Centre d'étude de la forêt

The physiological mechanisms behind the earlywood-to-latewood transition: a process-based modelling approach

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UNIVERSITÉ DU QUÉBEC
À CHICOUTIMI

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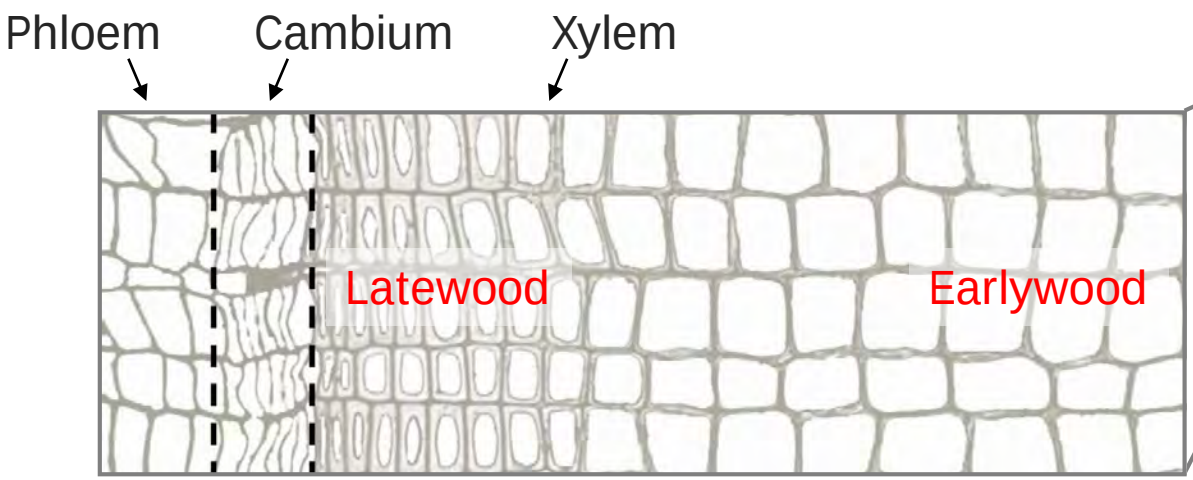
Xylogenesis

Cell production

Cell differentiation

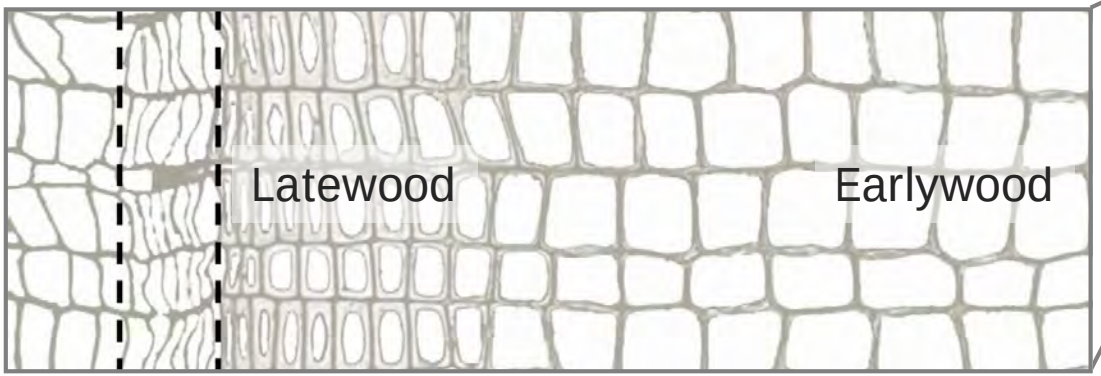
- Enlargement
- Secondary cell wall deposition and lignification

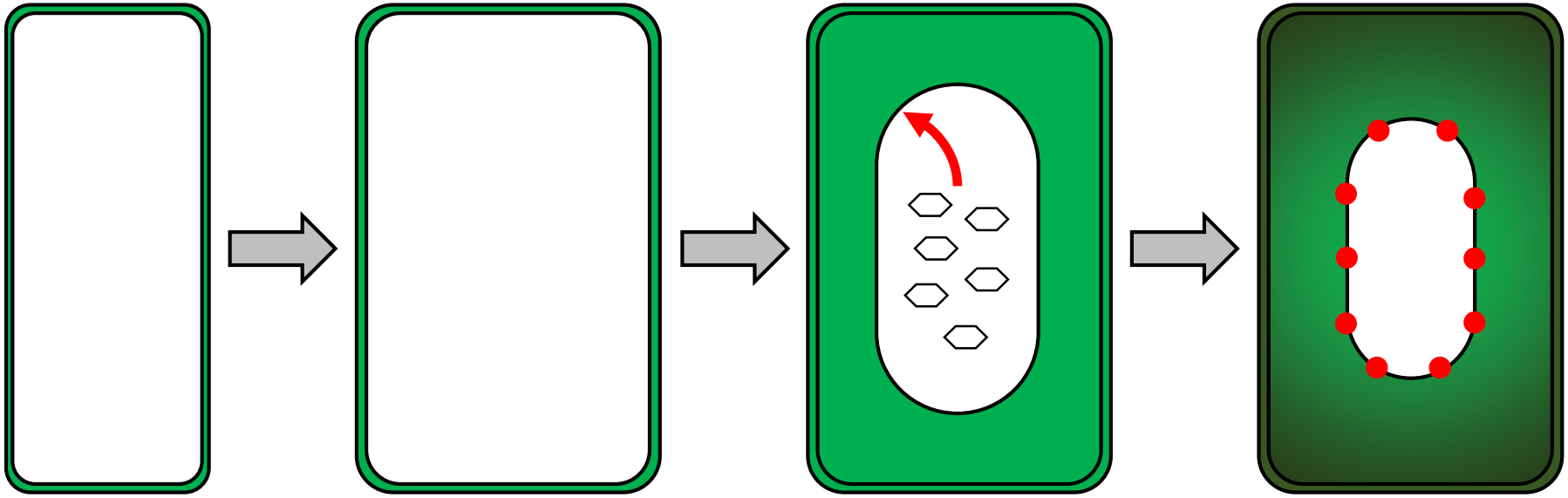


Research question:

What are the factors that can explain

the variation of tracheids anatomical features?





Cell enlargement

Wall deposition

Wall lignification

- ✗ Water availability
- ✓ Wall elasticity

- ✗ Temperature
- ✗ Photoperiod
- ✓ Sugar availability
- ✓ Lumen perimeter

Model assumptions

- Enlargement is slowed down by wall thickening
- Cellulose and lignin deposition rates increase with sugars availability
- Cellulose and lignin deposition rates increase with lumen perimeter
- Cells mature when the wall is completely lignified

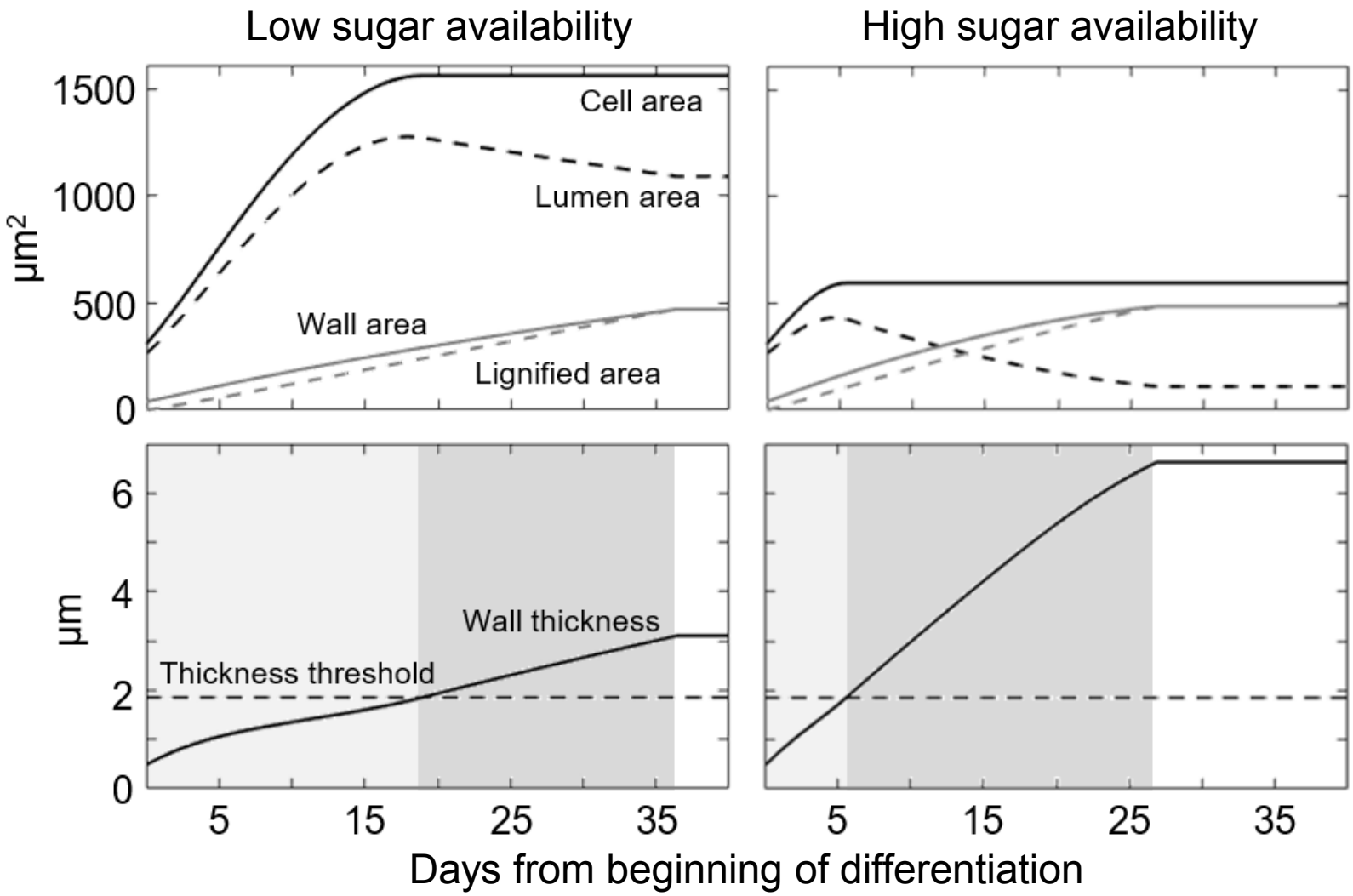
Model equations:

$$\frac{dCA}{dt} = v_c \cdot CA\left(1 - \frac{CA}{CA_{\max}}\right)\left(1 - \min\left(1, \frac{WT}{WT^*}\right)\right)$$

$$\frac{dWA}{dt} = v_w \cdot S\left(1 - \frac{WA}{WA_{max}}\right)\left(1 - \frac{1}{\left(1 + {(CA - WA)}/{m_W}\right)^{sw}}\right) Death$$

$$\frac{dLWA}{dt} = v_l \cdot S\left(1 - \frac{1}{\left(1 + {(CA - LWA)}/{m_L}\right)^{s_L}}\right) Death$$

Temporal dynamics of tracheid development

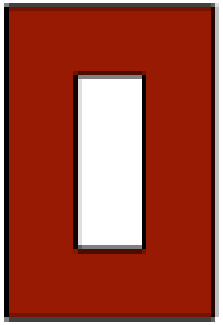


Temporal dynamics of tracheid development

Low sugar availability

Earlywood

High sugar availability



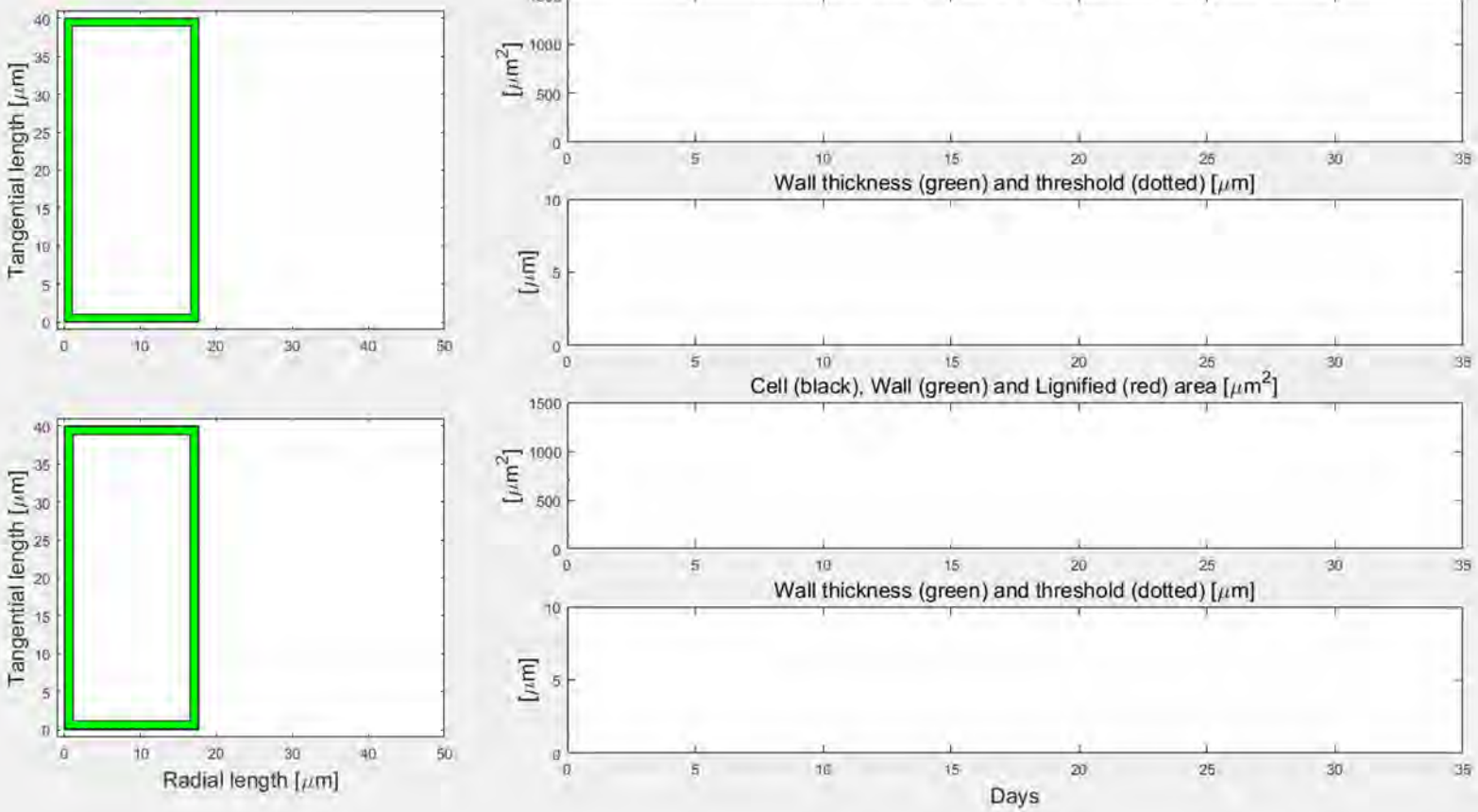
Latewood

Temporal dynamics of tracheid development

Sugar availability

Low

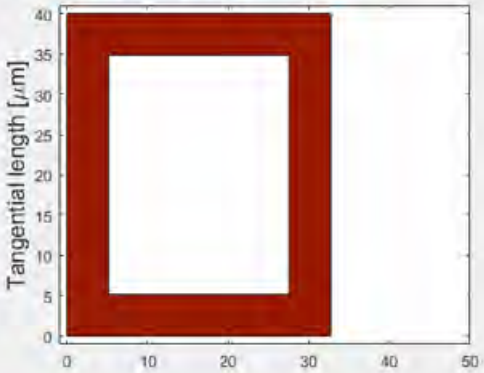
High

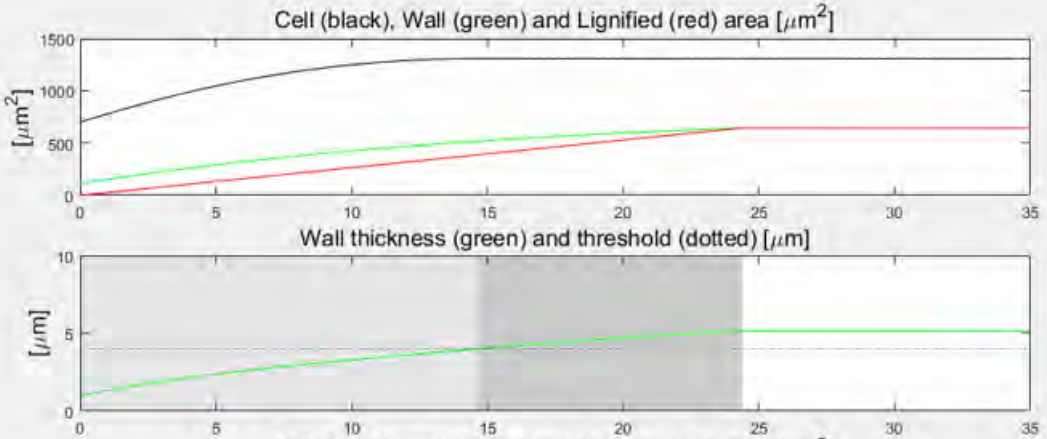


Temporal dynamics of tracheid development

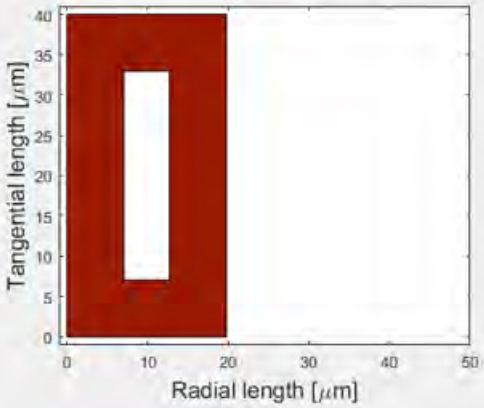
Sugar availability

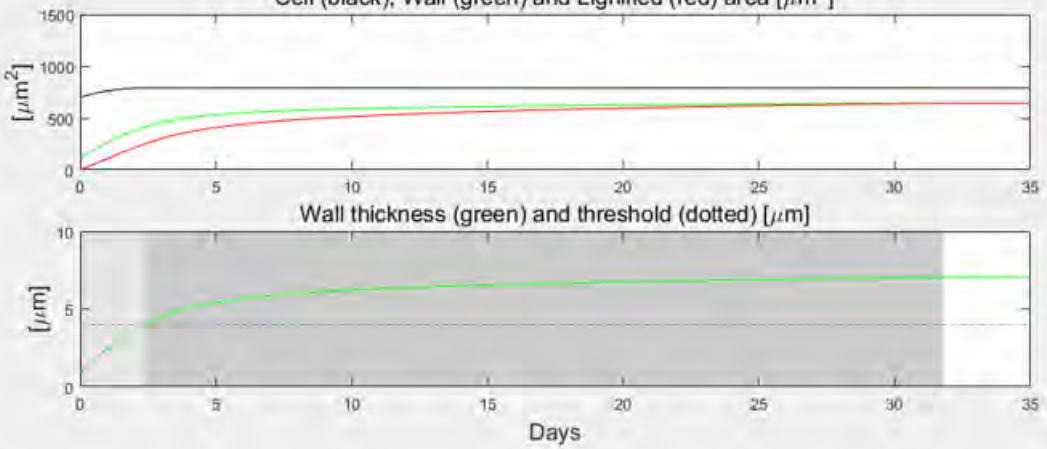
Low





High





Model calibration

Experimental site 1:

Italy (2001)

46°27′ N, 12°08′ E

Species:

- *Pinus cembra*
- *Picea abies*
- *Larix decidua*

Model calibration

Experimental site 2:

Quebec (1999-2004)

48°13′ N, 71°15′ W

Species:

- *Picea mariana*

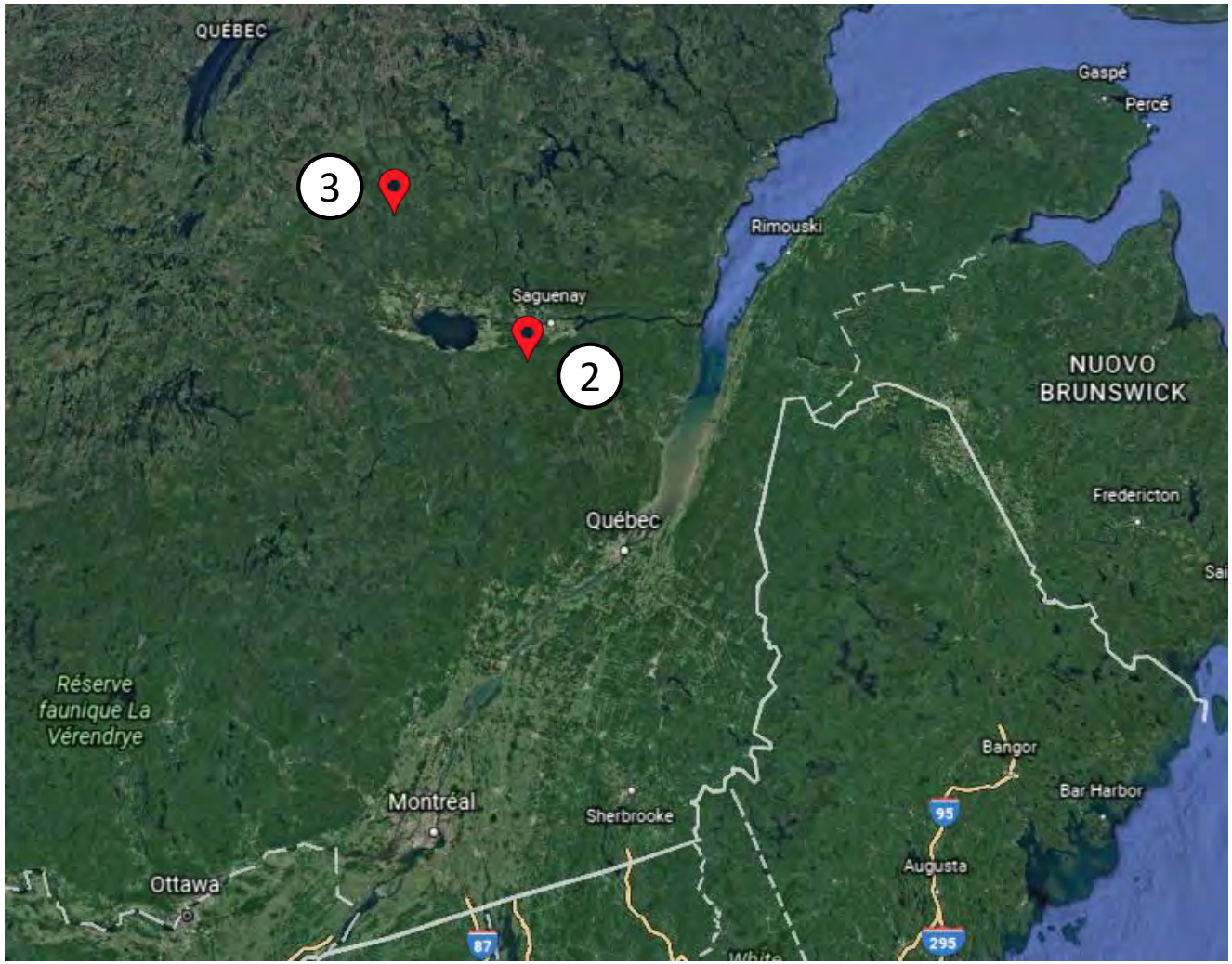
Experimental site 3:

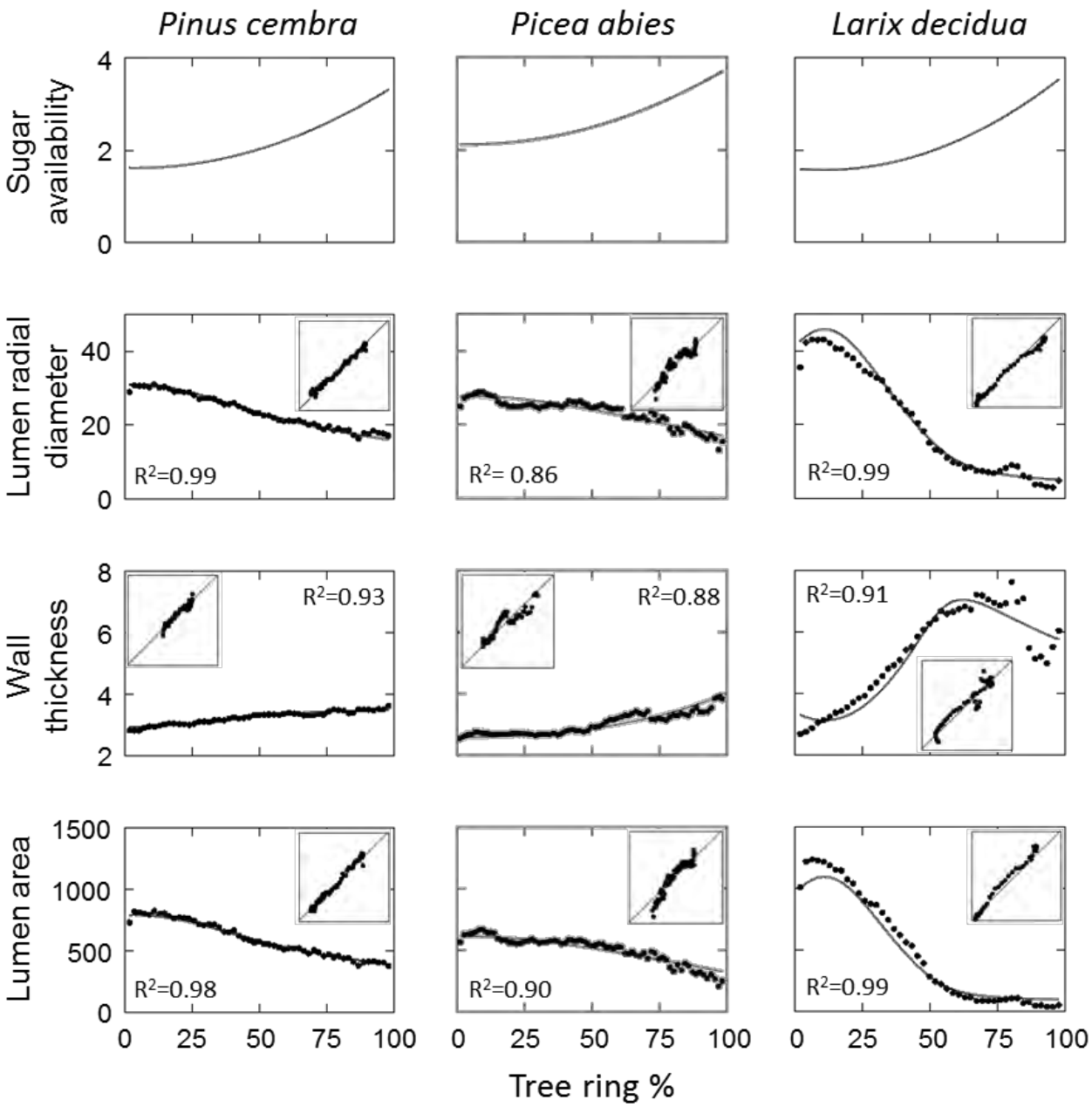
Quebec (1998-2000)

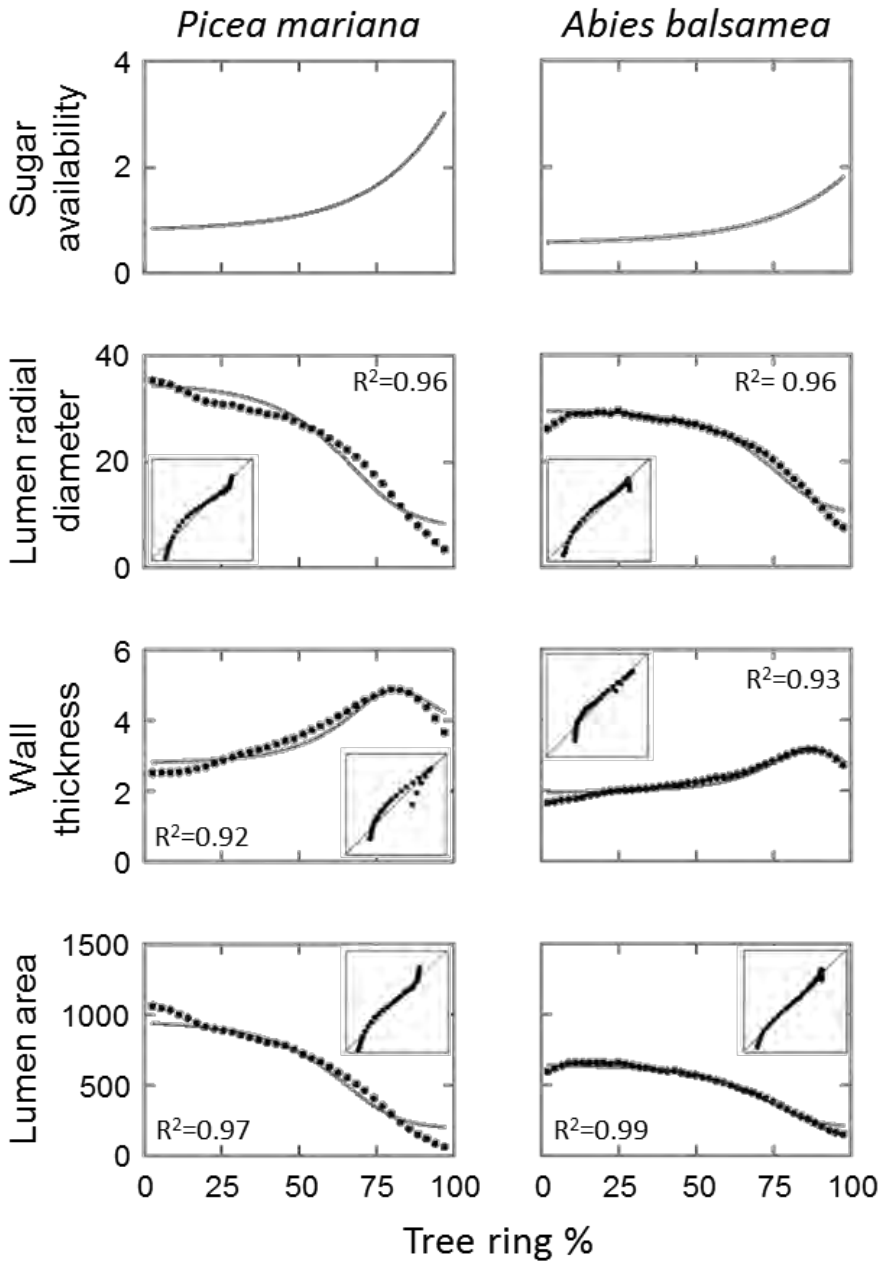
49°58′ N, 72°30′ W

Species:

- *Abies balsamea*



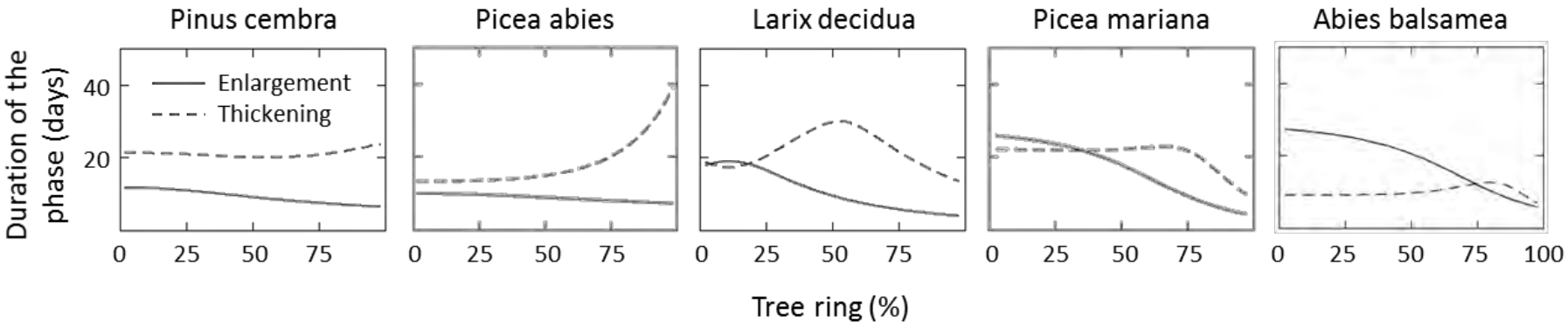

Pinus cembra
Picea abies
Larix decidua
Sugar availability
Lumen radial diameter
Wall thickness
Lumen area
R²=0.99
R²= 0.86
R²=0.99
R²=0.93
R²=0.88
R²=0.91
R²=0.98
R²=0.90
R²=0.99
Tree ring %


Picea mariana
Abies balsamea
Sugar availability
Lumen radial diameter
Wall thickness
Lumen area
R²=0.96
R²= 0.96
R²=0.92
R²=0.93
R²=0.97
R²=0.99
Tree ring %

Observed and simulated percentages of latewood in the tree ring

Species	Observed (%)	Simulated (%)
Pinus cembra	0	0
Picea abies	1.4	0.9
Larix decidua	55.6	57.8
Picea mariana	26.5	29.4
Abies balsamea	11.6	11.6

Estimated timings of cell enlargement and cell-wall thickening



Final considerations:

- The model was able to reproduce observed tree ring patterns
- We considered basic cellular processes
- Results support the metabolic theory
- Carbon availability can explain both rates and durations of xylogenesis
- Better understanding of the dynamic functioning of the system

Ongoing work:

- Include cell division
- Include external factors (e.g. water, temperature and photoperiod)

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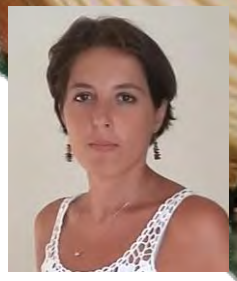

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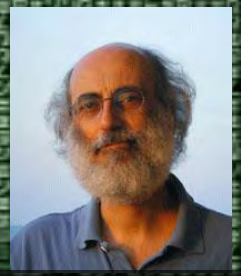

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