

# Modelling the trade-off between water usage and photosynthesis in trees

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Background

Trade-off in Water and Photosynthesis



Background

Trade-off in Water and Photosynthesis

# How trees use water



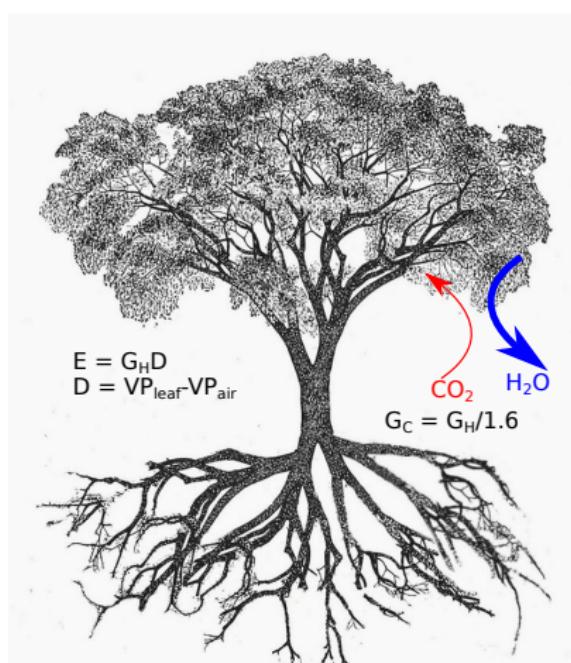
- Is there optimal water usage strategy?
- What is the standard of “optimal”?
- Is maximal profit a good standard?

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## How to optimize water usage?

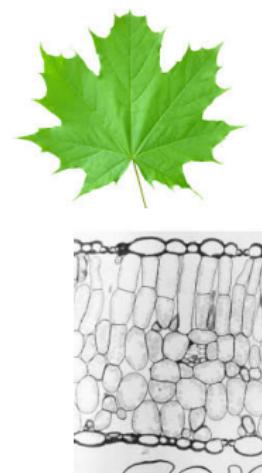
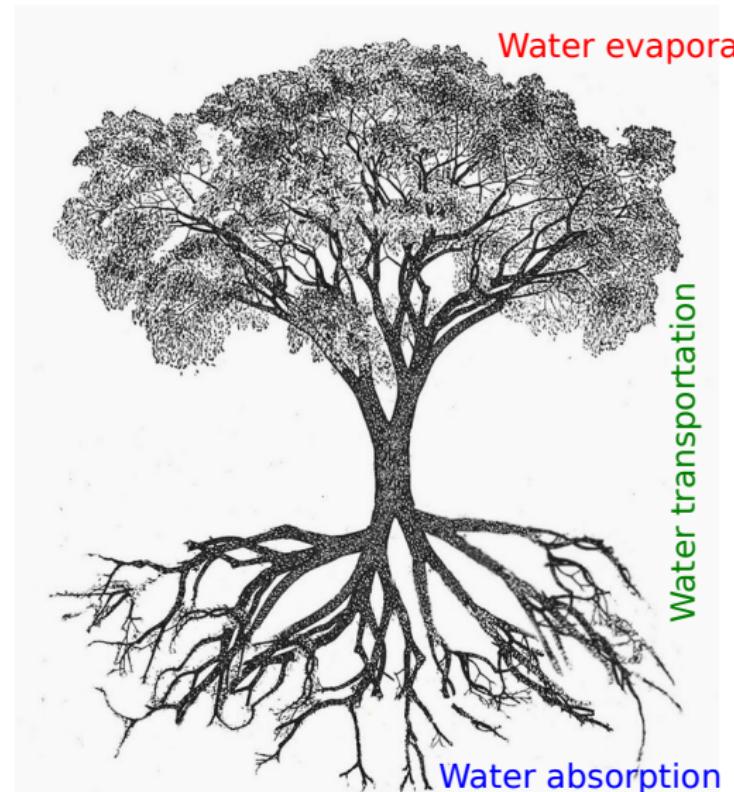
### ■ Why do trees use water?



Background

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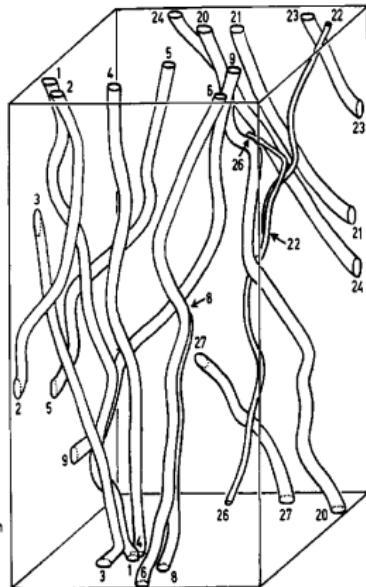
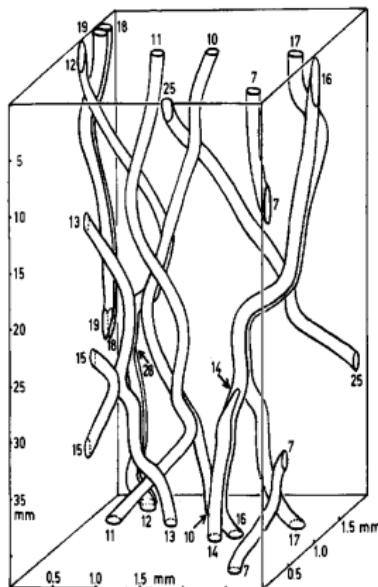
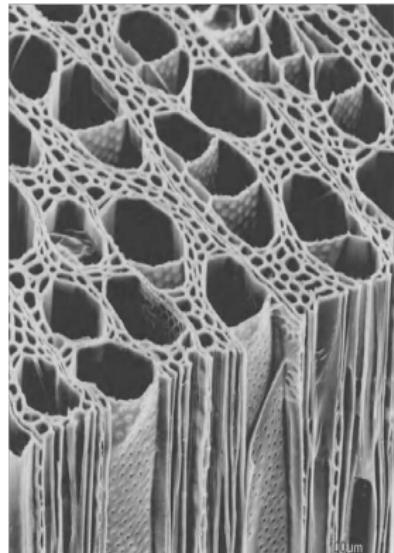
# How trees use water



Background

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# Water transportation — vessel network<sup>1</sup>

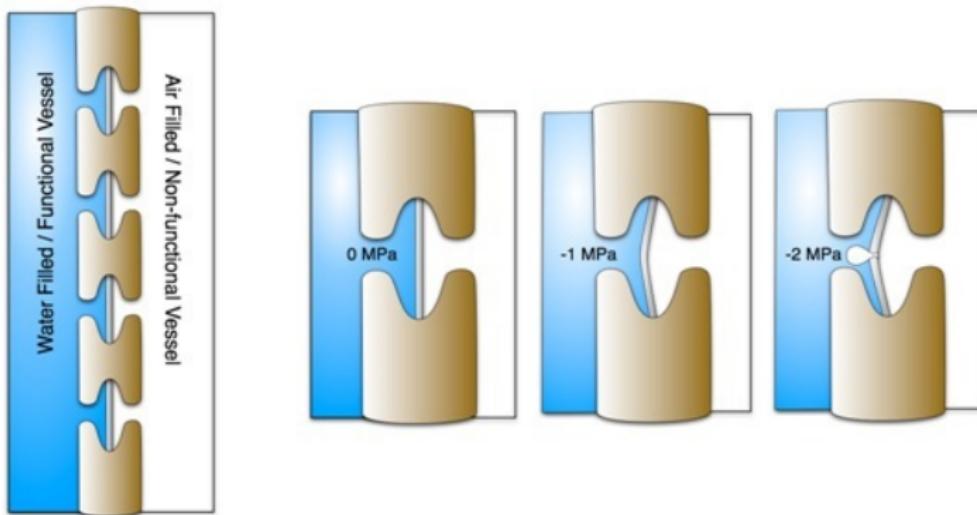


<sup>1</sup>Tyree and Zimmermann, 2002.

Background

Trade-off in Water and Photosynthesis

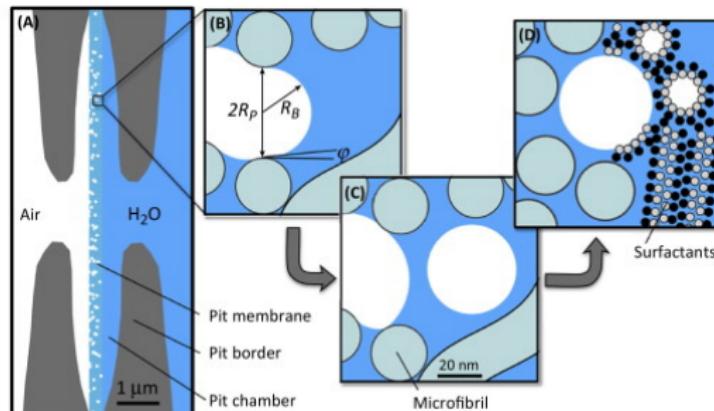
# Air seeding and cavitation



Background

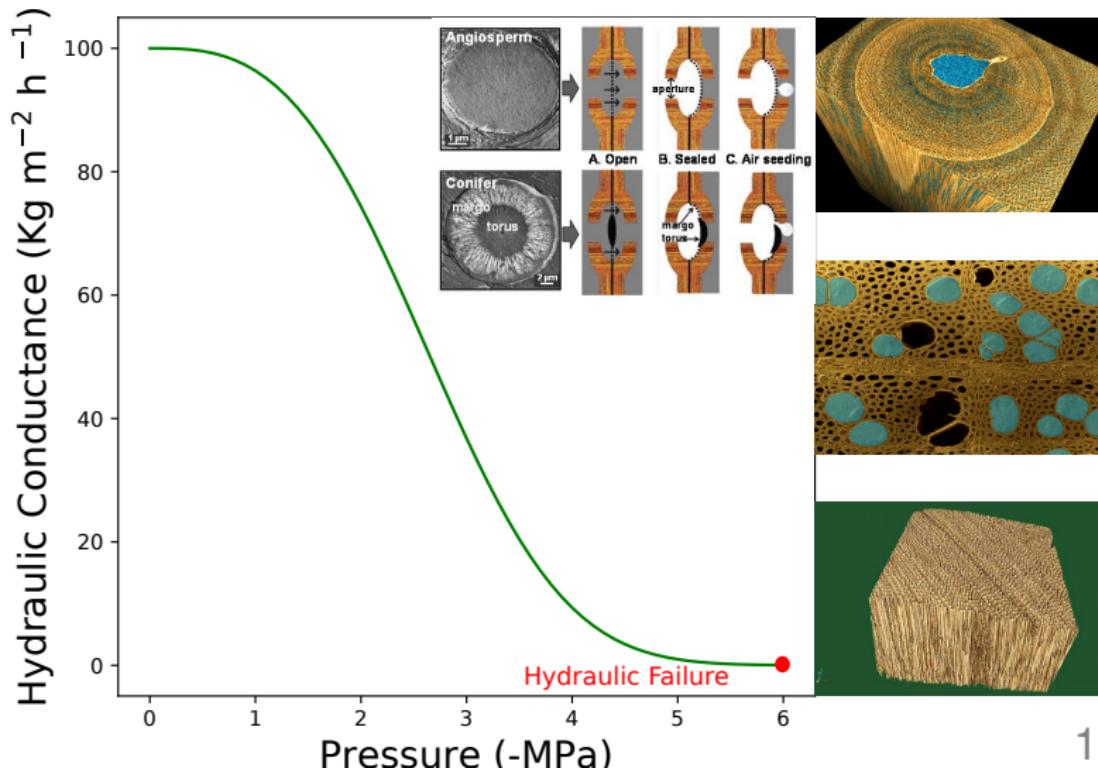
Trade-off in Water and Photosynthesis

# Air seeding and cavitation



TRENDS in Plant Science

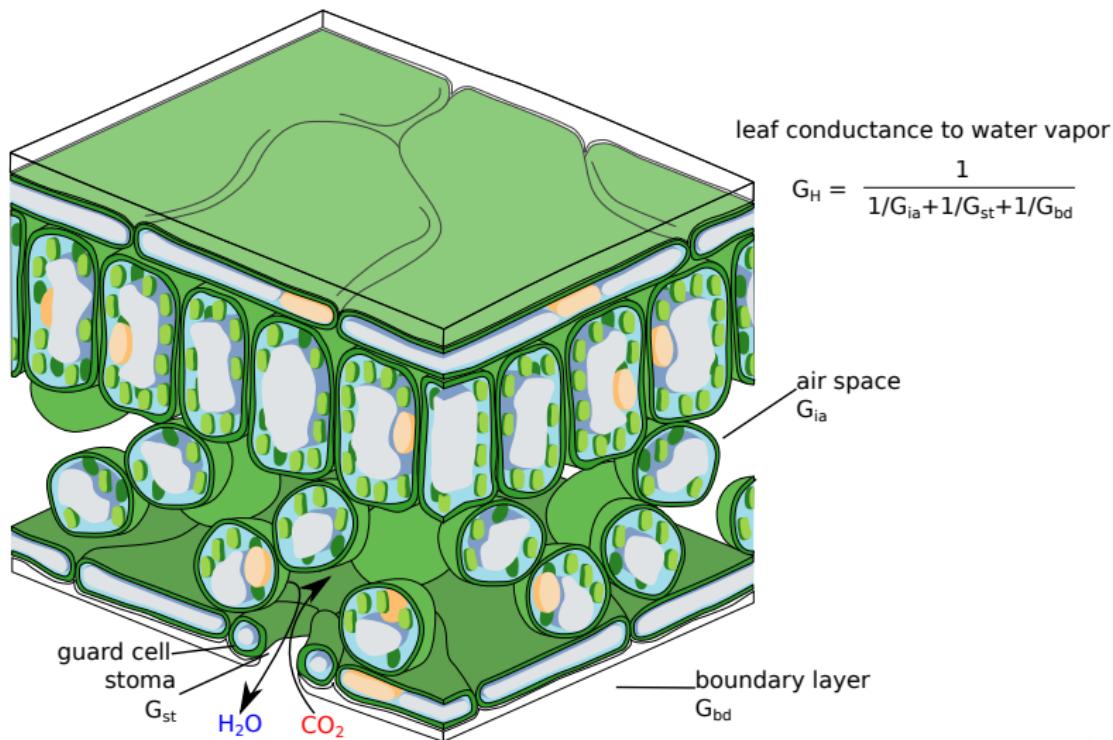
# How trees use water — water transportation



Background

Trade-off in Water and Photosynthesis

# How trees use water — gas exchange



└ Background

  └ Trade-off in Water and Photosynthesis

## How could tree optimize water usage

- Via the root water absorption;
- Via the water transportation pathway;
- Via the gas exchange.

Background

Trade-off in Water and Photosynthesis

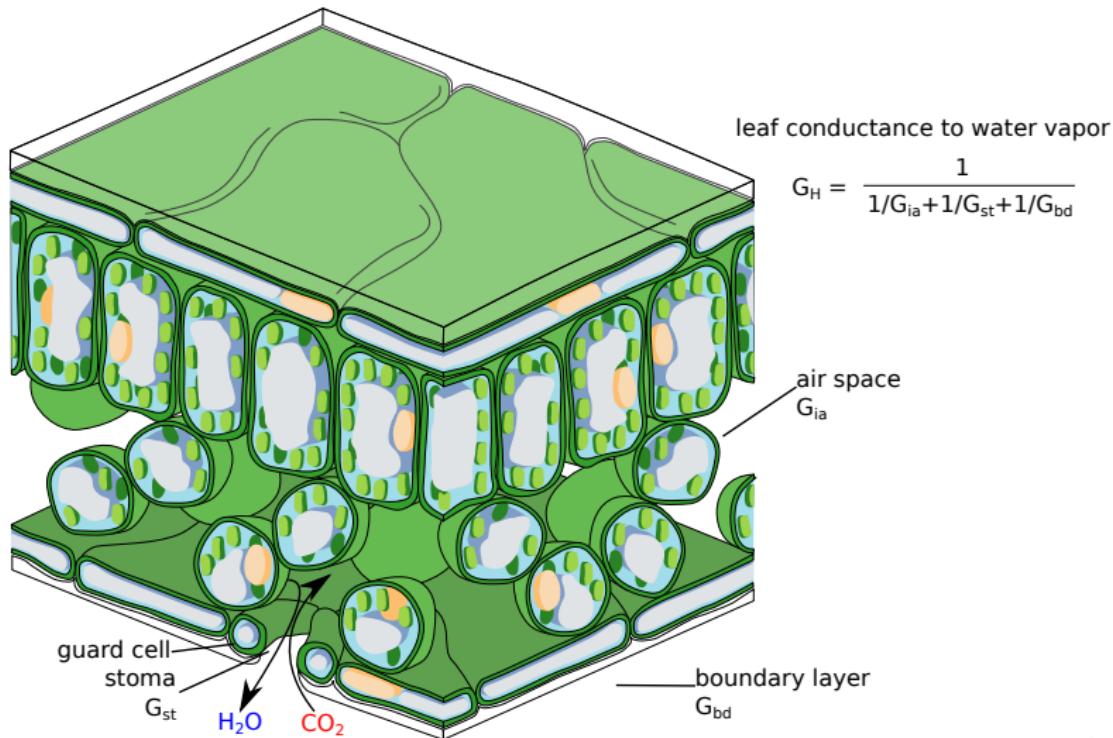
# How trees use water



Background

Trade-off in Water and Photosynthesis

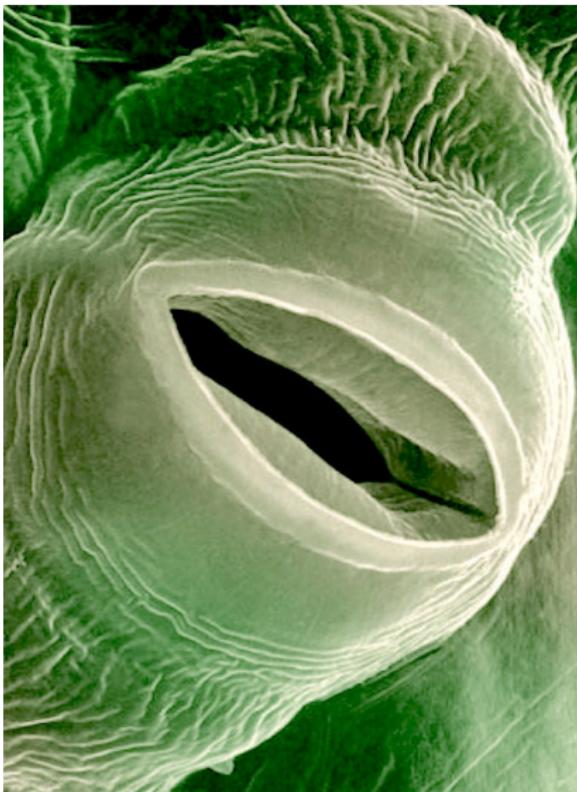
# How trees use water — gas exchange



Background

Stoma and Gas Exchange

## How do stoma regulate the pore size?



### Feedback control

- VPD;
- Soil water potential;

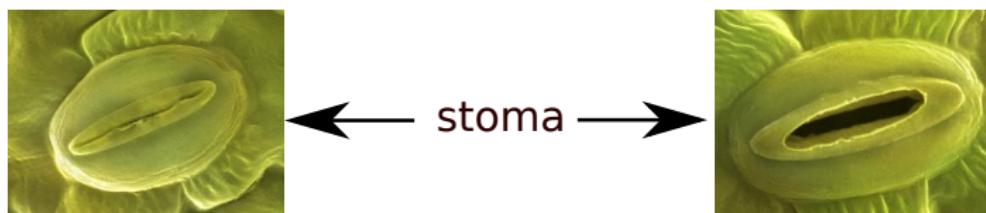
### Active control

- ABA;
- Light.

Background

Stoma and Gas Exchange

## How stoma regulates pore size



Higher [CO<sub>2</sub>]

Lower Humidity

Drier Soil

Save water

Lower [CO<sub>2</sub>]

Higher Humidity

Wetter Soil

Gain carbon

└ Background

└ Stoma and Gas Exchange

## How to model stomatal control?

# Summarize?

# Guess?

└ Background

└ Current Models of Stomata Control

## Empirical Model

Ball, Woodrow and Berry (1987)

$$g_{sw} = k \cdot A \cdot \frac{h_s}{c_s} \quad (1)$$

Ball, Berry and Leuning

$$G_H = G_0 + \frac{a \cdot A}{(C_a - \Gamma)(1 + D_L/D_0)} \quad (2)$$

$G_0$ ,  $a$ , and  $D_0$  are fitted parameters.

# Photosynthesis Optimization Model

Cowan and Farquhar (1977)

$$\frac{\delta E}{\delta A} = \lambda \quad (3)$$

The disadvantage is the definition of  $\lambda$ , and there is no details of what  $\lambda$  should be.

└ Background

└ Hydraulics vs. Photosynthesis Trade-off Model

# We need better models!

Background

Hydraulics vs. Photosynthesis Trade-off Model

# Why do trees regulate stomata?

To reproduce?



To grow?



Profit should be optimized<sup>2</sup>.

└ Background

  └ Hydraulics vs. Photosynthesis Trade-off Model

Gain?

# Photosynthesis

└ Background

└ Hydraulics vs. Photosynthesis Trade-off Model

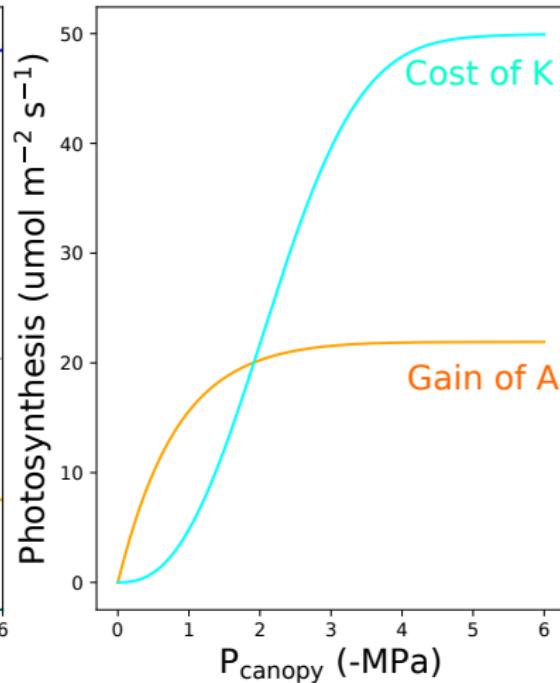
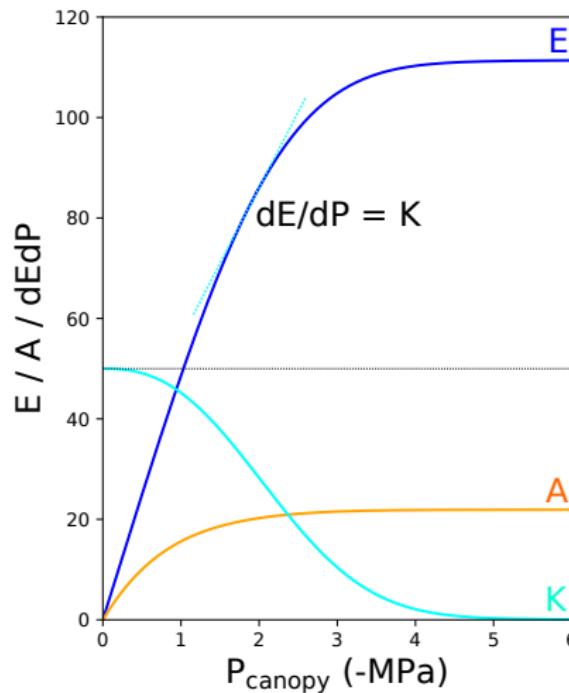
Cost?

Water?  
Hydraulics?  
Future?

Background

Hydraulics vs. Photosynthesis Trade-off Model

## Cost — Hydraulic impairment



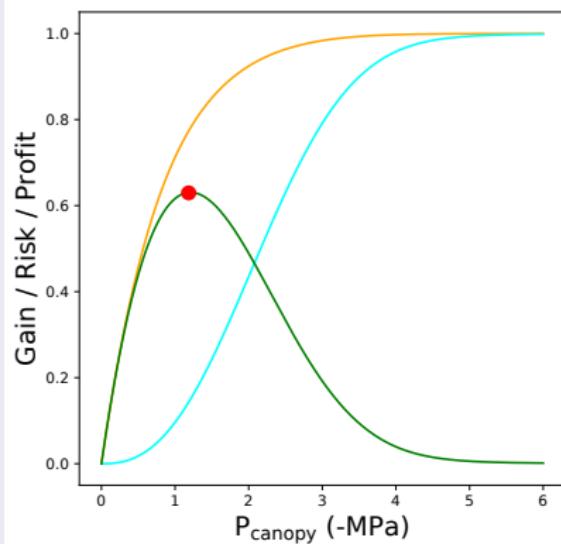
# Relative photosynthesis vs. hydraulics trade-off

Sperry et al. (2016)

$$gain = \frac{A}{A_{max}} \quad (4)$$

$$risk = 1 - \frac{dE/dP}{dE/dP_{max}} \quad (5)$$

$$profit = gain - risk \quad (6)$$

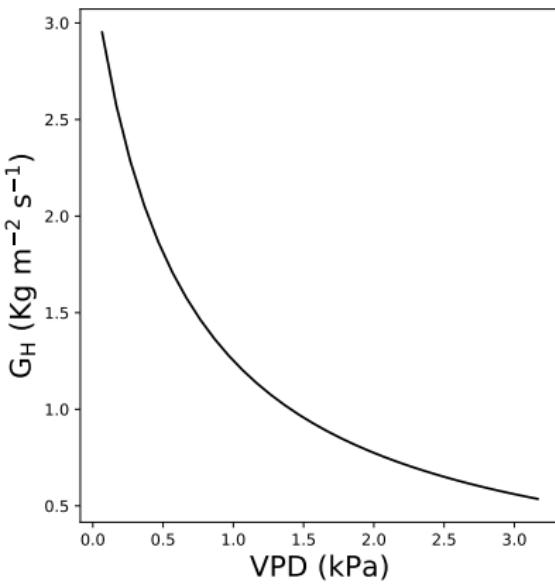
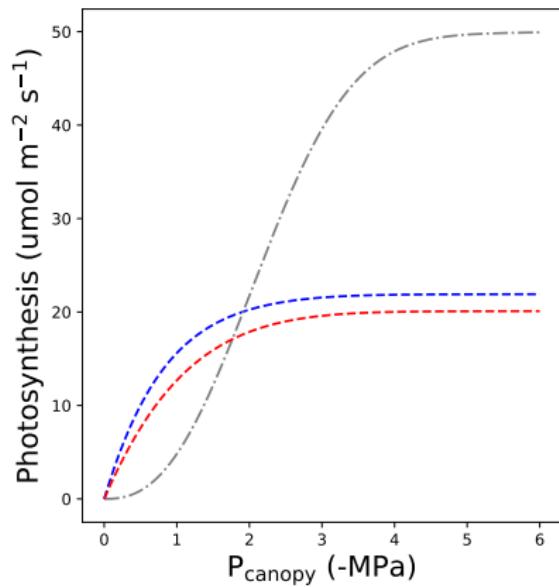


└ Model Simulations

  └ Hydraulics vs. Photosynthesis Trade-off Model

# How does the trade-off model behave?

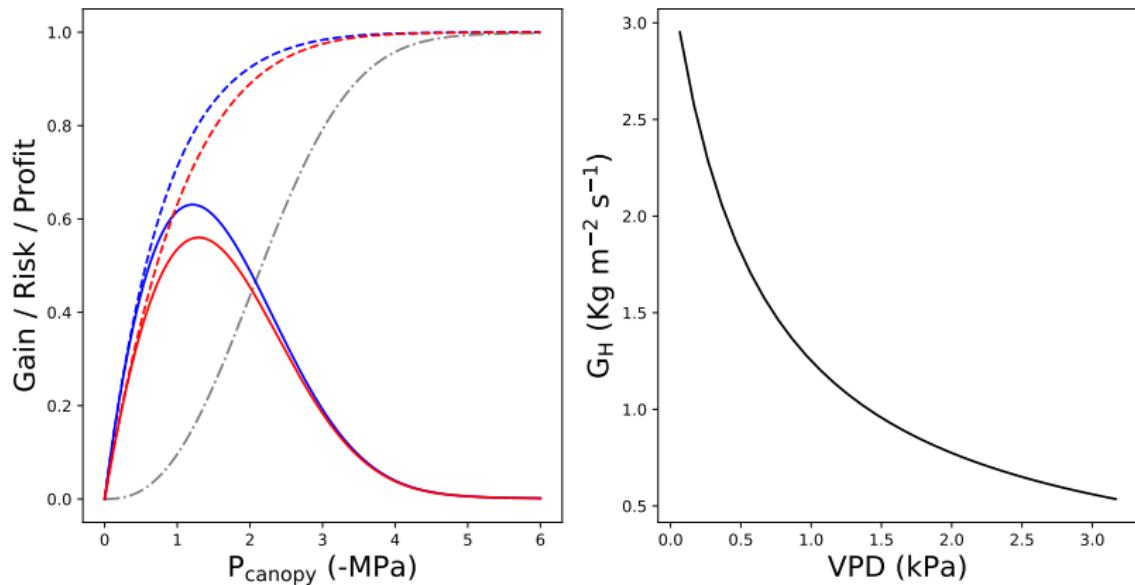
# Response to VPD



└ Model Simulations

└ Hydraulics vs. Photosynthesis Trade-off Model

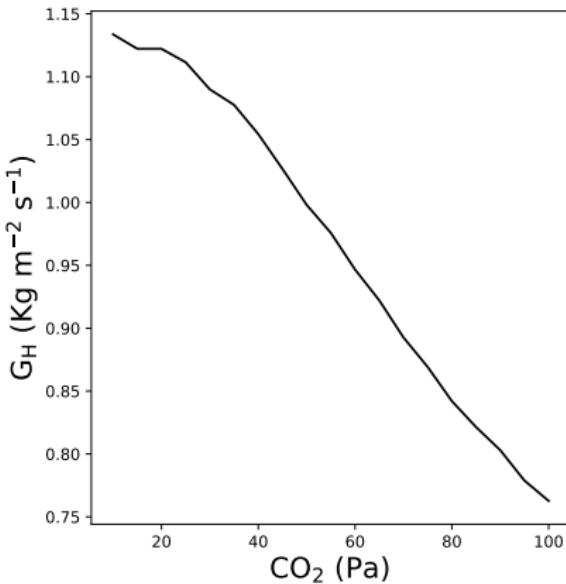
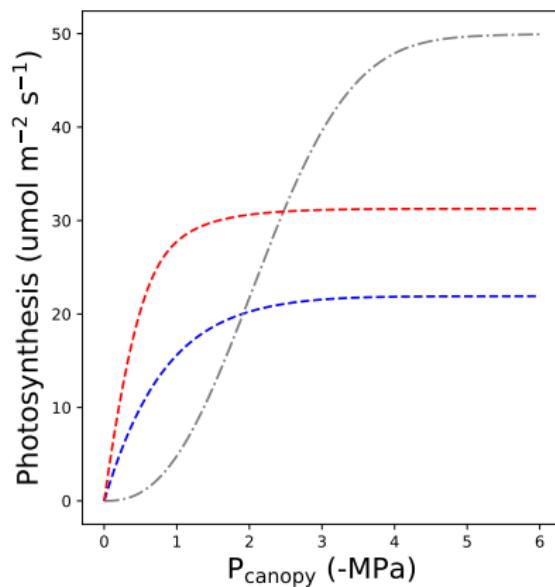
# Response to VPD



└ Model Simulations

└ Hydraulics vs. Photosynthesis Trade-off Model

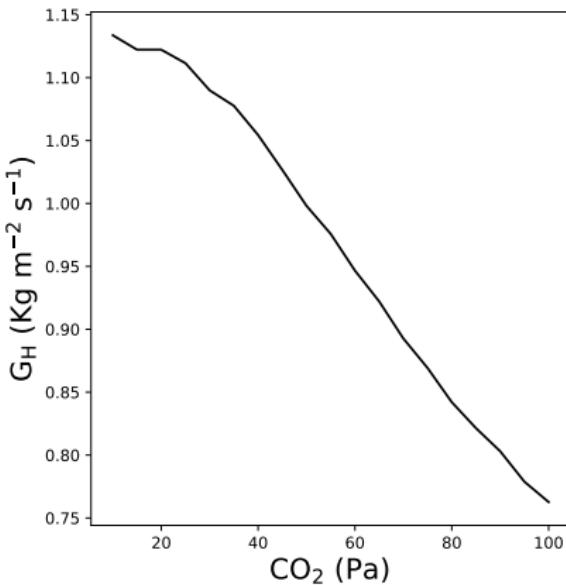
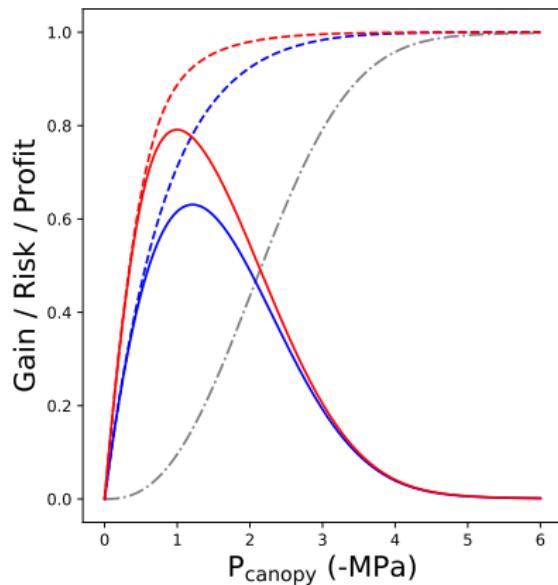
# Response to CO<sub>2</sub>



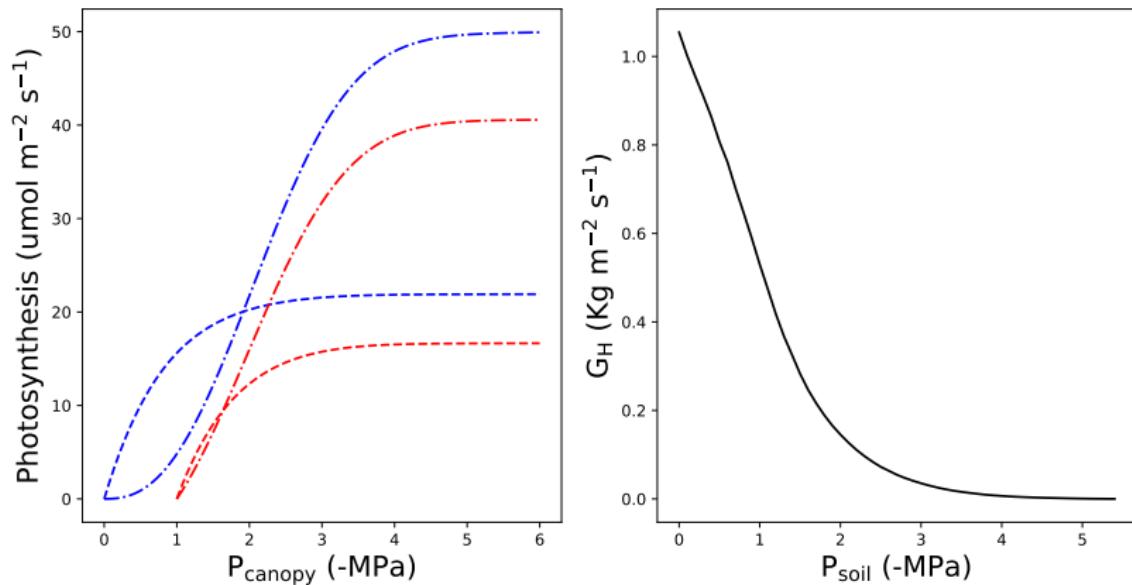
└ Model Simulations

└ Hydraulics vs. Photosynthesis Trade-off Model

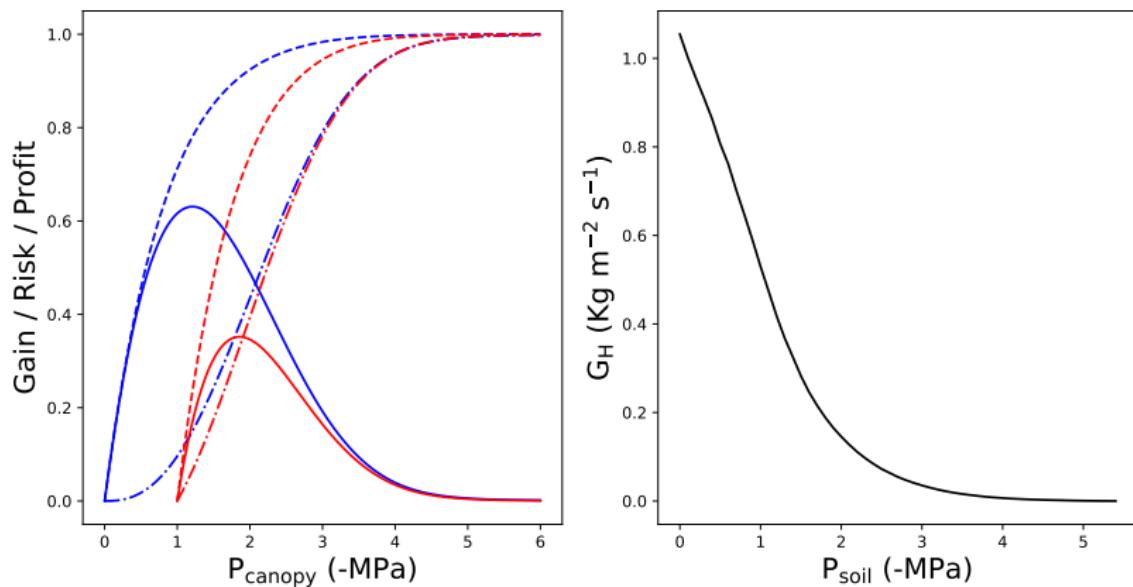
# Response to CO<sub>2</sub>



# Response to $P_{\text{soil}}$



# Response to $P_{\text{soil}}$



└ Objective

  └ Test the Trade-off Model

## Aims

- Test the accuracy of the model;
- Further develop the model;
- Apply the model to forest scale.

└ Results

└ Test the Accuracy of the Trade-off Model

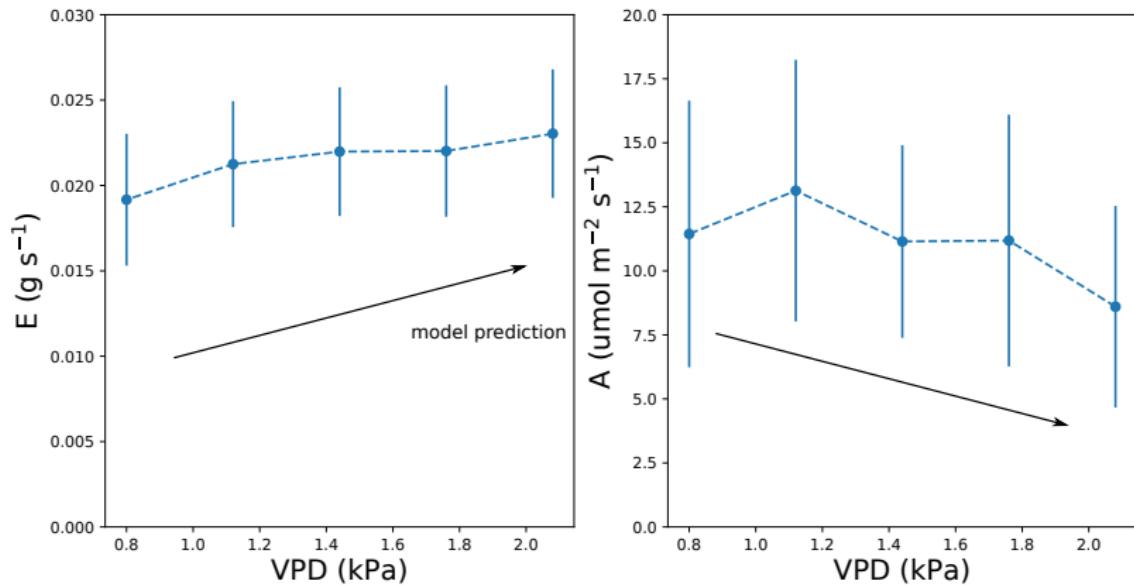
## Test the model in growth chamber

### Why growth chamber?

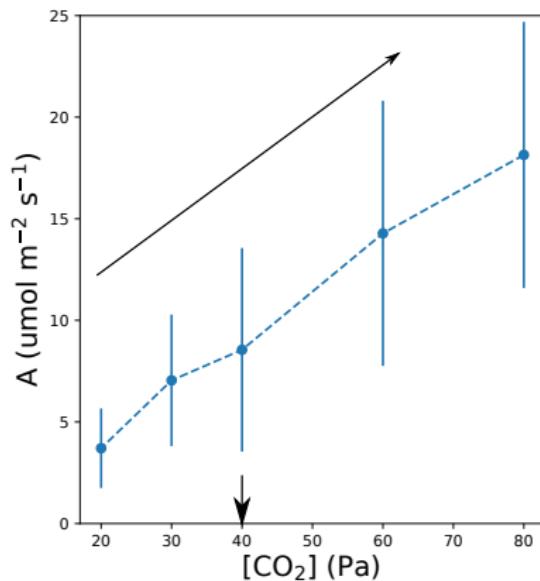
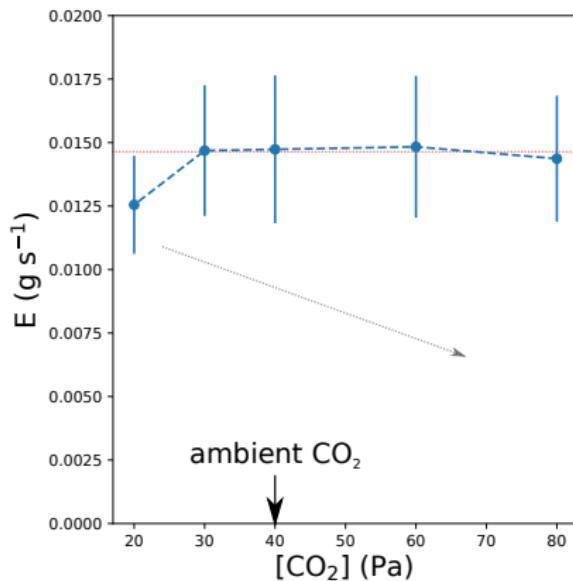
- Stable environment;
- The responses are in plant-level.



# VPD response of water birch



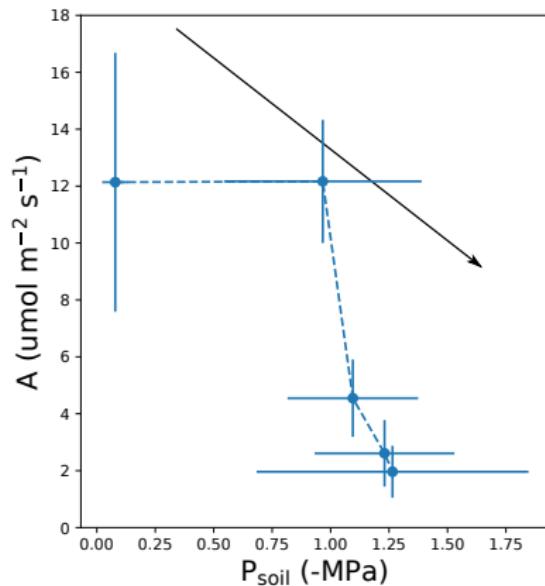
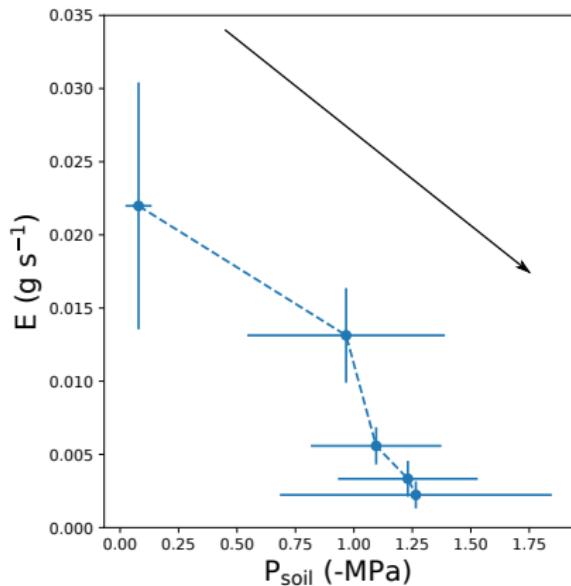
# CO<sub>2</sub> response of water birch



Results

Test the Accuracy of the Trade-off Model

# $P_{\text{soil}}$ response of water birch



## Future research on testing the model

- Measure the vulnerability curves of root, stem, and leaf;
- Run model simulations of different scenarios;
- Compare the model output and results;
- Further test the model on post-drought physiology.

# Acknowledgements

## Supervisory Committee

- John S Sperry
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- Tom Kursar



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# Questions?