Climatic variance and vulnerability to drought in Amazônia

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Scientific Questions

- **What climatic factors determine where fire-adapted vs. closed canopy forests are located?**

- **What mechanisms control the forest-savanna boundary?**

- **How much of the Amazonian forest is vulnerable to vegetation shifts with changing climate?**

Approach—

Using historical data on climate and vegetation distributions plus a simple hydrological model, we assess the factors that govern the boundaries between forest and savanna as observed in the 1980's.

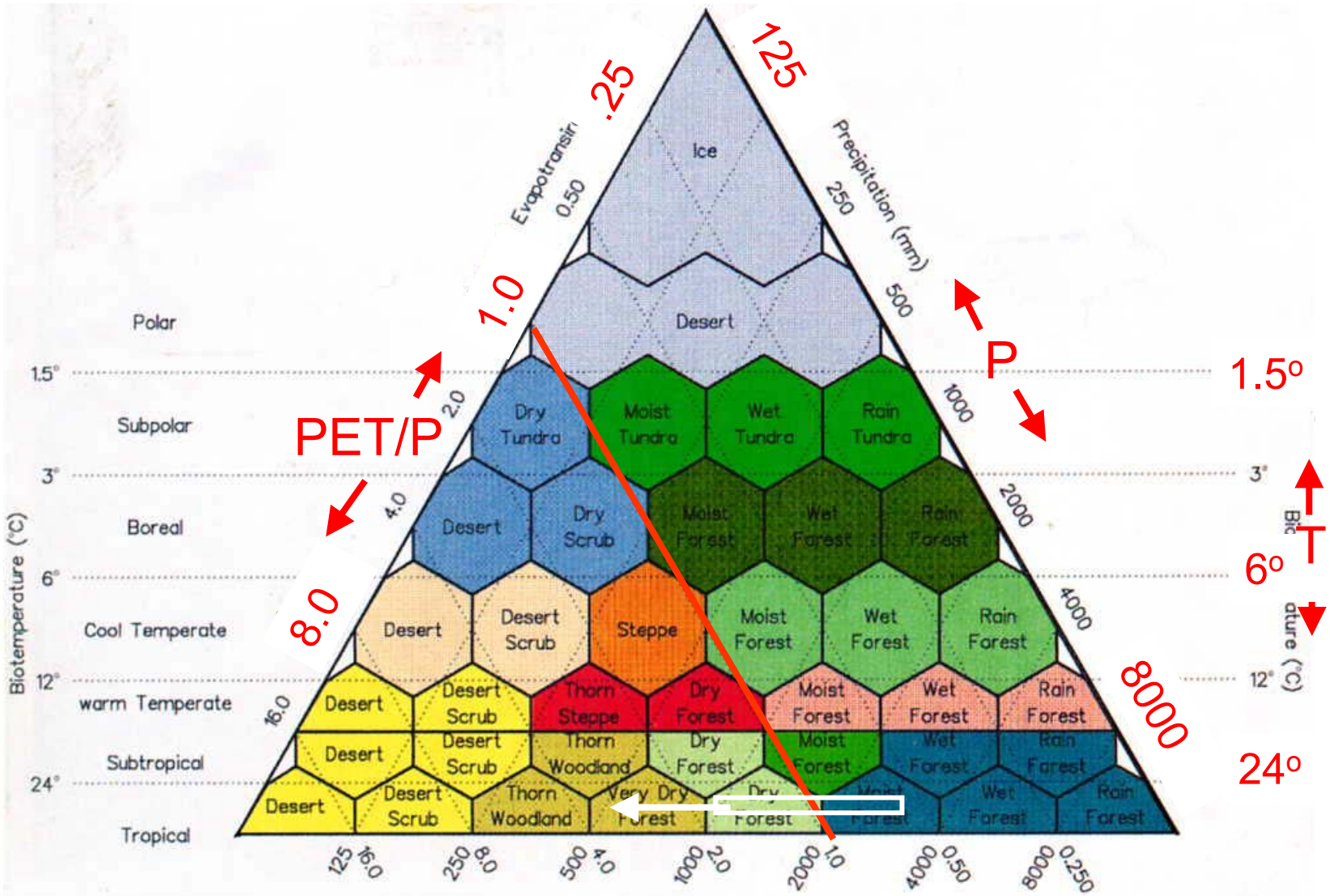
Challenges—

The observed gradients in climate are not as sharply delineated as ecotonal boundaries.

Hypothesis—

Higher order statistics of the climate are important in determining where fire-adapted vegetation dominates.

Holdridge Life Zones & potential vegetation: **Mean T, Precip, and PET/P control vegetation cover:** warmer-drier implies shift to fire-adapted veg.

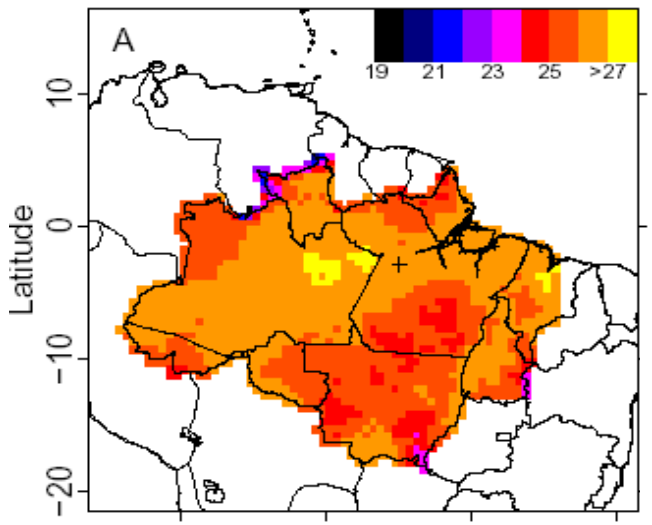


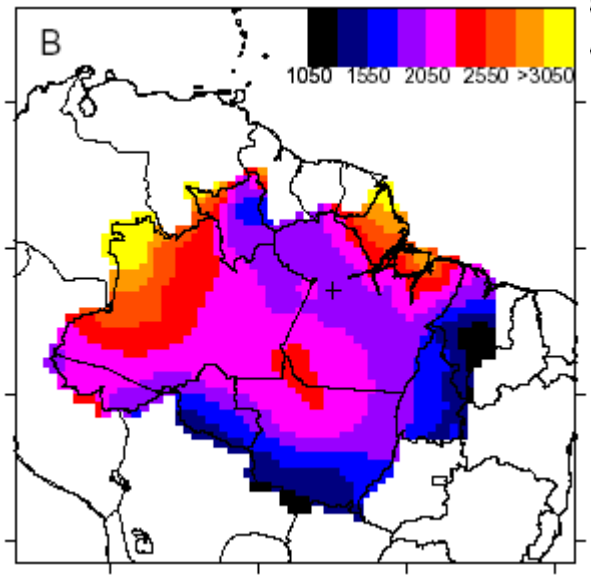
Holdridge life zones (Holdridge 1967)

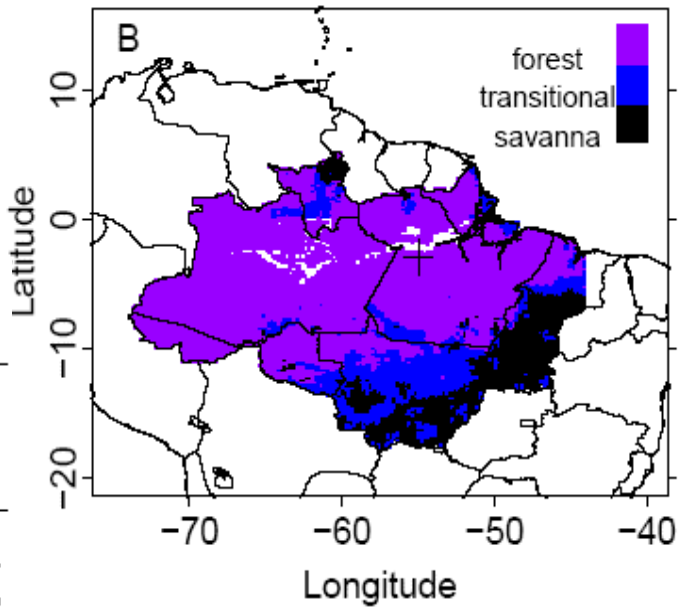
What are the climatic factors that control vegetation distribution in the Amazon?

Data sets used:

- **observed vegetation distribution (TRFFC, Skole et al.)**
- **gridded 100-year time series for T and precipitation (CRU)**
- **Forest Evapotranspiration from LBA tower data**
- **water balance (Plant Available Water, PAW) (Kleidon, 2004)**



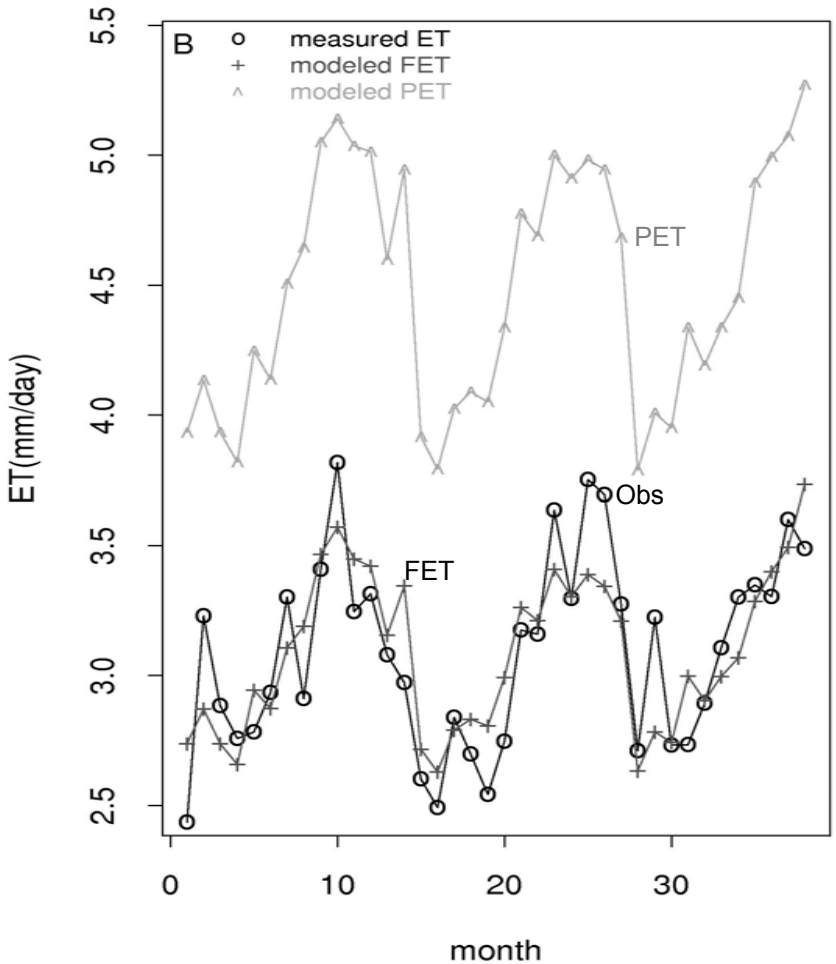




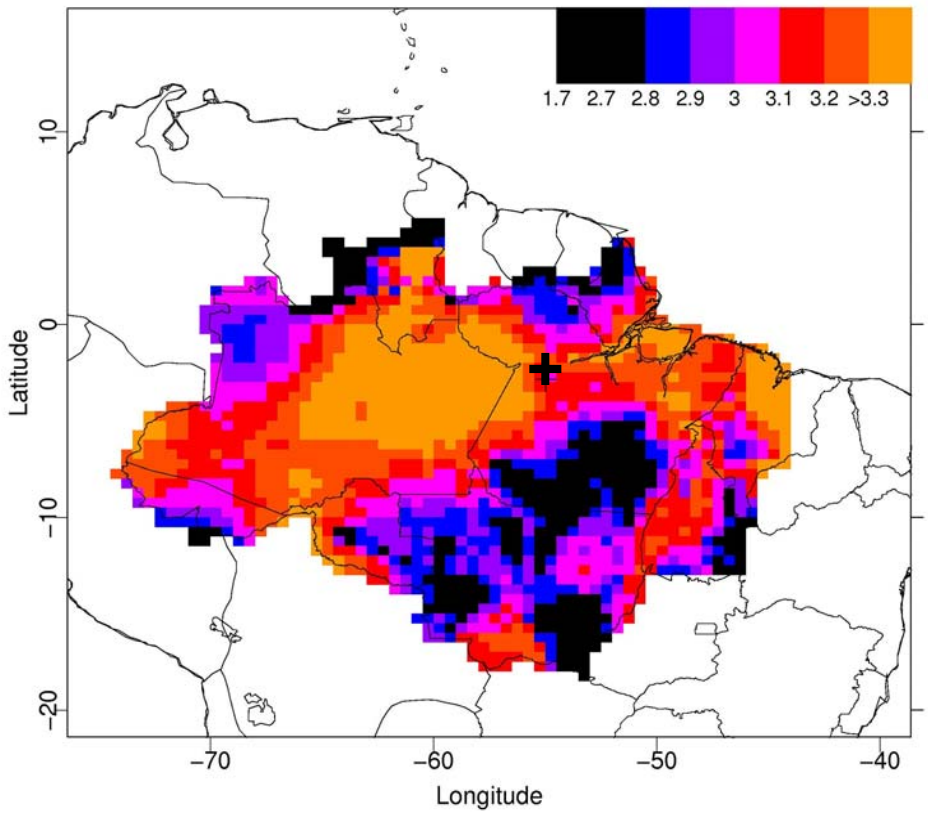
Forest Evapotranspiration

Evaporation in equatorial evergreen forests is dominated by transpiration, and it depends largely on T—limitation due to water stress is generally thought to be relatively small.

FET (mm/day) =
-6.7084 + 0.3764×T



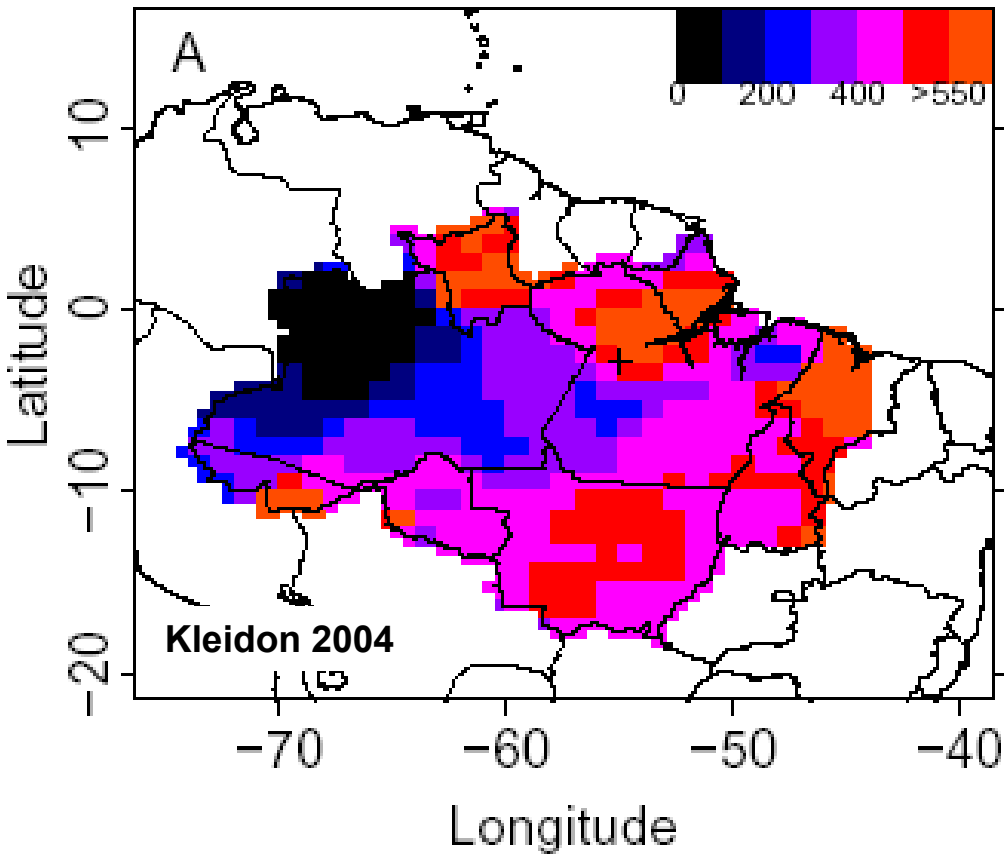
Annual Mean FET (mm day^{-1})



PAW, Evaporation, Rainfall

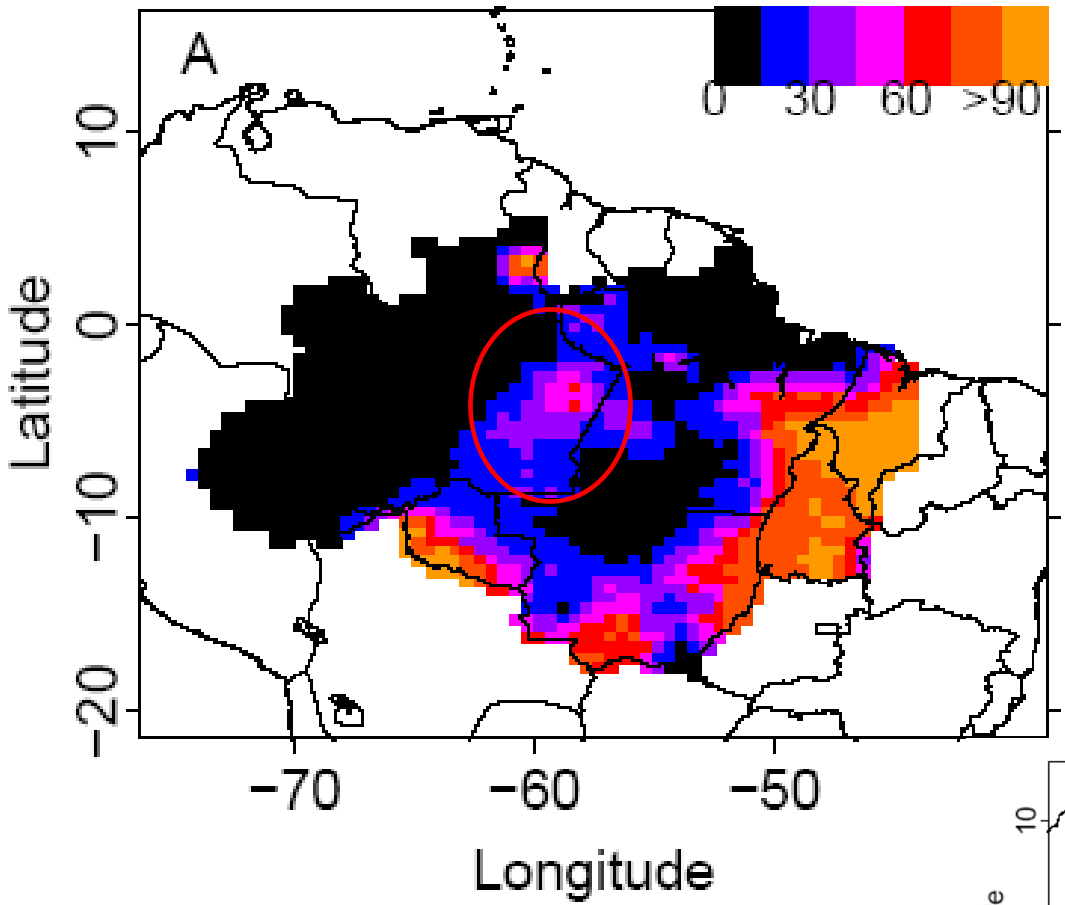
Plant Available Water (PAW) balance:

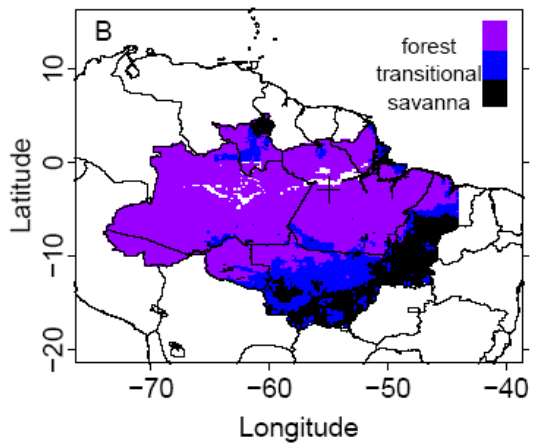
$$PAW_i = PAW_{i-1} + P_i - FET_i$$



Note:Initiated in 1900 with $PAW_i = PAW_{max}$

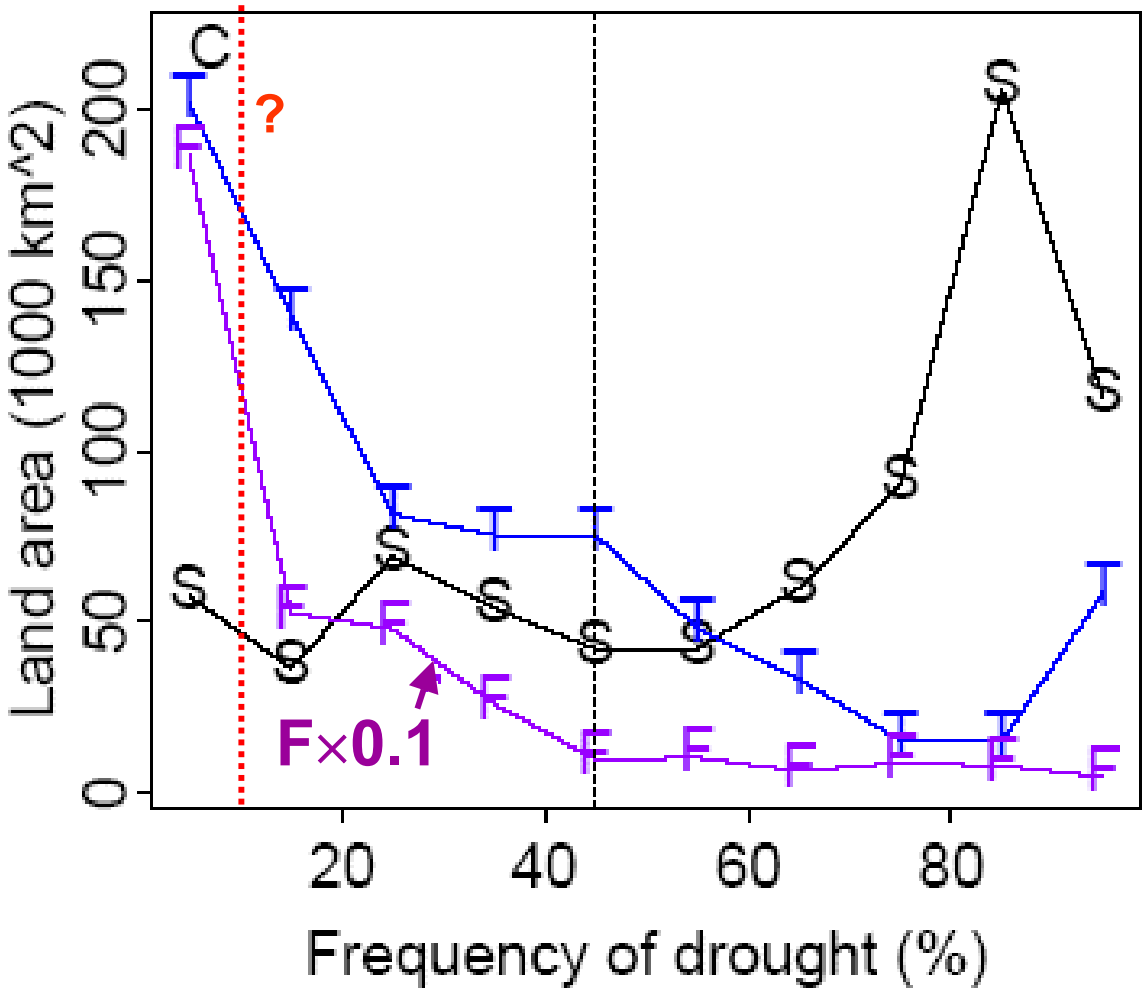
Drought Frequency

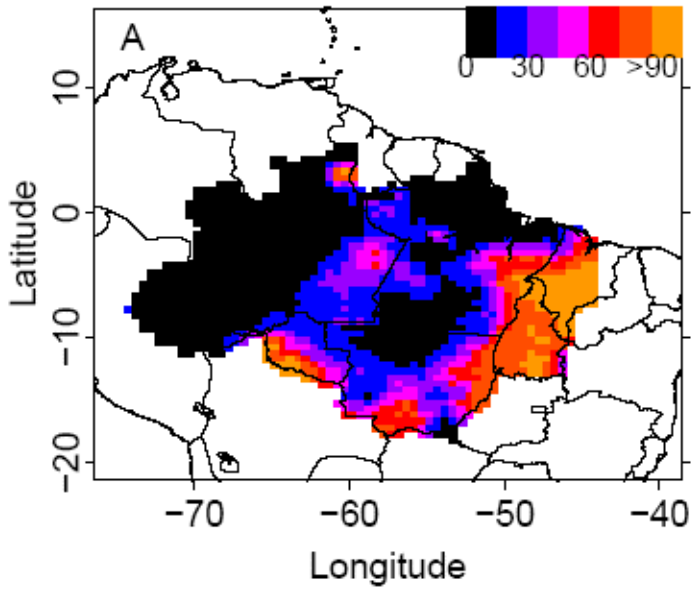


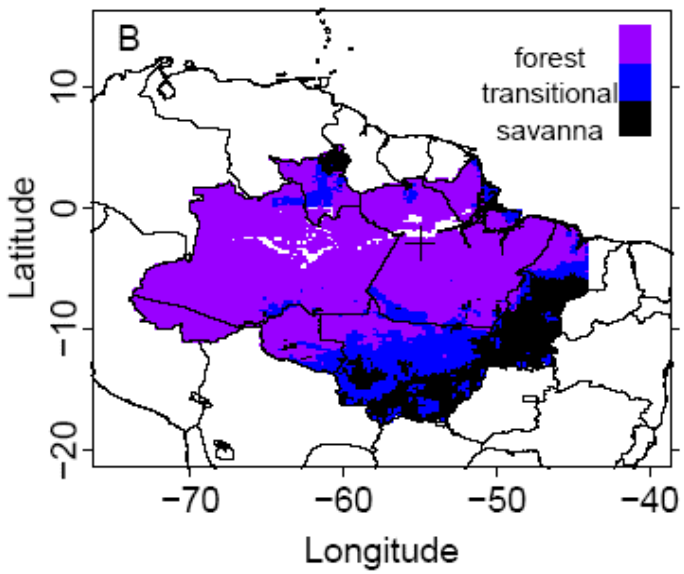


A drought was assessed at any grid cell where PAW declined to less than 75% of PAW_{max} for 5 or more months in a year, implying a dry period exceeding 6 or 7 months, longer than the mean dry season for most evergreen Amazon forests.

Vegetation distribution & spatial patterns of drought

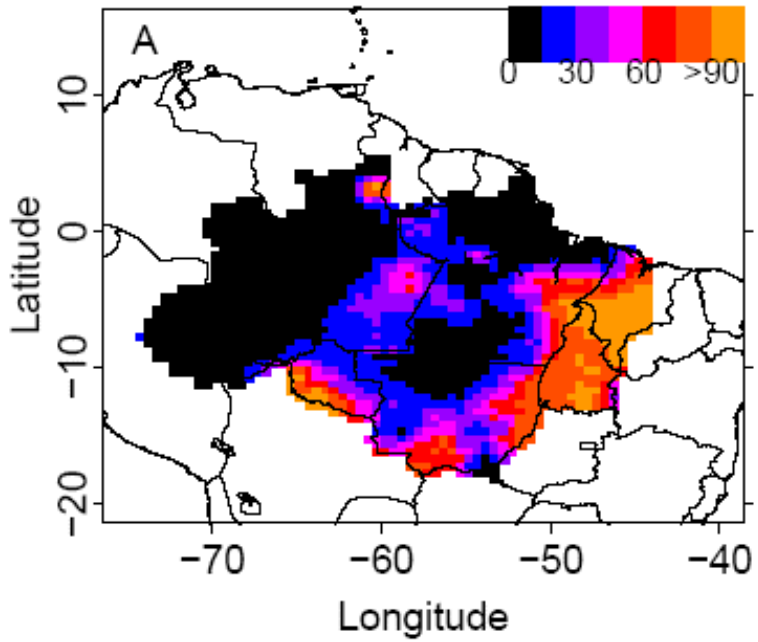






Vulnerable Forest Areas

	Drought Occurrence (0 — 44 per 100yr)	Drought Occurrence (45—100 per 100yr)
Forest	3,176,751 km^2	413,900
Transitional	550,023	197,027
Savanna	243,655	583,965



Areas of the legal Amazon within the two drought frequencies regimes for each vegetation type. Grey cells indicate areas vulnerable to degradation with increased aridity. A 45% frequency of drought implies a mean return interval of 2.2 years.

Conclusions

- The historical location of the Forest-Savanna boundary is associated with frequent droughts—every two to five years. Hence forest vegetation seems to be resilient to frequent droughts.
- Nonetheless, over 600,000 km^2 of forest currently vulnerable to vegetation change. Modest increases in T or decrease in precipitation could bisect Amazonian forest cover.

- *Other factors may interact with climate, such as increasing sources of ignition [Cochrane and Laurance, 2002] and/or fragmentation due to land conversion.*

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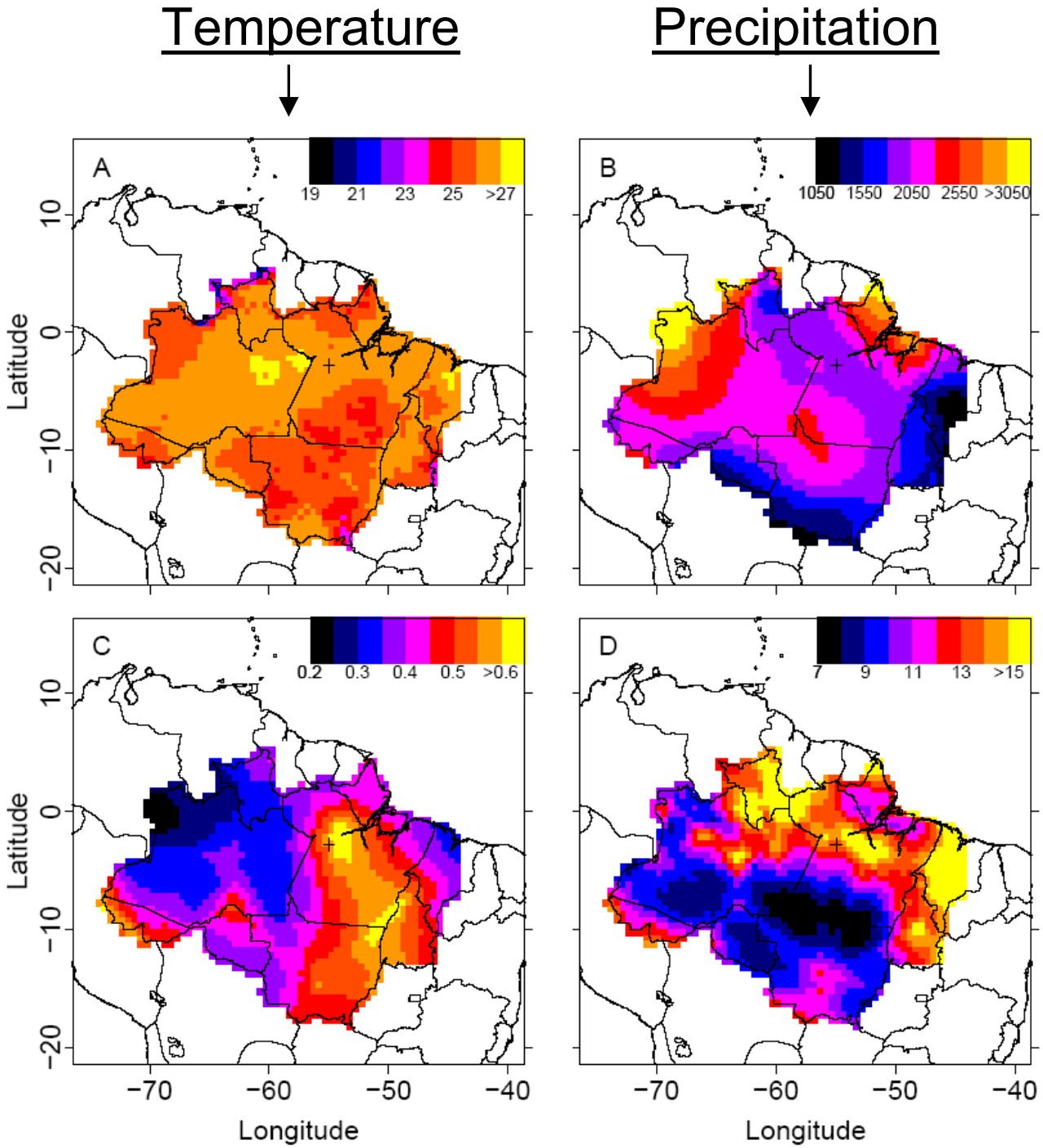
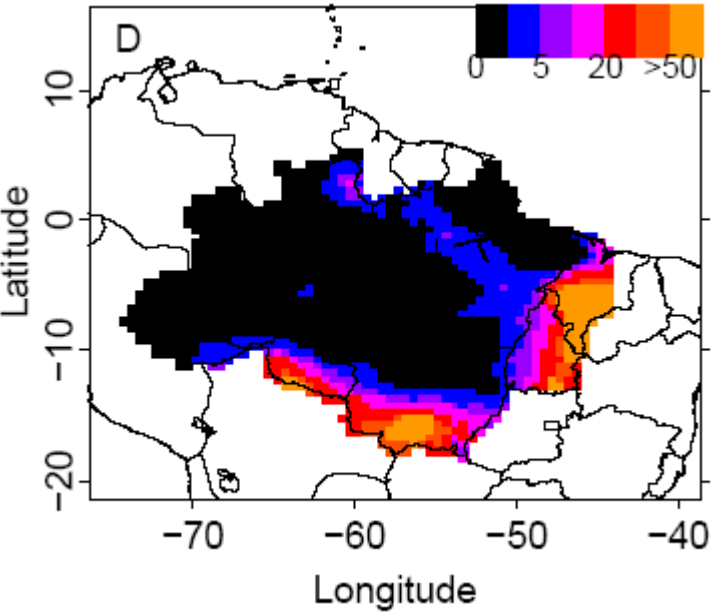


(A) Mean annual temperature (deg C); (B) mean annual precipitation (mm year^{-1}); (C) standard deviation for 100 year time series of temperature; (D) coefficient of variation for 100 year time series of precipitation (%).

Talk agreement with Nix and correlations



Nix [1983] Criteria	Correlation coefficient
1. Annual totals of solar radiation between 6 and 8 GJ m^{-2} yr^{-1}	NA
2a. Mean precipitation > 1000 mm/yr	0.28
2b. Mean precipitation < 1500 mm/yr	0.56
2. 1000 mm/yr <mean Precipitation<1500 mm/yr	0.56
3. High seasonality in rainfall	NA*
4. Precipitation > 600 mm/yr during wettest 6 months	0.05
5. Precipitation < 50 mm/yr during driest 3 months	0.75
6. Mean temperature > 24°C	0.08
7. Mean min temperature of coldest month between 13° and 18°C	NA
Parameters 2 and 5	0.59
Parameters 2 through 6	0.58