

Climate and Economics: Tropical Forests Part I

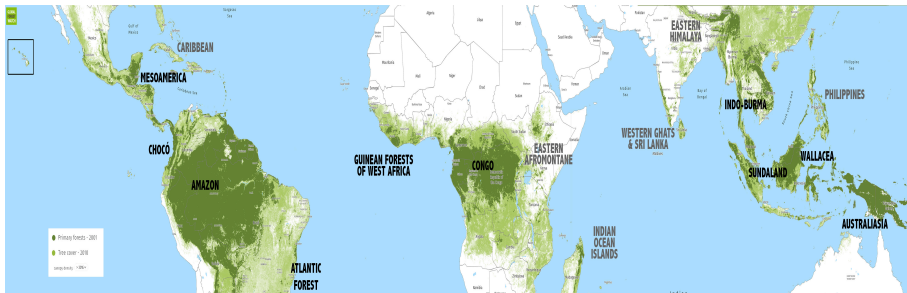
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Tropical rainforests

- Rainforests are forest ecosystems characterized by high levels of rainfall, enclosed canopy and high species diversity.
- Tropical (rain)forests are rainforests that are located between the tropics.
- Carbon-dense and bio-diverse.
- Major tropical forests
 - Amazon forest: ~ 630 million hectares of tree cover. 60% in Brazil. Also Peru, Colombia...
 - Congo basin forest: ~ 290 million hectares of tree cover. DRC, Republic of Congo, Cameroon, Gabon...
 - Sundaland forest: ~ 100 million hectares of tree cover. 73% in Indonesia. Also Malasia.
 - Australasia forest: ~ 90 million hectares of tree cover. Indonesia and Papua New Guinea.
 - Mesoamerica forest, Guinean Forest...

World tropical rainforests



The Amazon Forest I

- All lectures will cover papers on the Brazilian Amazon
- In general, scientific data used in these papers are available for all tropical forests.
- Economic data?
- The Amazon rainforest accounts for approximately a quarter of global emissions from land use change, due in part to its' immense size, carbon storage, and recent history of land use change (Bullock and Woodcock [2021]).
 - Deforestation
 - Degradation from other man-made causes: Unintended fires, edge effects, selective logging.
 - Degradation from global climate change.
 - These causes are not orthogonal - unintended fires are often the result being at the edge of human activity.
 - Land management in agriculture or cattle-ranching.

The Amazon Forest II

- Lapola et al. [2023] estimates that 25% of the total burned forest area was within 120m of an edge, affecting 17% of the total edge area.
- Edge effects indicate reforestation more beneficial if in contiguous areas.
 - Public versus private projects.
- Carbon currently stored in the Amazon, if released, would produce approximately 600 Gigatons of CO_2 , Flores et al. [2024] equivalent to more than 15 times the estimate by the International Energy Agency of global energy-related emissions during 2023.
- As other tropical rainforests, the Amazon plays a crucial role in regulating local and regional precipitation and temperature and are thought to have a large impact in global climate. (Flores et al. [2024]).

The Amazon Forest III

- The forest “recycles” rain (evapotranspiration) and trade-winds carry moisture to areas southwest, affecting other portions of the forest, including portions in other countries (Araujo et al. [2023]), and economic activities, including agricultural productivity in the crucial cerrado region (Araujo [2023]).

Biodiversity I

- The Amazon is incredibly biodiverse; it holds approximately 10% of the world's vertebrate and plant species (Amazon Assessment Report 2021 <https://www.theamazonwewant.org>).
- More than 15000 tree species with 99% rare.
- In northwest or central Amazon forest, single hectare may contain 300+ species.
- Diversity enhances carbon storage in tropical forests (Poorter et al. [2015])
 - If true, biodiversity is not just a byproduct of conservation and reforestation aimed at avoiding increasing atmospheric CO₂ but also a contributor to carbon capture.

Biodiversity II

- Rare species help resist severe disturbance.
 - In rainy portions of the Amazon forest, drought resistant species are rare but could replace dominant species in case in a drier future (Flores et al. [2024])
 - Diversity provides option value.
 - Option value increases with uncertainty
- Half of Amazonian tree species are threatened with extinction due to deforestation, degradation and climate change. (Gomes et al. [2019])
- Not much literature in economics of biodiversity
- State of the literature: Dasgupta and Levin [2023]
- Dasgupta and Levin [2023] cites a species–area relationship:

$$S = aA^b,$$

with $0 < b < 1$.

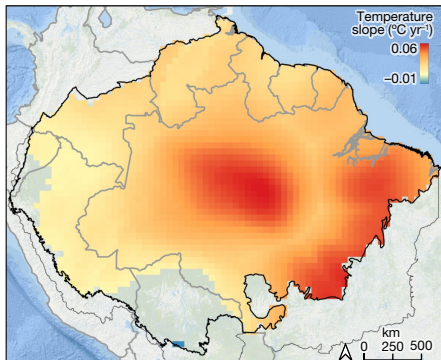
Biodiversity III

- b could be dependent on type (birds vs. rodents)
- If we knew b , formula could be used to estimate effect of percentage loss of habitats.
- Dasgupta and Levin [2023] claims that $b \in [.2, .8]$ for birds.
- Biodiversity measures: species count, Shanon index $-\sum_{i=1}^S p_i \ln(p_i)$, genetic diversity...
- Pricing biodiversity

Global climate change impacts on Amazon forest

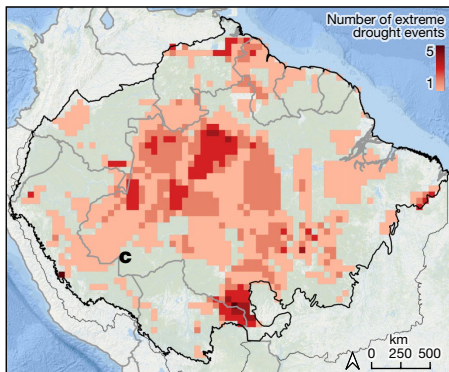
- Papers we will cover here do not account for how climate change affects the Amazon.
- Since the early 1980's Amazonian region warming at an average rate of $.27^{\circ}\text{C}$ per decade during dry season.
- Large parts of the center and southeast of the Amazon are now 2 degrees warmer.

Changes in mean temperature in dry season (July-October) from 1981 to 2020



- Flores et al. [2024]
- While southeast has suffered much deforestation, center has been less affected.

Multiple extreme drought events (1981-2020)



- Flores et al. [2024]
- Extreme drought: two sd in maximum cumulative water deficit (MCWD) during dry season.

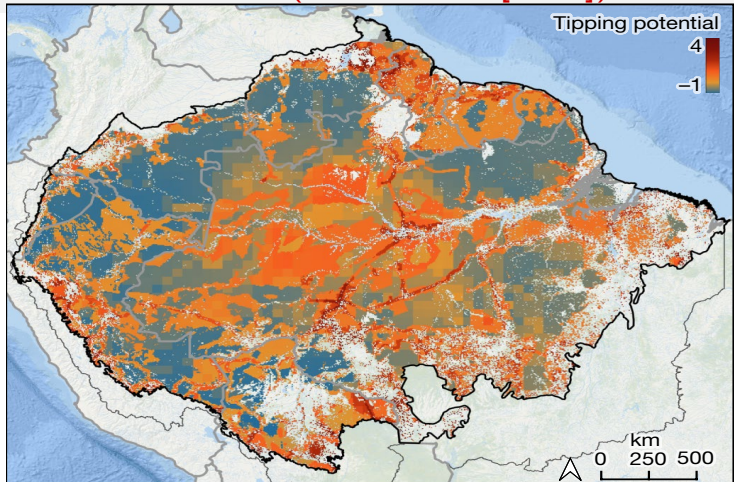
Rising temperatures

- Rising temperatures and extension of dry spells that result from global warming and forest degradation reduce forest productivity, carbon storage capacity and cause leaf damage in other areas.
 - Araujo et al. [2023] shows cascading of losses of leaf area index, a dimensionless variable that describes the ratio of leaf area to ground surface area.
- Raising temperature and extension of dry spells, reduce biodiversity.
- By 2050 significant increases in consecutive dry days (+10-30 days) and annual maximum temperatures (+2-4) degrees in the Amazon are possible ([https://report.ipcc.ch/ar6/wg1/IPCC AR6 WGI FullReport.pdf](https://report.ipcc.ch/ar6/wg1/IPCC_AR6_WGI_FullReport.pdf)).

Tipping points

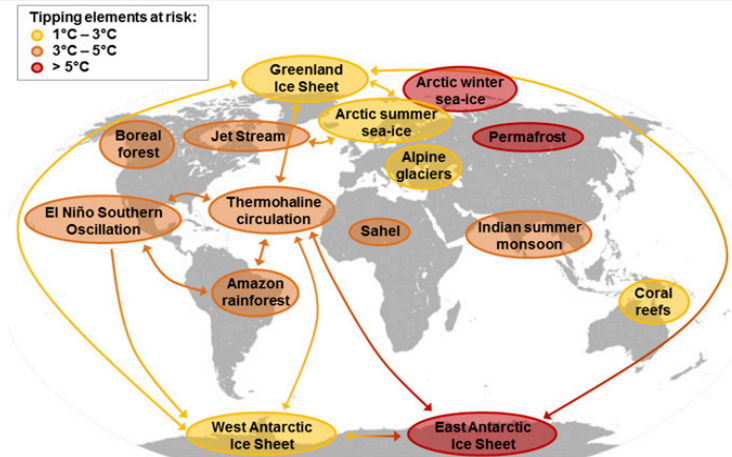
- Papers we will here do not explicitly incorporate tipping points.
- Tipping points: Human activity has potential to push large components (over 1000 km length) of the Earth system past critical states and into qualitatively different modes.
- Several papers, including Steffen et al. [2018], argue that the Amazon forest will tip with 3-5 degrees warming.
 - Note overlap range proposed by IPCC
- Earlier literature proposed tipping to a savanna.
- Recent literature more subtle and discusses other possibilities including a much poorer forest and sensitivity to local climate conditions. Flores et al. [2024]

Amazon transition risks (Flores et al. [2024])



- Higher index associated with higher transition risks

Tipping points (Steffen et al. [2018])



- Tipping Amazon possibly affecting other major climate systems.

Economics of tipping points

- Pioneering paper by Cai et al. [2015]
- Follow suggestion from Hoel and Sterner [2007] to augment DICE models by adding an environmental good S in a CES with elasticity of substitution < 1 between S and C .
- Tipping point modeled with arrival rate that depends on temperature.
- At tipping point, S suffer a discrete loss.

Outline

- Present a few papers in some detail so that you become acquainted with data, models and computational methods.
 - ① Carbon capture potential of reforestation in tropical forests. Assunção et al. [2023]
 - ② Identifying externalities in forest loss/degradation. Araujo et al. [2023]
 - ③ Can law enforcement stop deforestation? Assunção et al. [2022]
 - Particularly important for viability of item 1
 - ④ Integrated model of deforestation, rainfall and agriculture. Araujo [2023]
 - Agriculture affects rain that affects productivity in agriculture.

References I

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