Optimality Theory informed Carbon Storage Allocation under Drought

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Plant carbon **storage is crucial during drought**: it provides energy and material during stress and recovery.

The **opportunity cost of storage** can be substantial: if carbon is stored rather than allocated to increasing structural or productive biomass, the opportunity to increase light capture and photosynthetic capacity is missed.

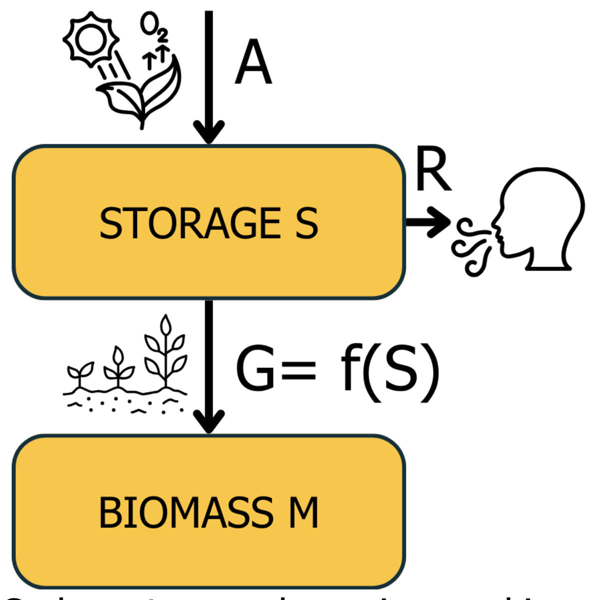
This leads to a **Growth-Storage Trade-off.**

Modeling carbon storage can be challenging: (1) storage compounds are highly mobile; (2) dynamics change with plant species, stress duration, stress intensity, plant age, local adaptation; (3) measurements are time consuming and sensitive.

Optimality theory can inform understanding of **storage dynamics and the growth-storage trade-off** as a strategy that evolved to avoid carbon depletion[1].

We use several modeling approaches to get insights into testable carbon storage dynamics during drought.

The analysis go from **(1) individual** to **(2) demographically assembled community** to **(3) evolutionarily assembled community.**



Carbon storage dynamics used in our models.

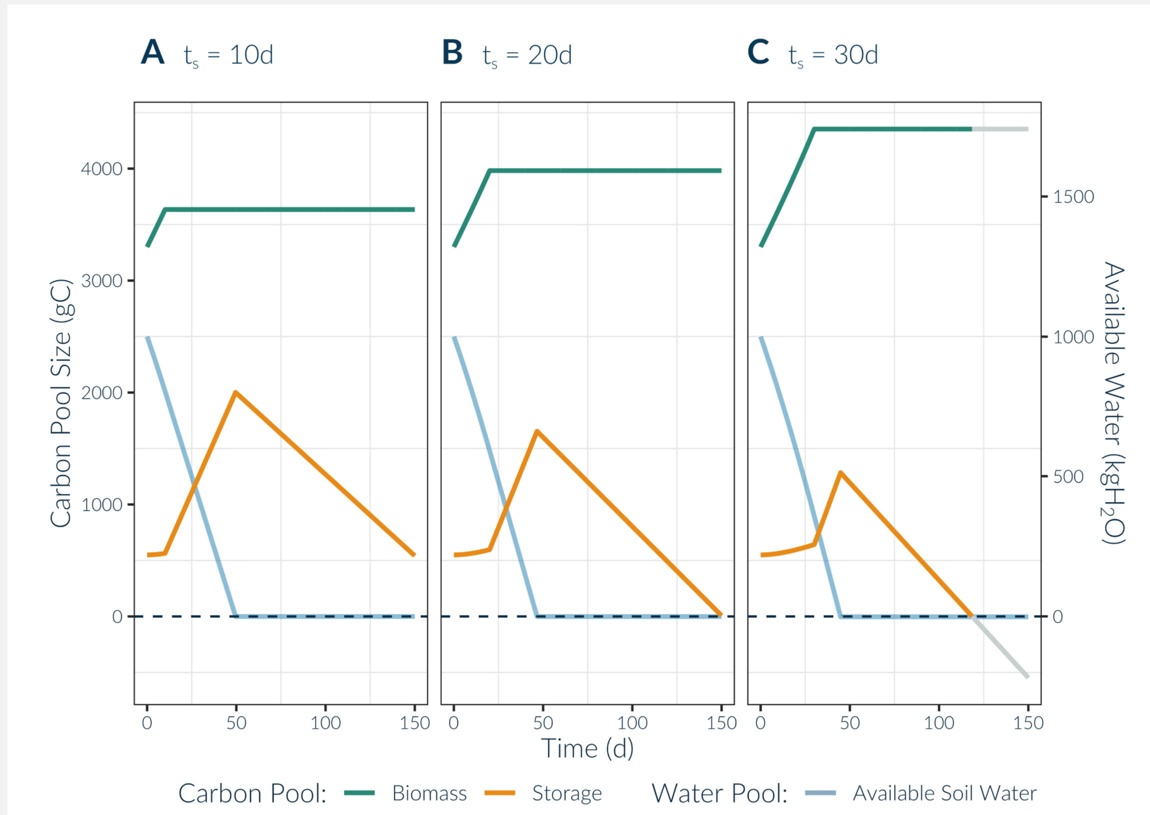
1. Explore Optimal Storage Dynamics

We created a simple **Toy Model** of an individual plant subjected to a drought.

We found the **optimal carbon storage use trajectory** by solving the model using optimal control theory.

Optimal solution is characterized by a **three-phased growth pattern**: (1) growing, (2) storage and (3) stress.

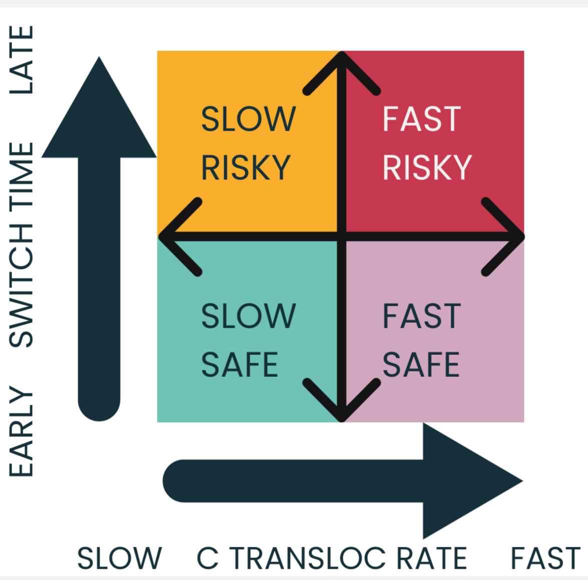
Crucially, the **switch time** between **growth** and **storage** allocation **can be used as a proxy for the storage strategy.**



At switch time ts=20d (middle) the plant maximises its overall biomass growth. This strategy leads to a total depletion of storage at the end of the drought period.

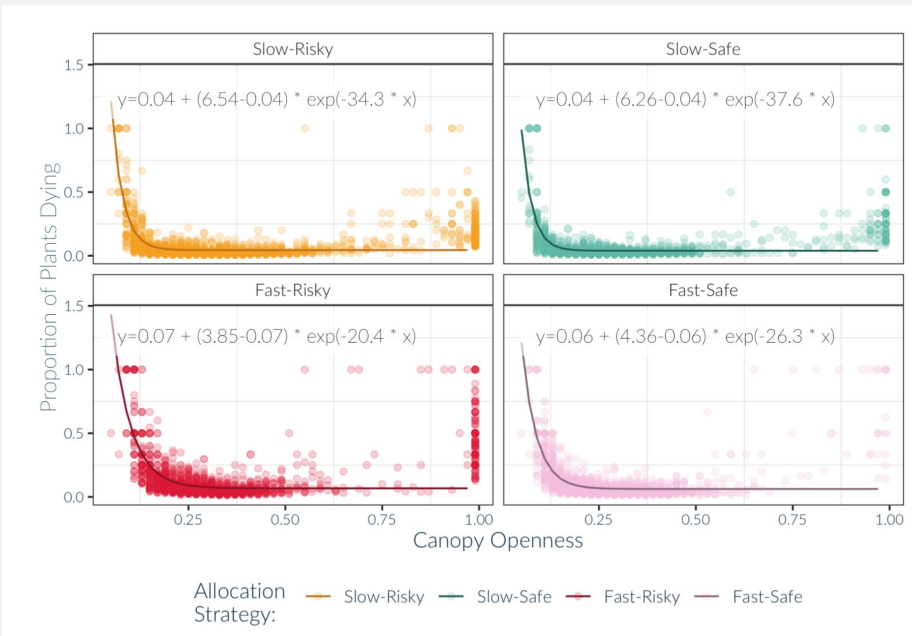
2. Simulate C Storage Trait-Space

Informed by the toy model results we defined **4 carbon storage strategies**:



We modeled a population of trees competing for light using a **gap model** and different stress scenarios (changing in stress intensity and disturbance stochasticity) for 100 years.

Can we use shade-tolerance traits and phenology to inform species' strategies?



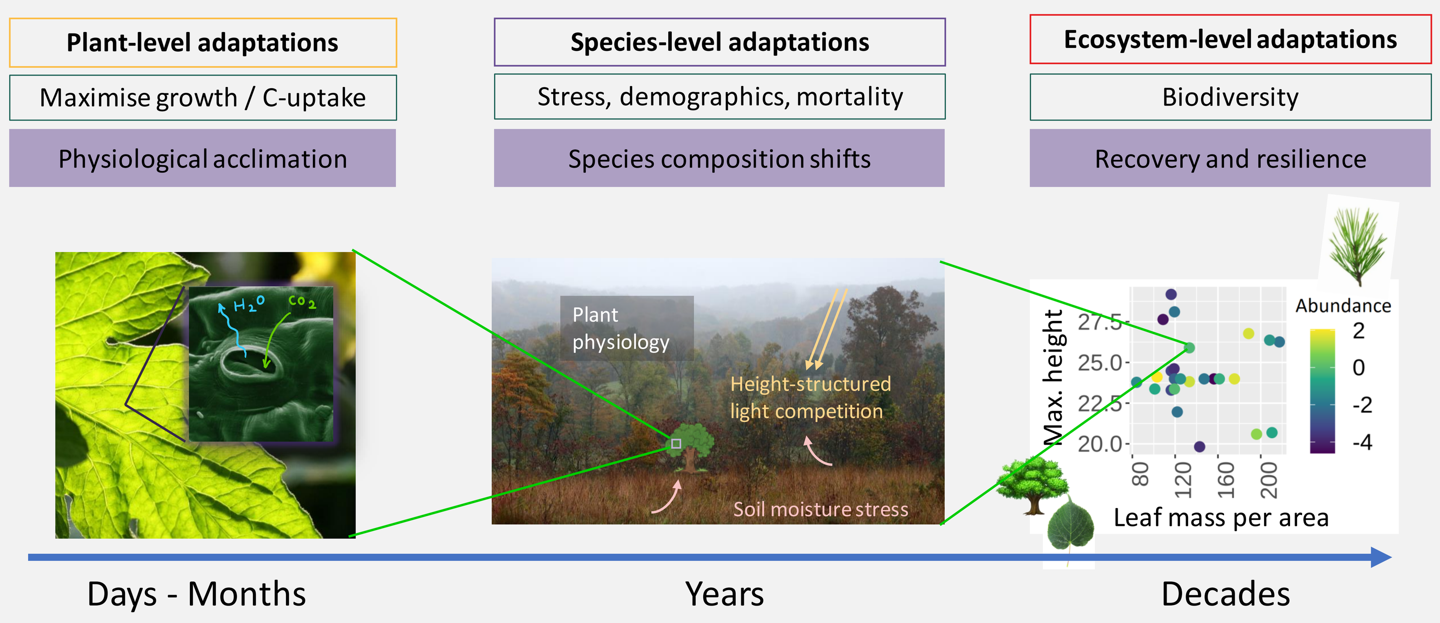
We found that **mortality** under shade and stress was most responsible for species dominance. **Rate of C translocation** was related to shade-tolerance and **length of growing season** was associated with stress-tolerance.

3. Investigate Eco-Evolutionary Outcomes

We will use results from optimality theory and the gap model to explore carbon storage and trait evolution with the **trait-based eco-evolutionary model Plant-FATE**.

Plant-FATE has 5 key features:
1. Plant physiology acclimation
2. Vegetation demographics
3. Functional diversity
4. Light competition
5. **Community trait-evolution**

With the 4 carbon strategies implemented, **storage traits will be allowed to evolve** under different climate and drought scenario simulations.



PREPRINT

[1]Wiley, E. and Helliker, B. (2012), A re-evaluation of carbon storage in trees lends greater support for carbon limitation to growth. New Phytologist, 195: 285-289. https://doi.org/10.1111/j.1469-8137.2012.04180.x