Are Neotropical rainforest canopy tree species at risk of hydraulic failure during normal and severe dry seasons?

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Background

Xylem vulnerability to embolism, which is associated to survival under extreme drought conditions[1], is being increasingly studied in the tropics. However, an assessment of the risk of hydraulic failure, considered globally as a major mechanisms of tree mortality[2], is lacking for lowland Neotropical rainforest canopy-tree species.

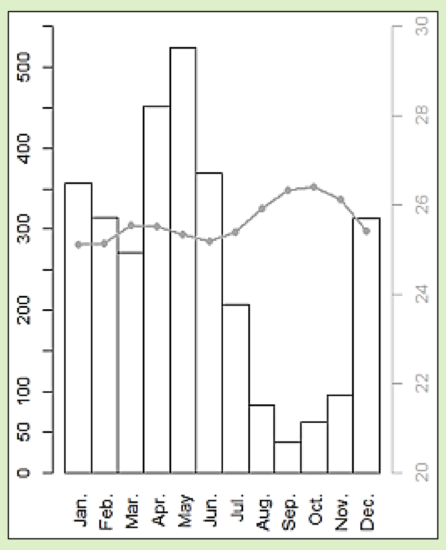
Research questions

- What is the range of variation in branch xylem vulnerability to embolism in abundant, co-occurring lowland tropical rainforest canopy-tree species?
- Are these species at risk of branch hydraulic failure during normal and severe dry seasons?

Materials & Methods

Study site:
- Paracou, a lowland tropical rainforest in French Guiana.

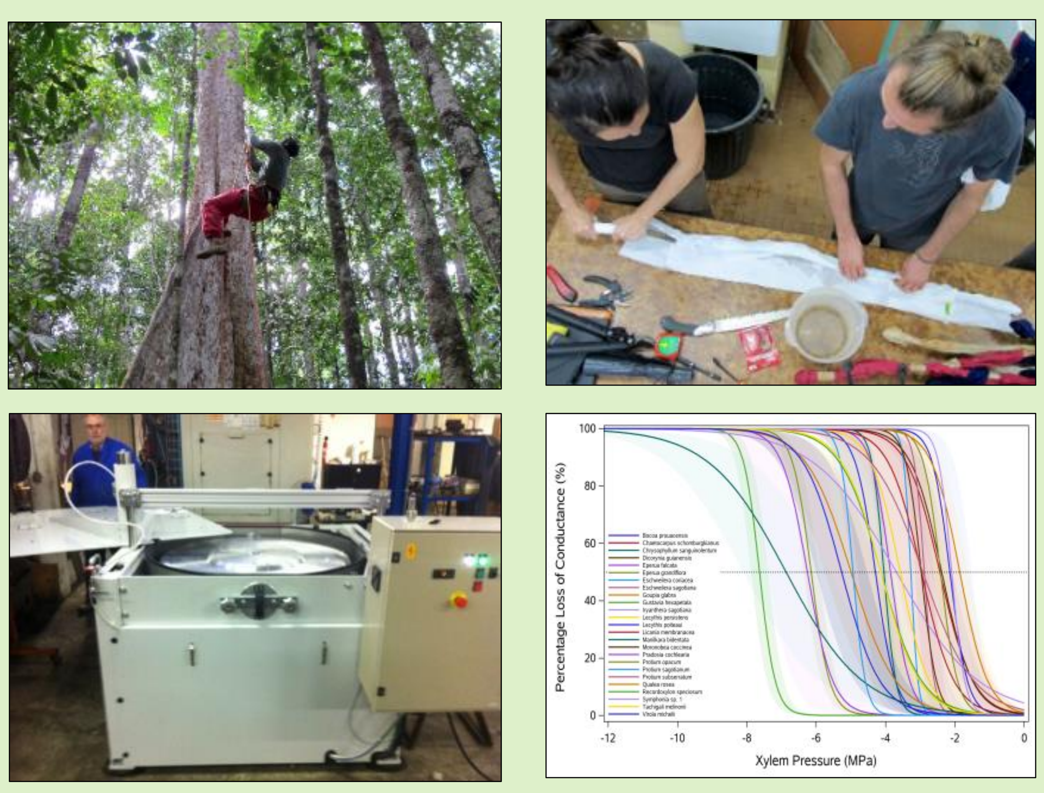
Species and samplings:
- 25 canopy tree species
- 2m-long sun-exposed branches and leaves



Ombrothermic diagram of Paracou from 2001 to 2014 (precipitation in m, left; temperature in C, right).

Hydraulic traits measurements :

- **Ψ_{50} (MPa):** Branch xylem vulnerability to embolism (flow centrifugation, Cavi1000).
- **Ψ_{md} (MPa):** Minimum midday leaf water potential during a normal (2018) and severe (2008) dry season (pressure chamber, Model 1505D PMS).
- **π_{tlp} (Mpa):** Leaf turgor loss point (osmometer, VAPRO 5520).
- **HSM (Mpa):** Hydraulic Safety Margin, the difference between Ψ_{50} and Ψ_{md}.



Climber on his way up to the canopy (top left); preparing branches for shipment (top right); the Cavi1000, a 1-meter wide cavitron (bottom left); vulnerability curves for 25 tree species (bottom right)

Variability in branch xylem vulnerability to embolism

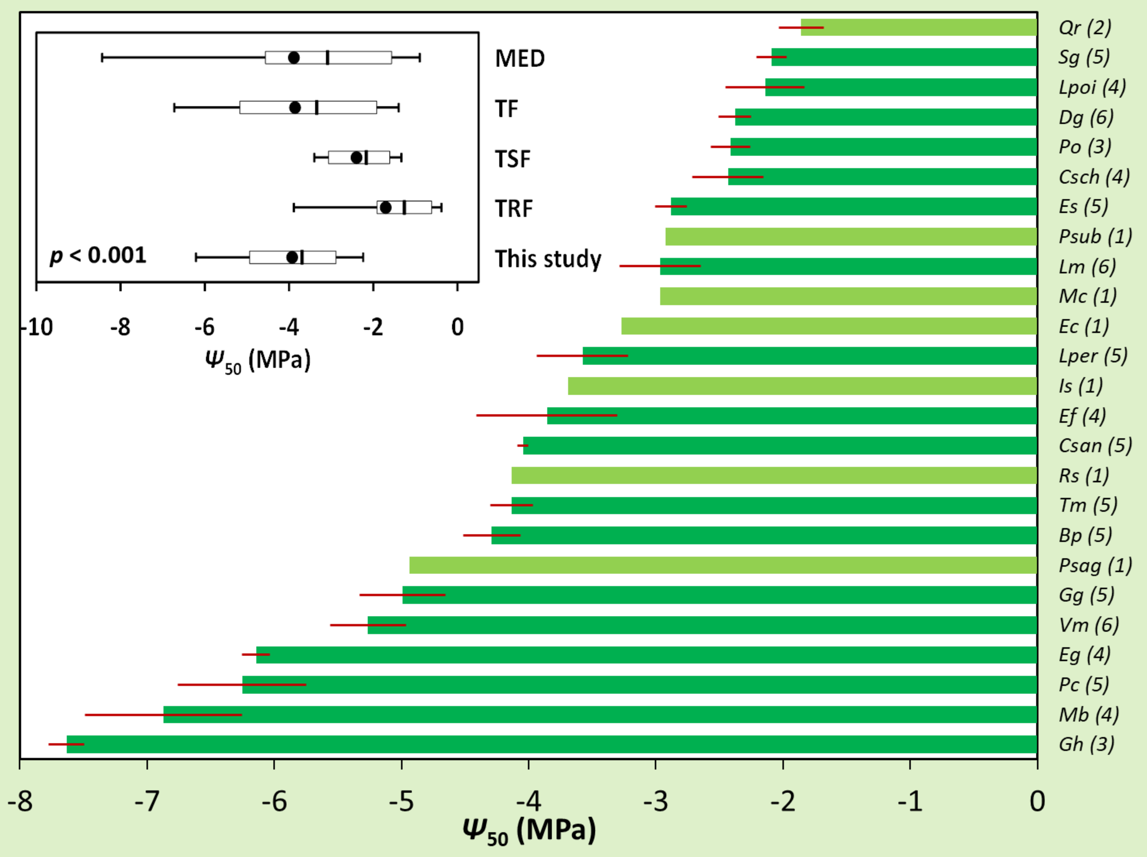


Figure 1. Branch xylem vulnerability to embolism Y_{50} (MPa). Means ± SE for 25 canopy-tree species from French Guiana (green, n ≥ 3; light green n < 3). Insert : Means Y_{50} for adult tree species from MED: Mediterranean forests/Woodlands, TF: Temperate Forest, TSF: Tropical Seasonal Forest, TRF: Tropical Rainforest[3].

- Ψ_{50} varied four-fold among the co-occurring species and reached very negative values (-1.86 to -7.63 MPa).
- Mean Ψ_{50} values in this study were more negative than the global mean for tropical rain- and dry-forests and comparable to drier biomes such as temperate and Mediterranean forests[3].
- **Our results expand the known range of Ψ_{50} for this biome and contrast with global and inter-biome patterns where precipitation is thought to be the main driver.**

Risk of hydraulic failure during normal and severe dry seasons

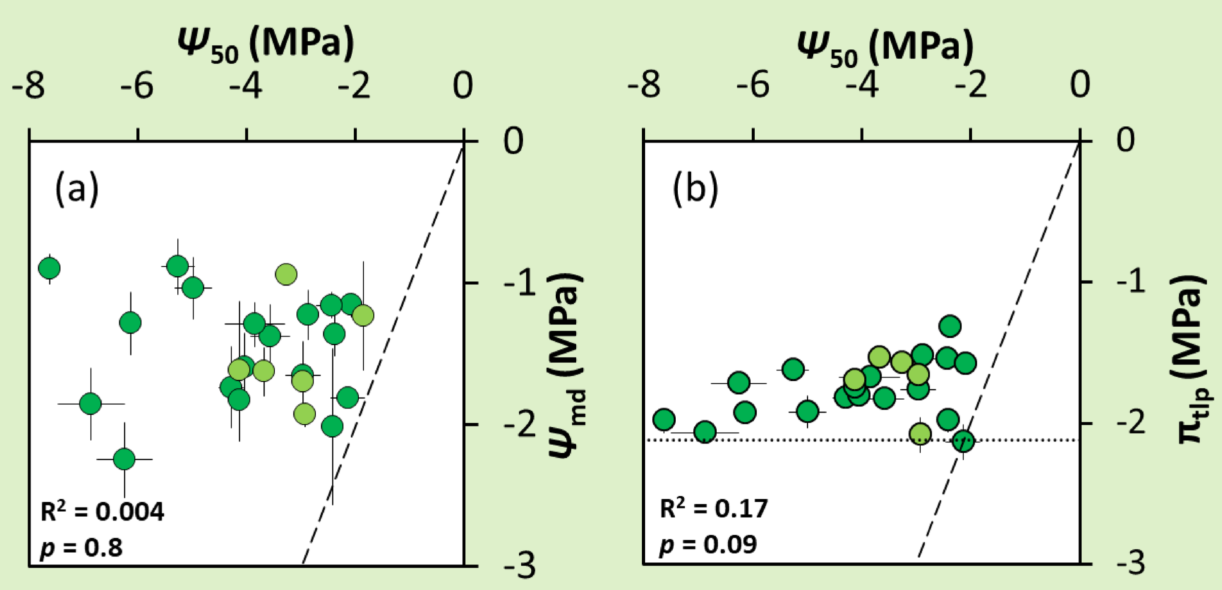


Fig. 2 Relationships between branch xylem vulnerability to embolism and (a) seasonal minimum midday leaf water potential measured during a normal dry season or (b) the water potential at turgor loss point for 25 canopy-tree species sampled in French Guiana (green, n ≥ 3; light green n < 3). The 1:1 line (dashed lines) and the 99% percentile of π_{tlp} (-2.12 Mpa, dotted line) are represented.

- Ψ_{50} was more negative than Ψ_{md} and π_{tlp} with subsequent positive HSM, varying broadly along a continuum.
- There was no relationship between traits and π_{tlp} reached a plateau regardless of Ψ_{50}.
- **Most of the studied species operate without developing any branch xylem embolism during normal dry season conditions. Stomata closed before an absolute water potential threshold allowing increasing hydraulic safety with decreasing Ψ_{50}.**

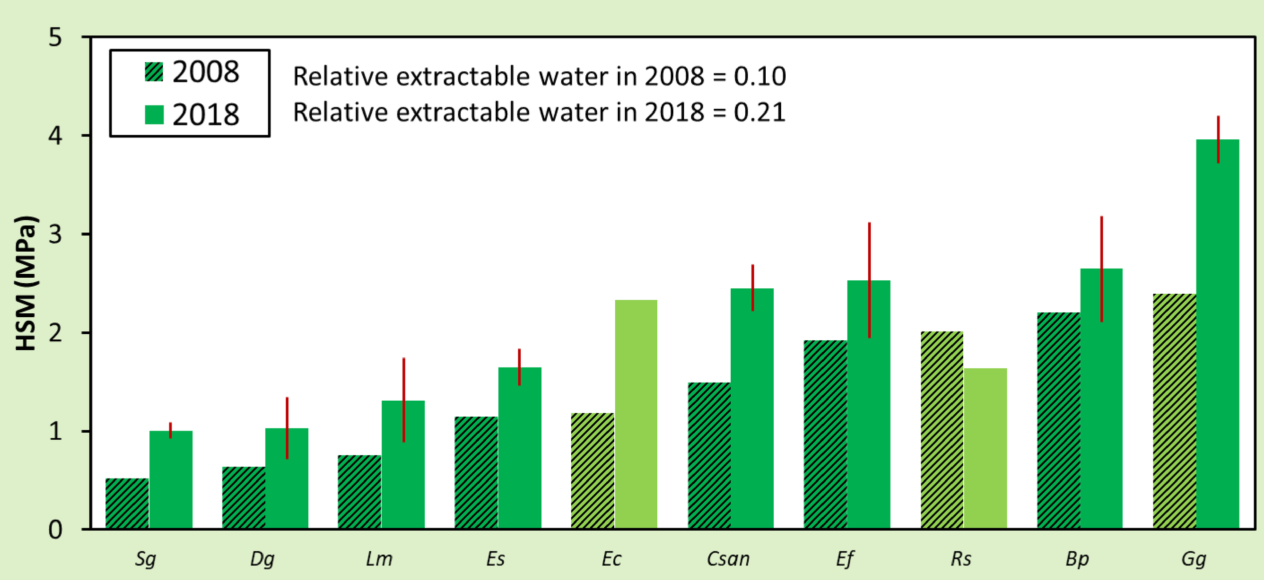


Fig. 3 Xylem hydraulic safety margin during a normal (2018) and a severe (2008) dry season. Means ± SE for 10 canopy-tree species sampled in French Guiana and common to both years (green, n ≥ 3; light green n < 3).

- Ψ_{md} was lower during the severe 2008 dry season but HSM remained positive.
- **During the most severe dry season in the past four decades, most of the sudied species operated without developing critical levels of branch xylem embolism. However, a few species had narrow (< 1MPa) HSM.**

Conclusions

- Variation of branch xylem vulnerability to embolism is not linked to leaf tolerance to turgor loss.
- Low risk of hydraulic failure is attained thanks to low vulnerabilty of branch xylem to embolism and early leaf turgor loss.
- Hydraulic failure in Neotropical canopy-tree species could only occur under extreme water deficit associated with exceptionally severe drought events.

References

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Acknowledgments

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