Long-term simulation of the effect of climate changes on the growth of main Central European forest tree species.

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Process-based model BIOME-BGC (Thornton, 1998)

Biome-BGC: C and N dynamics with disturbance components
(bold indicates interface with historical database)
Adaptation and modification of the model

- Management options: thinning, felling, planting of another species;
- Change of rainfall interception and evaporation routine
- Direct input of N deposition time series
- Independent setting of fine roots mortality
- Climate changes: gradual linear change of Tmin, Tmax, Precipitation, VPD and Radiation available, both at annual or monthly base

Input data for simulation

- Yield tables (Černý et al., 1996)
- Permanent research plots in Czech Republic
- Daily meteorological data from 44 stations recalculated for each plot
- Earlier obtained parameterizations for spruce, pine, beech and oak stands (Cienciala and Tatarinov, 2006)
- **Expected environmental changes in 2000-2100**
CO$_2$ concentration change

(mean of available emission scenarios SRES-A1 and SRES-B2)
N deposition change

(data for 1850-2000 from Kopáček & Veselý, 2005)
Climate changes (3 scenarios)
(recalculated for Czech Republic by Dubrovsky et al. (2005))
Dashed lines present annual means

Mean daily temperature changes in 2100

Precipitation changes in 2100

Scenarios:
- CSIRO
- HadCM3
- NCAR-PCM

(recalculated for Czech Republic by Dubrovsky et al. (2005))

Dashed lines present annual means
Management scenarios
(Actual scenario see Cienciala & Tatarinov, 2006)

Spruce plot 501621

Scenario:
- Actual
- Basic

Actual planting (1926)

Prescribed thinning

Actual thinning
Totally 14 monospecies plots included:
4 spruce, 4 pine, 3 beech, 3 oak.
For each plot the following data were available

• Elevation
• Annual precipitation total
• N deposition in 2002
• Soil type
• Data from 4 to 8 forest inventories before and after thinning
Quantifying the effect of environmental changes

Change of variable $X$ at the year $t$ (or effect of environmental changes on $X$),

$$\Delta X(t) = \frac{X_{\text{changed\_climate}}(t) - X_{\text{constant\_climate}}(t)}{X_{\text{constant\_climate}}(t)}$$
Results
Basic scenario: examples of environmental change effects

Spruce 501625

Year

Stem C change (%)

0 5 10 15 20

Stem C (kg m⁻²)

Stem C (control)

Change for scenario

CSIRO

HadCM3

NCAR-PCM

Beech 501118

Year

Stem C change (%)

0 5 10 15 20

Stem C (kg m⁻²)

Stem C (control)

Change for scenario

CSIRO

HadCM3

NCAR-PCM

Pine 500622

Year

Stem C change (%)

0 5 10 15 20

Stem C (kg m⁻²)

Stem C (control)

Change for scenario

CSIRO

HadCM3

NCAR-PCM

Oak 501069

Year

Stem C change (%)

0 5 10 15 20

Stem C (kg m⁻²)

Stem C (control)

Change for scenario

CSIRO

HadCM3

NCAR-PCM
Mean effect of environmental changes on carbon pools
(mean % of change for 2080-2100 under environmental changes relatively to control scenario).

![Graph showing mean effect of environmental changes on carbon pools across different scenarios and species. The graph includes data for Spruce, Pine, Beech, and Oak species under different Scenarios: CSIRO, Spruce Pine Beech Oak, HadCM3, and NCAR-PCM. The x-axis represents the species, and the y-axis shows the percentage change in carbon pools (Litter C, Soil C, Total C, Stem C).]
Why growth could decrease under climate change scenarios (especially HadCM3)?

Sole effect of climate (no CO$_2$ and N deposition changes) and N deposition changes.

### Precipitation changes in 2100

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>1</th>
<th>62</th>
<th>122</th>
<th>183</th>
<th>244</th>
<th>304</th>
<th>365</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSIRO</td>
<td>-30%</td>
<td>-20%</td>
<td>-10%</td>
<td>0%</td>
<td>4%</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>HadCM3</td>
<td>-16%</td>
<td>-12%</td>
<td>-8%</td>
<td>-4%</td>
<td>0%</td>
<td>4%</td>
<td></td>
</tr>
</tbody>
</table>

### Soil water change

<table>
<thead>
<tr>
<th>Mean ±0.95 Conf. Interval</th>
<th>1</th>
<th>62</th>
<th>122</th>
<th>183</th>
<th>244</th>
<th>304</th>
<th>365</th>
</tr>
</thead>
<tbody>
<tr>
<td>-50%</td>
<td>-40%</td>
<td>-30%</td>
<td>-20%</td>
<td>-10%</td>
<td>0%</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>-40%</td>
<td>-30%</td>
<td>-20%</td>
<td>-10%</td>
<td>0%</td>
<td>10%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Daily NPP change

<table>
<thead>
<tr>
<th>Mean ±0.95 Conf. Interval</th>
<th>1</th>
<th>62</th>
<th>122</th>
<th>183</th>
<th>244</th>
<th>304</th>
<th>365</th>
</tr>
</thead>
<tbody>
<tr>
<td>-30%</td>
<td>-20%</td>
<td>-10%</td>
<td>0%</td>
<td>10%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-20%</td>
<td>-10%</td>
<td>0%</td>
<td>10%</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

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For more detailed analysis and graphs, refer to the attached figures.
Sole effect of climate is usually negative for conifers, positive for deciduous, but smaller than with CO$_2$ and N deposition changes included.

Climate + CO$_2$ + N

<table>
<thead>
<tr>
<th>Species</th>
<th>Scenario HadCM3</th>
<th></th>
<th></th>
<th></th>
<th>Scenario NCAR-PCM</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Litter C</td>
<td>Soil C</td>
<td>Total C</td>
<td>Stem C</td>
<td>Litter C</td>
<td>Soil C</td>
<td>Total C</td>
</tr>
<tr>
<td>Spruce</td>
<td>-10%</td>
<td></td>
<td></td>
<td></td>
<td>-10%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pine</td>
<td>5%</td>
<td></td>
<td></td>
<td></td>
<td>5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beech</td>
<td>0%</td>
<td></td>
<td></td>
<td></td>
<td>0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oak</td>
<td>10%</td>
<td></td>
<td></td>
<td></td>
<td>10%</td>
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<td></td>
</tr>
</tbody>
</table>

Only climate
### Mean changes of carbon pools in 2080-2100 under different scenarios: some examples

<table>
<thead>
<tr>
<th>Species</th>
<th>Environmental changes</th>
<th>Change of C pool, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Trees</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Climate</td>
</tr>
<tr>
<td>Spruce</td>
<td>HadCM3</td>
<td>+</td>
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<tr>
<td>Spruce</td>
<td>HadCM3</td>
<td>const</td>
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<tr>
<td>Spruce</td>
<td>const</td>
<td>+</td>
</tr>
<tr>
<td>Spruce</td>
<td>const</td>
<td>const</td>
</tr>
<tr>
<td>Spruce</td>
<td>const</td>
<td>+</td>
</tr>
<tr>
<td>Beech</td>
<td>HadCM3</td>
<td>+</td>
</tr>
<tr>
<td>Beech</td>
<td>HadCM3</td>
<td>const</td>
</tr>
<tr>
<td>Beech</td>
<td>const</td>
<td>+</td>
</tr>
<tr>
<td>Beech</td>
<td>const</td>
<td>const</td>
</tr>
<tr>
<td>Beech</td>
<td>const</td>
<td>const</td>
</tr>
</tbody>
</table>

- **Effect of increasing CO₂** is always *positive*.
- **Effect of decreasing N** is always *negative*.

BUT the combined effect of CO₂ and N may be different for different species.

In particular, under current parameterization spruce is more sensitive to N, than beech.

(Tatarinov & Cienciala, 2006)
### Mean changes of carbon pools in 2080-2100: monthly versus annual climate changes

<table>
<thead>
<tr>
<th>Species</th>
<th>Environmental changes</th>
<th>Change of C pool, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Climate</td>
<td>CO₂</td>
</tr>
<tr>
<td>Beech</td>
<td>H monthly</td>
<td>const</td>
</tr>
<tr>
<td>Beech</td>
<td>H annual</td>
<td>const</td>
</tr>
<tr>
<td>Pine</td>
<td>H monthly</td>
<td>const</td>
</tr>
<tr>
<td>Pine</td>
<td>H annual</td>
<td>const</td>
</tr>
<tr>
<td>Spruce</td>
<td>H monthly</td>
<td>const</td>
</tr>
<tr>
<td>Spruce</td>
<td>H annual</td>
<td>const</td>
</tr>
</tbody>
</table>

"Annual means of climate changes had considerably smaller effect than monthly changes"
Basic vs real management scenario

- A later stand planting results in higher response (peak) to climate change for young stand
- The effect of planting year becomes insignificant at stand maturity
Conclusions

• Monthly data are needed to study effect of climate change.
• Climate change in the conditions of Czech Republic may decrease forest carbon sink due to increasing summer drought.
• This effect is more pronounced for conifers, the growth of deciduous may slightly increase.
• N deposition dynamics is critical for predicting forest carbon balance.
Thank you!