Growth of woody plants

- tumajerj@natur.cuni.cz
**WHAT IS ‘GROWTH’?**

- = formation of new cells/tissues
- = division of meristematic initials

- Apical (primary)
  - Elongation of the stem and roots
  - All plants

- Radial (secondary)
  - Widening of stems, roots and branches
  - Woody plants
WHY DO THE PLANTS GROW?

- Reproduction of cells and tissues
- Formation of new types and forms of tissues (e.g., seeds, fruits)
- Effective competition with coexisting trees
WHY SHOULD WE CARE ABOUT THE PLANT GROWTH?

- Crucial driver in carbon cycle (Pan et al. 2011: Science)
- Current forest C stock ≈ 861 Pg C
  - (44 % in the soil, 42 % in the living biomass, 13 % deadwood + litter)
- Annual sink ≈ 2.5 Pg C
SECONDARY GROWTH

- seasonal meristematic activity of the **vascular cambium**
  - meristem = tissue composed of cells /initials/, which are able to divide
- Occurs only in woody species, not in herbs
PHASES OF SECONDARY GROWTH

1) Cambial division
   - Cambial cells divide into cambial cell and phloem/xylem mother cell
   - Cycle from 10 to 50 days

2) Cell differentiation
   1. Cell enlarging
   2. Deposition and lignification of the wall
   3. Cell death - maturation
HOW TO MEASURE SECONDARY GROWTH?

Temporal scale > 1 year
- Repeated forest inventories
**Graphical Abstract**

Environment and growth of Norway spruce

\[ \Delta \text{(CZT2015 - CZT2009)} \]

Sensitivity analysis of the spruce growth model (Eq. (4)): relative change of single covariate by 20%, the resulting change (effect) in BAI (%) and relative sensitivity (-; expressed as % of BAI change to % of explanatory variable change).

<table>
<thead>
<tr>
<th>Explanatory variable change by + 20%</th>
<th>Change in BAI (%)</th>
<th>Relative sensitivity (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DBH</td>
<td>35.0</td>
<td>1.75</td>
</tr>
<tr>
<td>AGE</td>
<td>-14.2</td>
<td>0.71</td>
</tr>
<tr>
<td>C/N</td>
<td>1.8</td>
<td>0.09</td>
</tr>
<tr>
<td>PH_KCL</td>
<td>10.4</td>
<td>0.52</td>
</tr>
<tr>
<td>N_DEP_75 x CLAY</td>
<td>0.8</td>
<td>0.04</td>
</tr>
<tr>
<td>SPI_49</td>
<td>1.6</td>
<td>0.08</td>
</tr>
</tbody>
</table>

BAI predicted (cm²/tree/yr)

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HOW TO MEASURE SECONDARY GROWTH?

Temporal scale = 1 year

- Dendrochronology, tree-ring analyses
AVAILABLE TREE-RING DATASETS

- ITRDB (Global)
  - [https://www.ncdc.noaa.gov/maps/paleo/?layers=0000000000000001](https://www.ncdc.noaa.gov/maps/paleo/?layers=0000000000000001)

- TreeDataClim (Czech Republic)
  - [https://storymaps.arcgis.com/collections/28e41085fc8740ae8f0840b5625091f5?item=1](https://storymaps.arcgis.com/collections/28e41085fc8740ae8f0840b5625091f5?item=1)
CLIMATIC RESPONSE OF TREE-RING WIDTHS - EUROPE
Fig. 4. Geographic distribution of the climate response of tree growth between 1930 and 1960 CE. The maps were produced by projecting the interpolated growth response to (A) temperature ($T_{\text{air}}$), (B) precipitation ($P_{\text{tot}}$), (C) vapor pressure deficit (VPD), and (D) standardized precipitation evapotranspiration index (SPEI) from 2710 sites into geographic space based on the growing season temperature and annual precipitation of each grid cell (see Fig. 3). Red colors indicate stronger water than energy constraints; blue colors indicate the opposite. Gray areas fall outside the climate envelope covered by the tree-ring network.
CLIMATIC RESPONSE OF TREE-RING WIDTHS - GLOBE
CLIMATIC RESPONSE OF TREE-RING WIDTHS - GLOBE

- Highly nonlinear response of boreal forests and tundra ecosystems to climate change!
  - 'Divergence phenomenon', decoupling
HOW TO MEASURE SECONDARY GROWTH?

Temporal scale < 1 year (i.e., intra-annual growth dynamics)

- Direct monitoring of intra-annual radial growth
  - Xylogenesis
  - Dendometers
- Indirect reconstruction of intra-annual radial growth
  - Process-based modeling of wood formation
  - Quantitative wood anatomy
STUDYING INTRA-ANNUAL PROGRESS OF WOOD FORMATION

1) Xylogenesis monitoring

2) Dendrometers

3) Quantitative wood anatomy

4) Process-based modelling
XYLOGENESIS

- Continuous monitoring of (i) the number and (ii) developmental stage of cells throughout the growing season
  - Frequency of 7-14 days
- Trephor
  - Puncher for wood extraction
XYLOGENESIS - METHODOLOGY

Sample extraction → histological fixation → paraffin embedding → microsectioning → staining (Safranin+AstraBlue) → ...
XYLOGENESIS - METHODOLOGY

... → microscopic observations → determining of developmental stage for each cell

CC = cambial zone
PC = ec = enlarging zone
SW = wtc = wall-thickening zone
XYLOGENESIS MONITORING OF CHARLES UNI.

>20 years

12 years
DENDROMETERS

- Devices monitoring (and possibly recording) intra-annual variability of stem circumference or radius
- Point X band dendrometers
- With automatic X manual reading
DENDROMETER RECORDS

- Phases of stem radius variability
  - Reversible (driven by variable water content during the day inside the stem)
    - Shrinking
    - Expansion
  - Irreversible (driven by increasing number of xylem cells and their growing diameter)
    - Increment (=growth)
WHY DOES THE STEM SHRINK?

Acer
Fagus
Quercus
MEAN GROWTH RATE FOR TEMPERATE SPECIES

Mean daily growth rate (µm/h)

Acer

Fagus

Quercus

\[ Y_1 = 0.80, \quad Y_2 = 2.14 \]

\[ Y_1 = 0.94, \quad Y_2 = 2.31 \]

\[ Y_1 = 0.01, \quad Y_2 = 1.46 \]

DOY

2015
Acer + Fagus

- Unimodal growth patterns with single peak of growth rates around the summer solstice

Quercus

- Multimodal growth pattern coinciding to wet periods
MEAN GROWTH RATE IN RELATION TO ENVIRONMENTAL CONDITIONS

- **Temperature optimum**: 12-18°C
- **VPD optimum**: < 0.1 kPa
MEAN GROWTH RATE IN RELATION TO ENVIRONMENTAL CONDITIONS

![Graph showing mean growth rate in relation to environmental conditions for Acer, Fagus, and Quercus. The graph plots temperature (°C) against VPD (kPa) with a color gradient indicating growth rate (µm/h).]
MEAN GROWTH RATE FOR EACH HOUR – DIURNAL CYCLE

Trees grow at night!
THANK YOU FOR YOUR ATTENTION!