Rootzone storage potential indicates the extent of rainforest resilience

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Motivation:

Amazonian rainforest is under pressure:

- ❖ Major deforestation and land-use change (LUC)
- ❖ Temperature increase
- ❖ Change in rainfall patterns
- ❖ Is there a threat of tipping towards a treeless savanna state?

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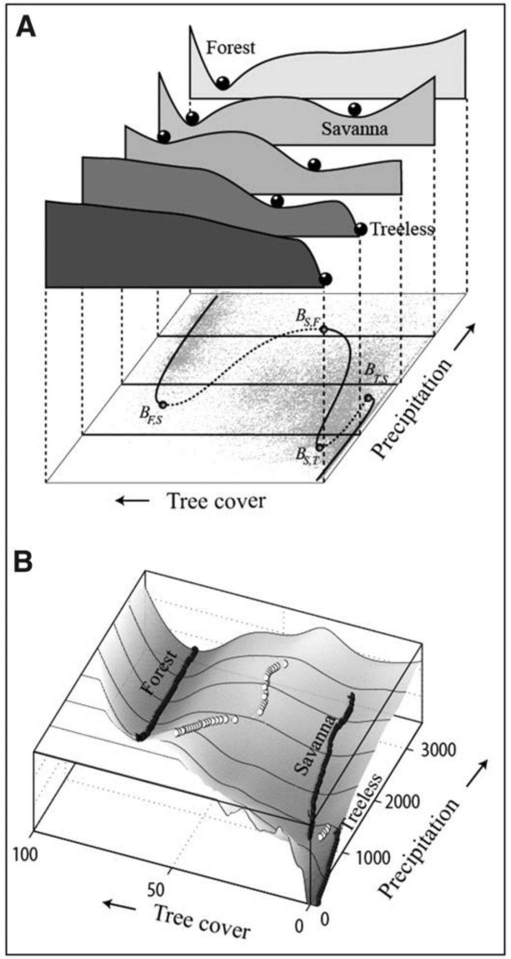
Introduction:



Change in rainfall patterns and extended drought events can cause water stress in the rainforest which can also lead to a permanent shift of the biome into a savanna state. Rainforest in response may adapt to such environmental stress conditions to sustain ecosystem functioning or reduce functioning altogether. Previous studies related to forest resilience have mostly relied on precipitation or climatological drought as a control variable, but neither is a direct measure of forest resilience. As such, forest adaptability dynamics of the forest is poorly understood. Our research defines this adaptation capacity of vegetation as a dynamic reserve which rainforest can utilize before a potential shift to an alternate stable state, as the resilience of the rainforest.

Fig. 1: *Stable and unstable states in the rainforest defined based on tree cover and mean annual precipitation. Figure from Hirota et al. (2011).*

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Rootzone storage potential ($S_{r,pot}$):

Here, we introduce the Rootzone Storage Potential as a direct water stress metric to understand adaptive forest resilience behavior, using the cumulative difference between precipitation and potential evaporation. Since the potential evaporation calculation is purely radiation-based, it includes the local ecosystem response, unlike MAP which is mostly climate driven. $S_{r,pot}$ is the potential of vegetation to optimize their resources enduring the greatest dry period.

Objectives:

- ❖ Can regime shift in the South American rainforest can be explained using rootzone storage potential ($S_{r,pot}$)?
- ❖ How is this different from previously reported resilience estimates?

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Data and methods:

Rootzone storage potential ($S_{r,pot}$) is calculated using:

$$D_t = PET_t - P_t$$

$$D_{a,t+1} = \max\left\{0, D_t + D_{t+1}\right\}$$

$$D_{a,y} = \max\left\{D_{a,t}, t = 1:n\right\}$$

$$S_{r,pot} = median\left(D_{a,y}\right)$$

Where PET_t is potential evaporation, and P_t is precipitation at time ‘*t*’.

Potential evaporation calculated using Priestley Taylor (PT) equation (Priestley et al. 1972)

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Data and methods:

Dataset used :

- Era5 Temperature (daily) [All Era5 products are between (1981-2016)]
- Era5 longwave net radiation (daily)
- Era5 shortwave downward radiation (daily)
- Era5 pressure (daily)
- Era5 Forecast albedo (daily)
- CHIRPS precipitation (daily) (1981-2016)
- MOD44B continuous tree cover (annual) (2001-2016)
- IGBP Landcover (2000) (excluded landcover 11,13,15,17)
- Crop and Pasture data (Foley et al. 2005) (excluded pixels with >30% cropland or pasture)

Resilience is calculated using logistic regression with $S_{r,pot}$ substituting for MAP (mean annual precipitation) (Hirota et al. 2011).

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Results:

a

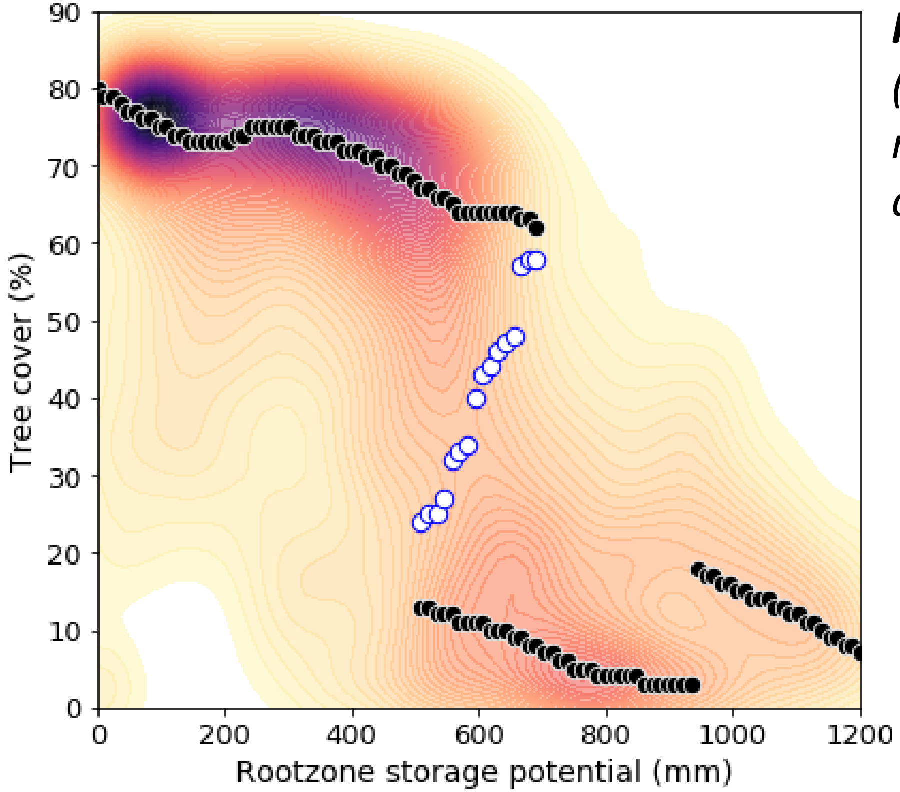
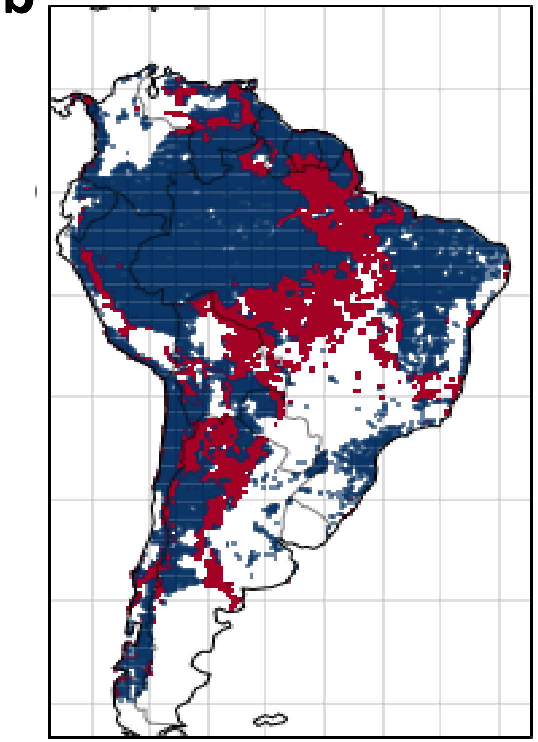


Fig. 2: *(a) Bifurcation plot between $S_{r,pot}$ and tree cover (%). Black dots represent stable state and white dots represent unstable state. (b) Region of stability (blue) and regions of bistability (red) for South America.*

b



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Results:

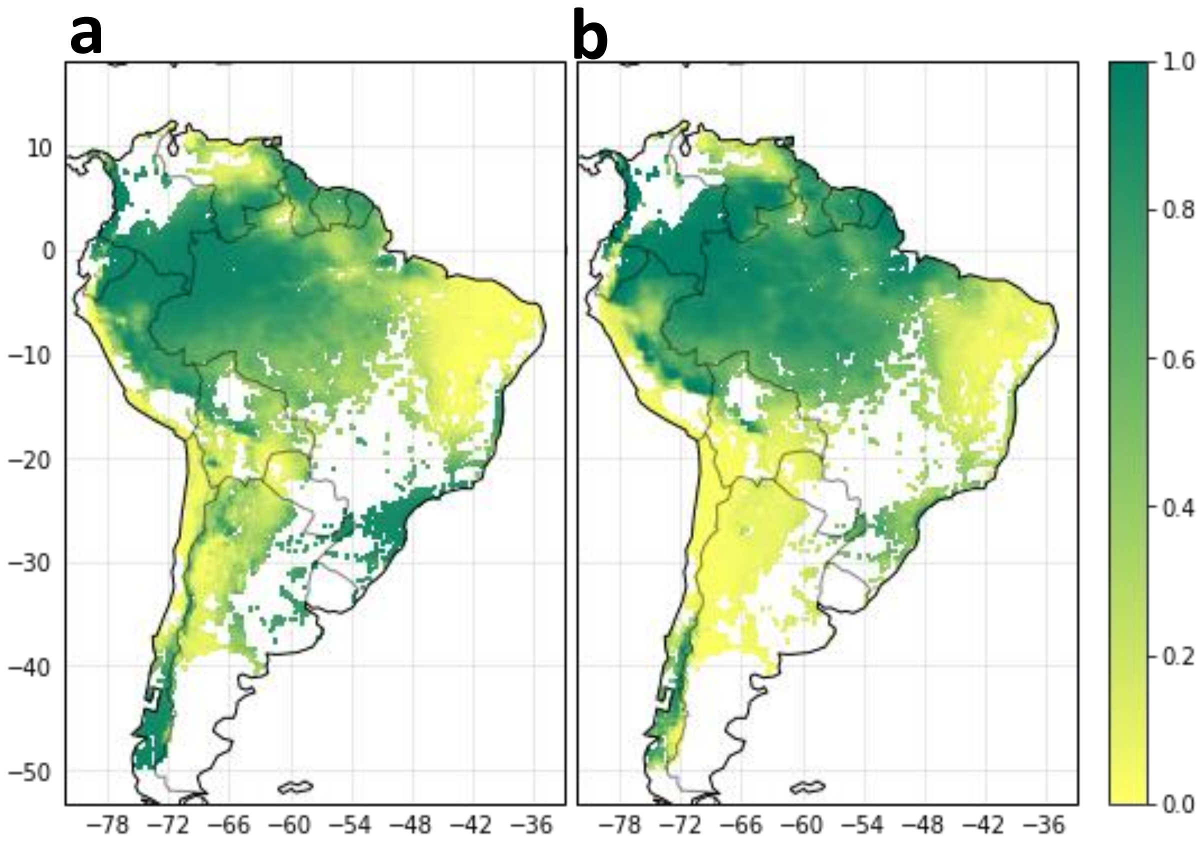

Fig. 3: *Resilience of forest (>50%) based on (a)* $S_{r,pot}$ *and (b) MAP using logistic regression.*

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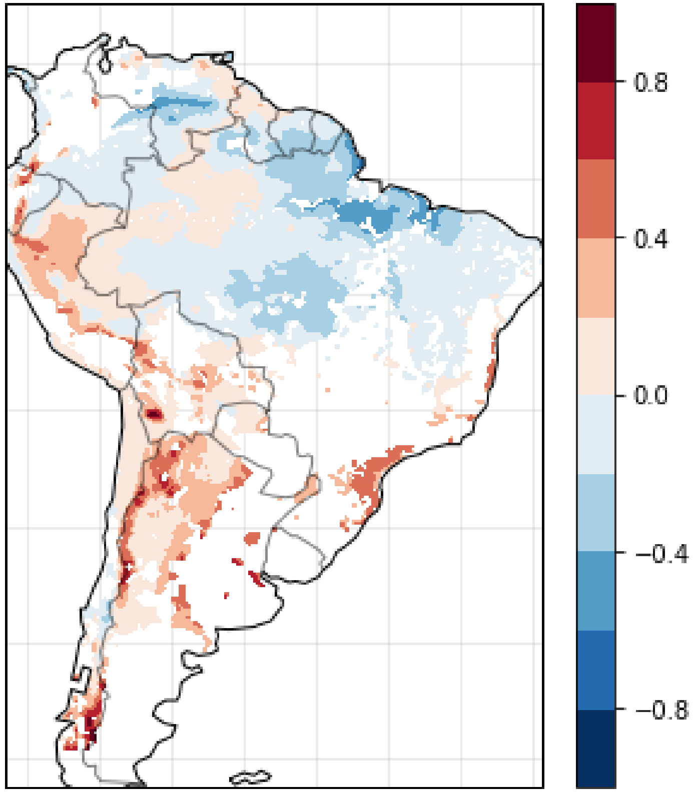

Fig. 3: *Difference in resilience between $S_{r,pot}$ and MAP derived resilience estimates. It can be observed that MAP overestimates (blue shade) the resilience of the rainforest in eastern Brazil and regions near the northern part of Brazil.*

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