**Title:** Vulnerability of tree growth to precipitation in Thailand

**Authors**

# Abstract

# Introduction

Tree woody growth key is a key component of aboveground productivity and affects the global carbon carbon cycle, but the drivers of its variation are poorly understood. - Woody growth contributes x% of the aboveground woody productivity - Long-lasting effects on the terrestrial carbon pool - Intrinsic and extrinsic factors affecting variation.

* Large trees tend to undergo greater growth declines during drought compared to smaller trees (e.g., **bennett\_larger\_2015?**; **mcgregor\_tree\_2021?**; **anderson-teixeira\_joint\_2022?**).
* It remains poorly understood the extent to which this is shaped by tree size itself, crown exposure, water access, and traits that tend to covary with size (e.g., decidiousness) – all of which interact to shape drought resistance
* There is theory and evidence that tree size itself matters.
* Theoretically, we expect that greater height makes trees more vulnerable to drought based on the physics of hydraulic flow through a porous medium, as described by Darcy’s law (**mcdowell\_darcy\_2015?**; **fernández-de-uña\_role\_inpress?**).
* Height… (see refs in **vinod\_thermal\_2023?**; **olson\_plant\_2018?**; **couvreurWaterTransportTall2018?**).
* As tree size increases, leaves exert lower control over hydraulic resistance (**wolfe\_leaves\_2023?**).
* (**chen\_hydraulic\_2022?**)
* There is theory and evidence that crown exposure matters (**vinod\_thermal\_2023?**; **refs\_in\_?** vinod\_thermal\_2023; **scharnweber\_confessions\_2019?**).
* Microclimate buffering leads to cooler, moister understory air (**vinod\_thermal\_2023?**).
* Soils under closed canopies would also be cooler during hot times of the year (**lembrechts\_global\_2022?**).
* Reduced evaporative demand would also make them moister, and this might be added to by hydraulic redistribution.
* Trees with exposed crowns suffered significant crown dieback at greater rates in the 2012-16 CA drought (**ma\_tree\_2023?**).
* Water access….
* Larger trees have larger root systems, but do not necessarily access deeper water (**ref\_from\_Panama?**)
* Even when trees are accessing deeper water, this does not mean that they’re in better shape during drought. Rather, trees that rely on regular access to deep water may be more vulnerable during severe droughts when those sources are depleted (**rutuja?**)
* indeed, there is evidence that trees near streams undergo greater growth declines (**mcgregor\_tree\_2021?**) and increases in mortality (**zuleta?**) during drought
* rather than necessarily helping during drought, water access will shape the size the size and traits of species living in habitat, with stream habitats tending to have larger trees (**ref?**) and more evergreen trees, and also their average growth rate
* Many hydraulic-related traits vary with tree height (**vinod\_thermal\_2023?**), including the frequency of dry season deciduous leaf loss – both within species and at the community level (**condit\_ref?**; **meakem?**).
* (discuss drought strategies - avoidance / adaptation )

-High Crown exposure makes trees more vulnerable to drought, but drought deciduous habit or perennial water access allows them to escape this  
-Disentangling the effects of tree size, crown exposure, water access, and deciduousness on drought sensitivity

Here we use a 14-year record of dendrometer band measurements in seasonally dry forest in Thailand to test the vulnerability of tropical tree growth to drought. We expect variation in the absolute growth during drought years and drought resistance (growth in drought year/growth in a previous year with normal rainfall) across trees. We hypothesise that growth during drought is affected by:

* **habitat** : water availability is a key driver of tropical tree growth (Wagner *et al.*, 2012).
* **leaf habit** : drought resistance is higher in deciduous species because of leaf strategies that minimise water loss during months of high vulnerability. Deciduous and evergreen species have differential sensitivity to drought (De Souza *et al.*, 2020).
* **tree size** : larger trees face higher risk of mortality during drought, as well as greater growth reductions (e.g., **bennett\_larger\_2015?**; **mcgregor\_tree\_2021?**; **anderson-teixeira\_joint\_2022?**).
* **exposure** : trees with higher exposure because of their canopy position have lower drought resistance than trees with lower exposure due to the direct effects of temperature and vapour pressure deficit.
* **competition** : trees in denser stands have lower drought resistance than trees in sparser stands because of more intense competition for groundwater. Differences in rooting depths could add complexities to this effect, however, we do not have direct measures that could test this effect.
* **exposure x size** : While larger trees are likely to have uniform high exposure, smaller trees can have high or low canopy position based on stand characteristics (stand density, presence of a canopy gap etc.) Drought resistance of smaller trees with high exposure is expected to be lower than that of trees with low exposure because of the direct influence of temperature and light that could lead to cavitation. (BCI light x size interaction in Rüger *et al.* (2011))
* **leaf habit x exposure** : species canopy strategies along with their leaf habit could exacerbate or counteract drought vulnerability (Rahman *et al.*, 2019). Under high exposure, deciduous species are potentially more drought resistant than evergreen species, while the pattern could be less clear under low exposure.
* **leaf habit x habitat** : tropical evergreen and deciduous species have different habitat preferences (Kunert *et al.*, 2021) that could affect their drought resistance.
* **habitat x exposure** : trees with high exposure in upland habitats are expected to have lowest drought resistance because of the compounding influence of abiotic stressors.

# Methods

ForestGEO data (Anderson-Teixeira *et al.*, 2015)

***Sites and data***

*Huai Kha Khaeng plot* - location - annual precipitation - ecosystem type/association - long-term trends from (**vlam?**) et al etc

*Resistance* -Dendrometer band measurements - census protocol -Calculated DBH at each instance from first DBH and window size using Condit’s functions. -Removed measures with large decimal errors, large outliers (> 3 SD). - For all individuals with three points of measurements for each drought, calculated raw increment as difference between relevant censuses to get pre-drought increment and drought-year increment. - Resistance - difference between pre-drought and drought-year increment

*Tree size* - calculated DBH for at the start of the pre-drought year from dendrometer band window

*Deciduousness* -data from Williams *et al.* (2008). -Leaf phenology score - mean proportion of crown loss. -Continuous scale from 1 to 4, where 4 is maximum crown loss or deciduousness. -One value per species. - 7 species out of the top 51 species in the dendroband census have no values. (currently excluded from analysis but can fill these with best estimates and add them back in)

*Exposure* - crown illumination index for each individual, collected at each dendrometer band census - categorical variable with values 1 to 5 where 1 is least exposed and 5 is most exposed

*Topographic Wetness Index* - calculated from topography - estimate of water availability at a location

***Models***

For individual stems, we modelled drought resistance as:

# Results

# Discussion

# References

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