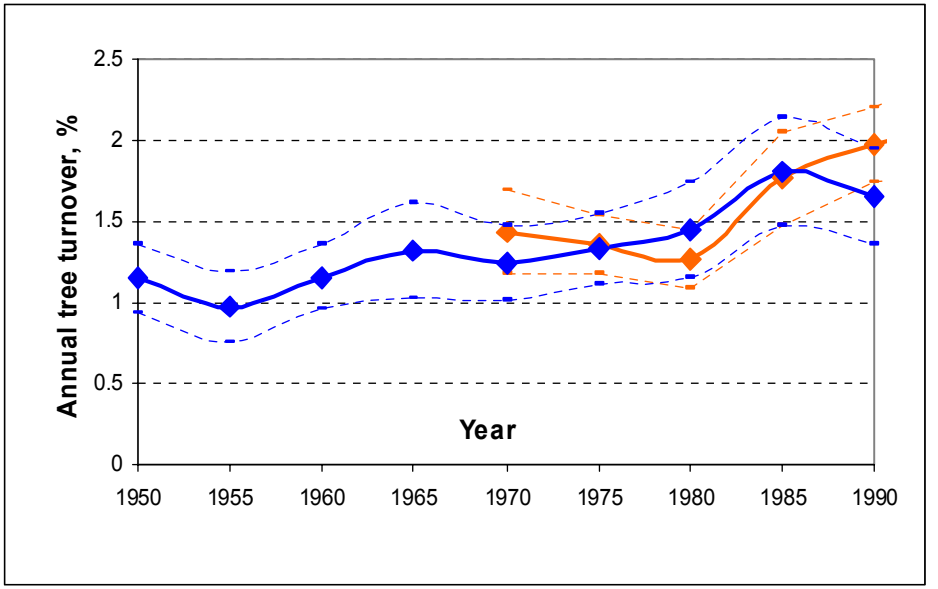

2.5
2.0
1.5
1.0
0.5
0
Annual rate, %
Biomass Growth
1980s
1990s

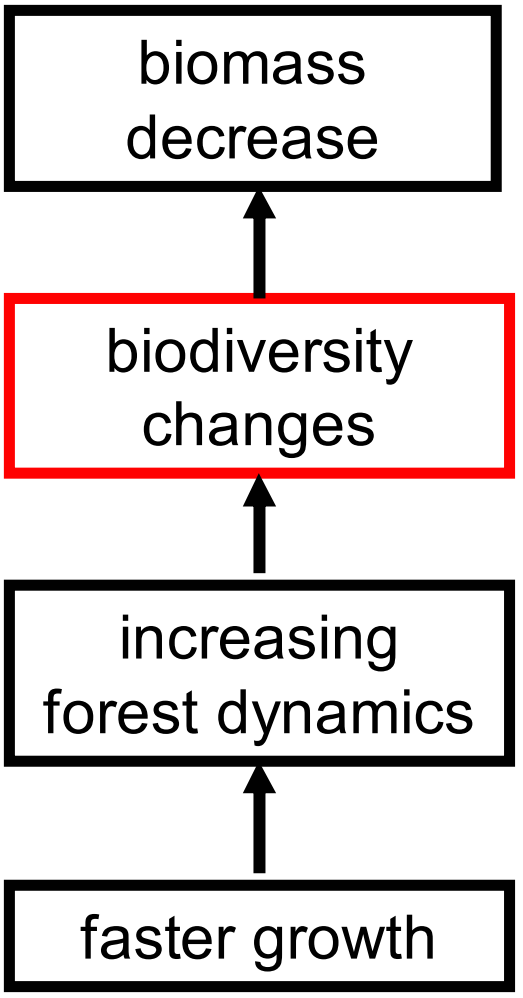
biomass decrease

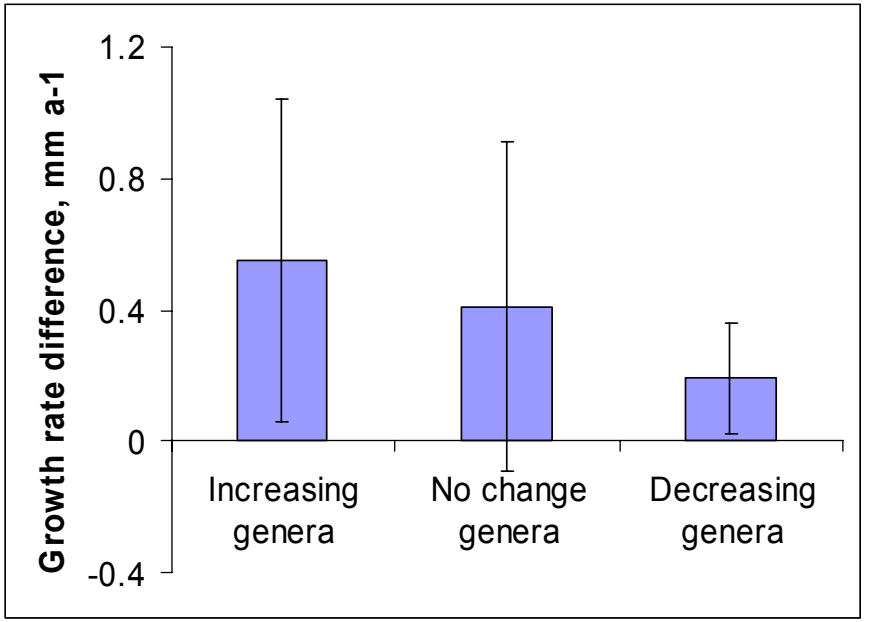
biodiversity changes

increasing forest dynamics

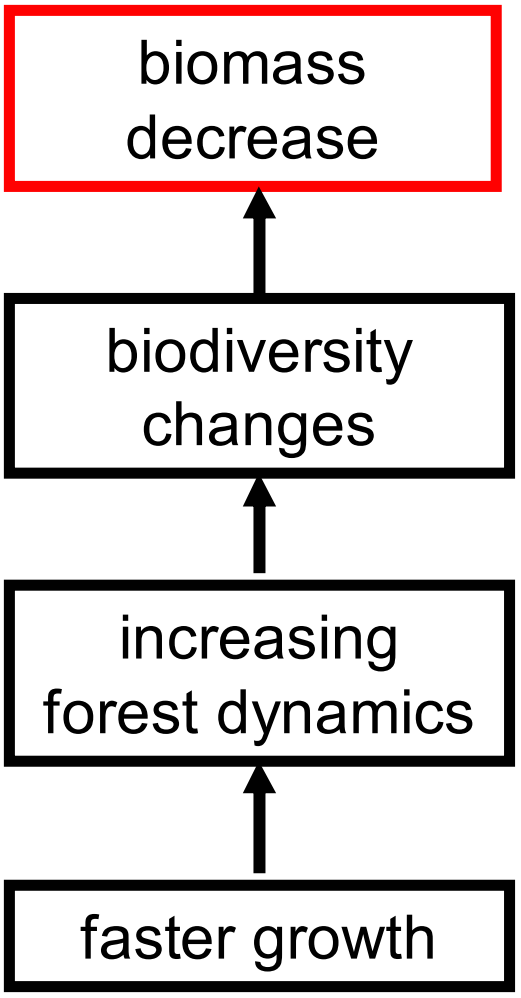
faster growth

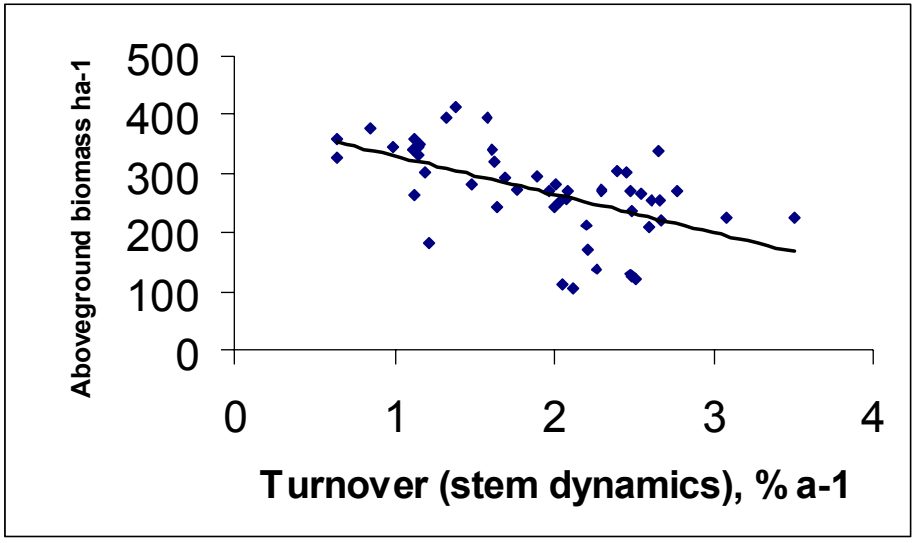






Laurance *et al.* 2004, *Science*





Tropical forests to become a major C source?

Tropical Forest Collapse: the drought route

- First GCM model to include dynamic vegetation and a carbon cycle responsive to it, showed massive die-back of the E. Amazon, due to drought, later this century.

- Resulting large flux of carbon further accelerates warming and droughts, a potential dangerous feedback.

Tropical Forest Collapse: the fire route

- Tropical forests can burn if they get dry
  - Rapid carbon losses
- As the world warms-up and dries-out more forest can potentially burn.
- Potential dangerous feedback: with warmer and more frequent and severe dry periods more forest would likely burn, thus further increasing atmospheric CO_2 concentrations, and resulting warmer and periodically drier conditions.

Conclusions

- Tropical forests are a C source from deforestation, and probably a C sink in remaining forest, both 1-2 Pg C a^{-1}.
- Even remote tropical forests are responding to global environmental changes, which may be having marked effects on Earth's biodiversity.
- Biodiversity changes alongside a warming and periodically drying world suggest that it is unlikely that the worlds remaining tropical forest will continue to be a significant carbon sink over the 21st century.
- Plausible mechanisms exist that show forest-human action-climate feedbacks may greatly accelerate the rate of climate change over the coming decades.