Leaf age controls photosynthetic efficiency and energy partitioning in Amazonian trees

Izabela Aleixo, Leonardo Ziccardi, Sabrina Garcia, Amanda Damasceno, Bruna Lima, José Carlos Soares, Bruno Takeshi, Tomas Ferreira Domingues, David Lapola, Carlos Alberto Nobre Quesada, Bruce Nelson and AmazonFACE team*

Izabela.faleixo@gmail.com

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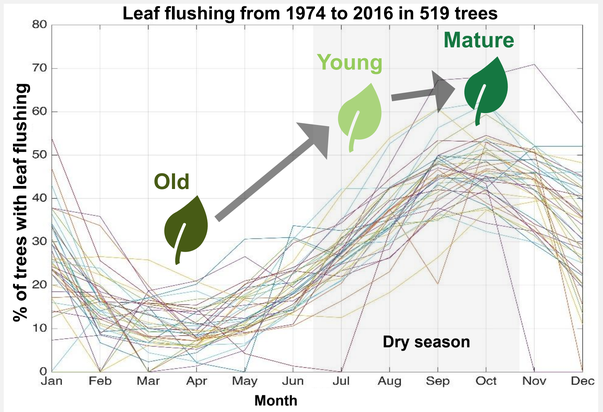
1. BACKGROUND

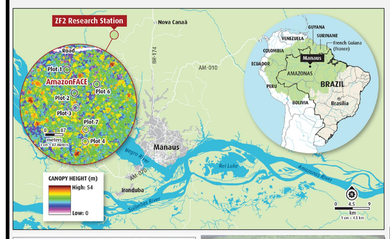
Dry-season leaf flushing shifts canopy composition toward younger and maturing leaves and increases ecosystem gross primary productivity (GPP)[1]. Yet, leaf age effects remain poorly understood and are poorly represented in Earth System Models.



Hypothesis: Leaf age regulates the partitioning of absorbed light energy and photosynthetic efficiency

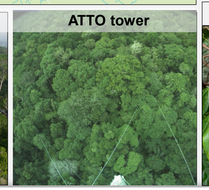
2. METHODS

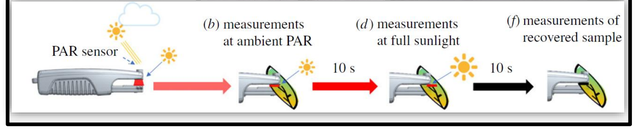
Central Amazon rainforest



→ 1,390 leaves aged from 30 to 1,789 (±30) days were sampled along a vertical profile.

→ Energy partitioning metrics[2] were collected during dry seasons (2023–2024).

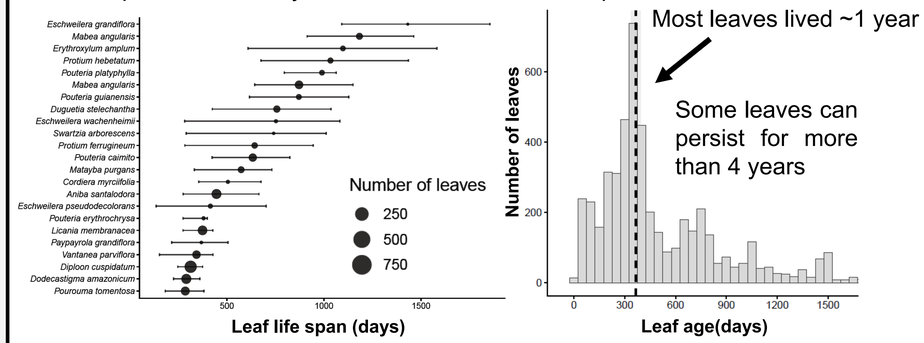




3. RESULTS

3.1 Leaf demography - more than 4,000 leaves with birth and fall day

Leaf lifespan varies widely across 23 Amazonian tree species

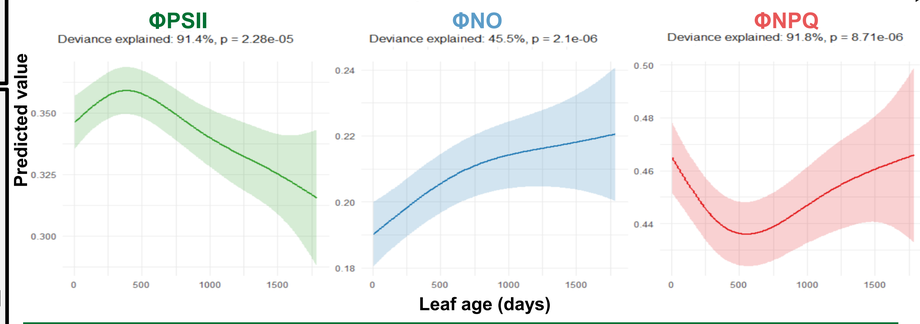


Leaf lifespan variability and dry-season leaf flushing define canopy age structure and drive age-dependent photosynthetic responses

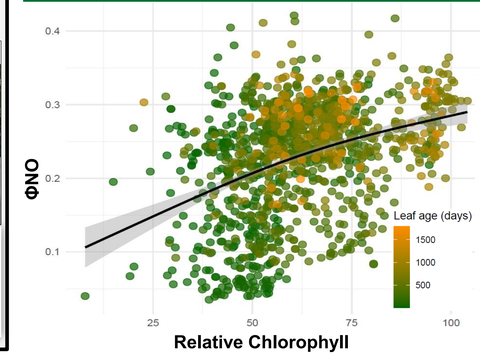
3.2 Age-dependent trajectories of energy partitioning (GAM model)

$$Y_o = \beta_o + \beta_1\,(PAR,\ k = 5) + \beta_2\,(VPD,\ k = 5) + \beta_3\,(Age_{days},\ k = 5) + \varepsilon$$

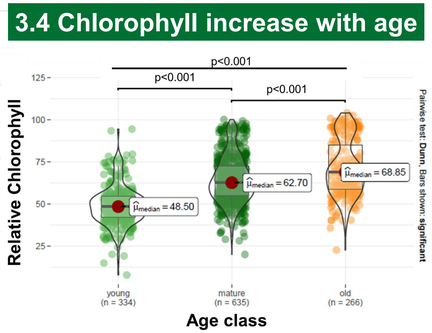
Where: Y_o = ΦPSII, ΦNO and ΦNPQ



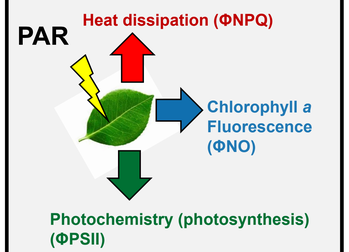
3.3 ΦNO increases with relative chlorophyll and leaf age



3.4 Chlorophyll increase with age



Light energy (PAR) is partitioned into photochemistry, regulated heat dissipation, non-regulated fluorescence, revealing how plants balance light-use efficiency and energy dissipation.



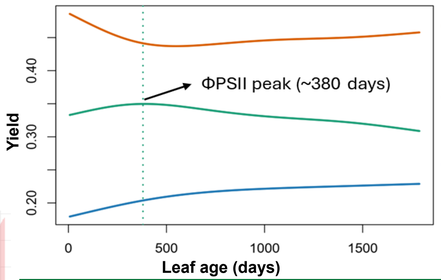
4. INTERPRETATION

Leaf age drives a biochemical shift in energy partitioning between photosynthesis and dissipation

Mature leaves are more light-use efficient (ΦPSII), whereas older leaves rely more on regulated heat dissipation (ΦNPQ) and non-regulated losses (ΦNO)

Chlorophyll content increases with leaf age, reflecting changes in leaf structure and function.

These coordinated shifts highlight leaf age as a key regulator of canopy photosynthesis and energy balance in tropical forests.

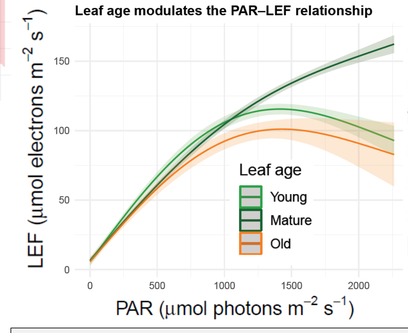


ΦNPQ (regulated dissipation)
Decreased early but increases again in older leaves

ΦPSII (photochemistry)
Increased early, peaks at ~380 days, then declines

ΦNO (non-regulated losses)
Increases steadily with age

3.5 Linear Electron Flow (Photochemistry x PAR)



→ Mature leaves maximize electron transport; younger and old leaves saturate earlier and decline under **high light**.

5. IMPLICATIONS

Leaf age helps interpret SIF–GPP signals and provides a mechanistic basis to improve predictions of tropical forest productivity under current and future climates.

References: [1]Wu, et al. (2016). *Science;* [2]Kanazawa et al. (2021) R. Soc. Open Sci.

Leaf age reveals how Amazon forests partition light energy between photosynthesis and dissipation

***AmazonFACE team:** Nathielly Martins, Laynara Lugli, Lucia Fuchslueger, Anja Rammig, Richard Norby, Iokanam Pereira, Yago Santos, Crisvaldo Souza, Katrin Fleischer, Gustavo Spanner

AmazonFACE Science Plan

Fenologia: Árvores da Amazônia (PT)

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