

Implications of changing climate on forest management

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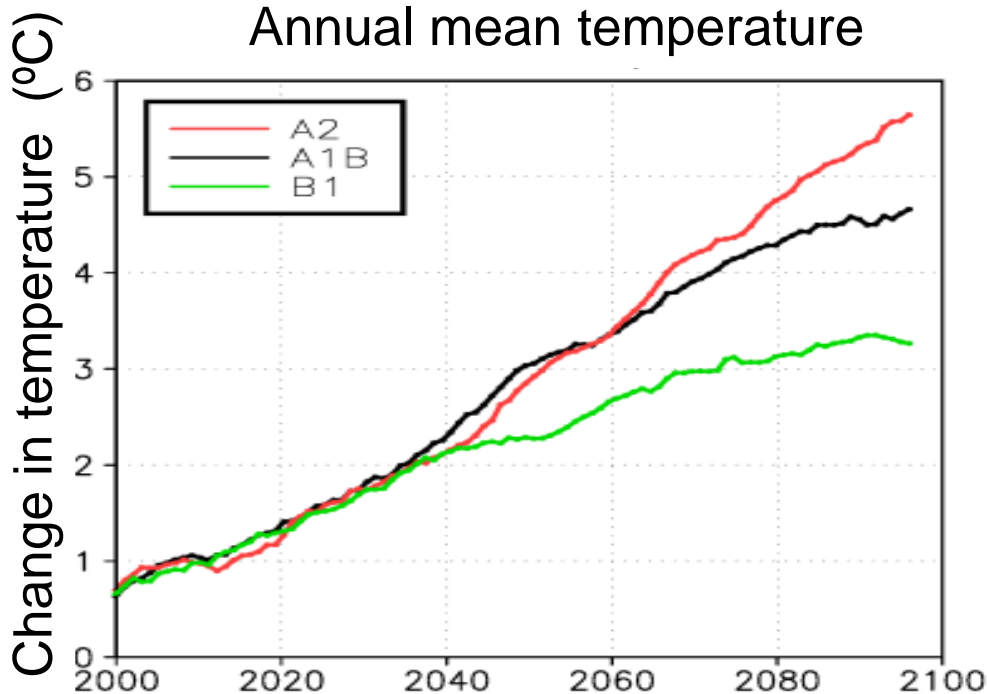
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Content

- Predicted climate change
- Changes in the forests already observed
- Expected changes in the forest growth
- Mitigation options under Climate Convention
- Adaptation of forest management
 - To reduce vulnerability
 - To optimize economic profitability of forestry
- Conclusions

Predicted climate change in the Northern Europe

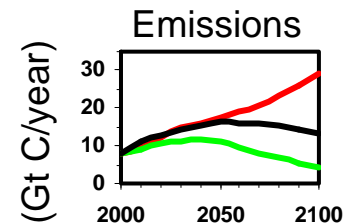
Warming in Finland by $\sim 0.4 \pm 0.1^\circ\text{C}/10$ yr during the next three decades



Scenario	Change (°C)
A2	5.1 (3.1 – 7.0)
A1B	4.4 (2.5 – 6.3)
B1	3.2 (1.5 – 4.9)

↑
Multi-model mean (19 GCMs)
and the 90% uncertainty range

- The rate of warming deviates little between the different emission scenarios up to by the 2040s.
- The warming by the end of the century would be about one third smaller in the B1 scenario compared to the A2 scenario.

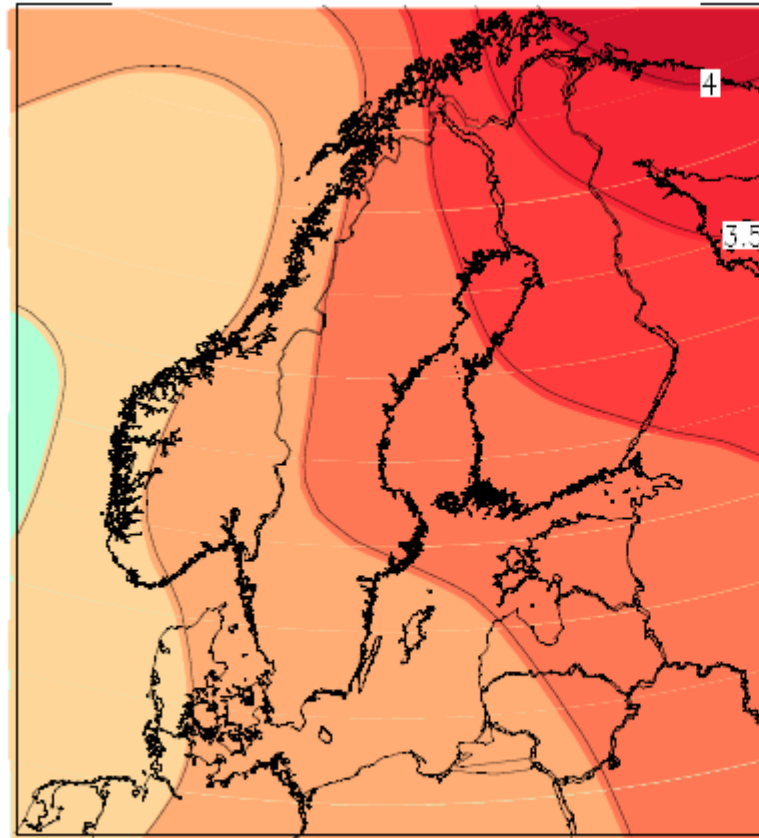


Source: Kirsti Jylhä, Finnish Meteorological Institute



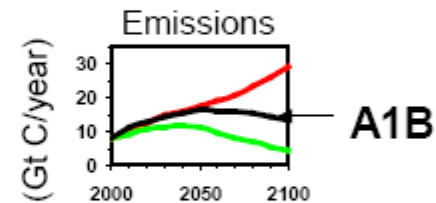
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Largest warming in continental region



Annual mean
temperature change (°C)

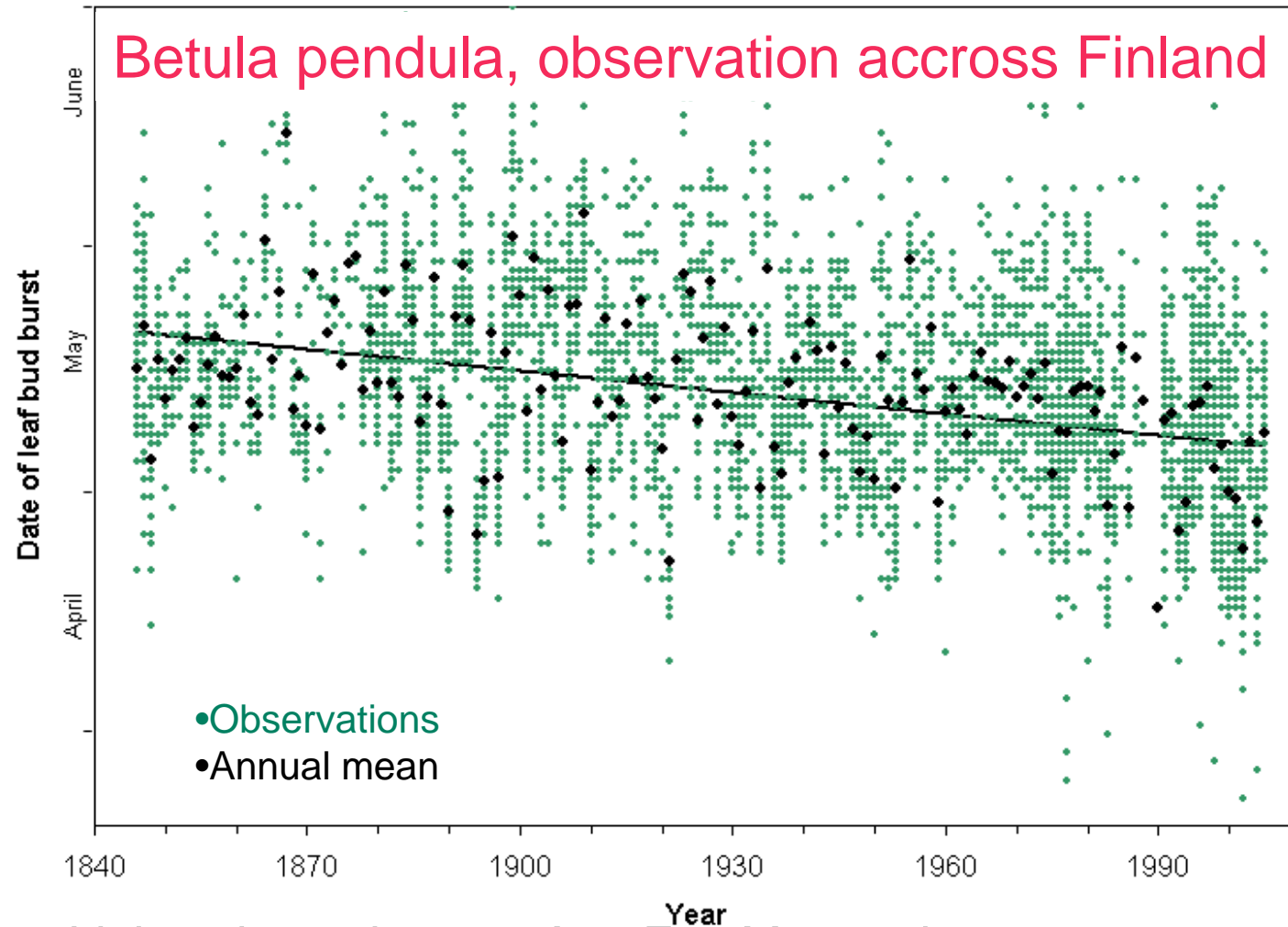
1971-2000 => 2040-2069



- Wintertime changes in the north exceed those in the south
- Summertime changes are rather uniform across the country.

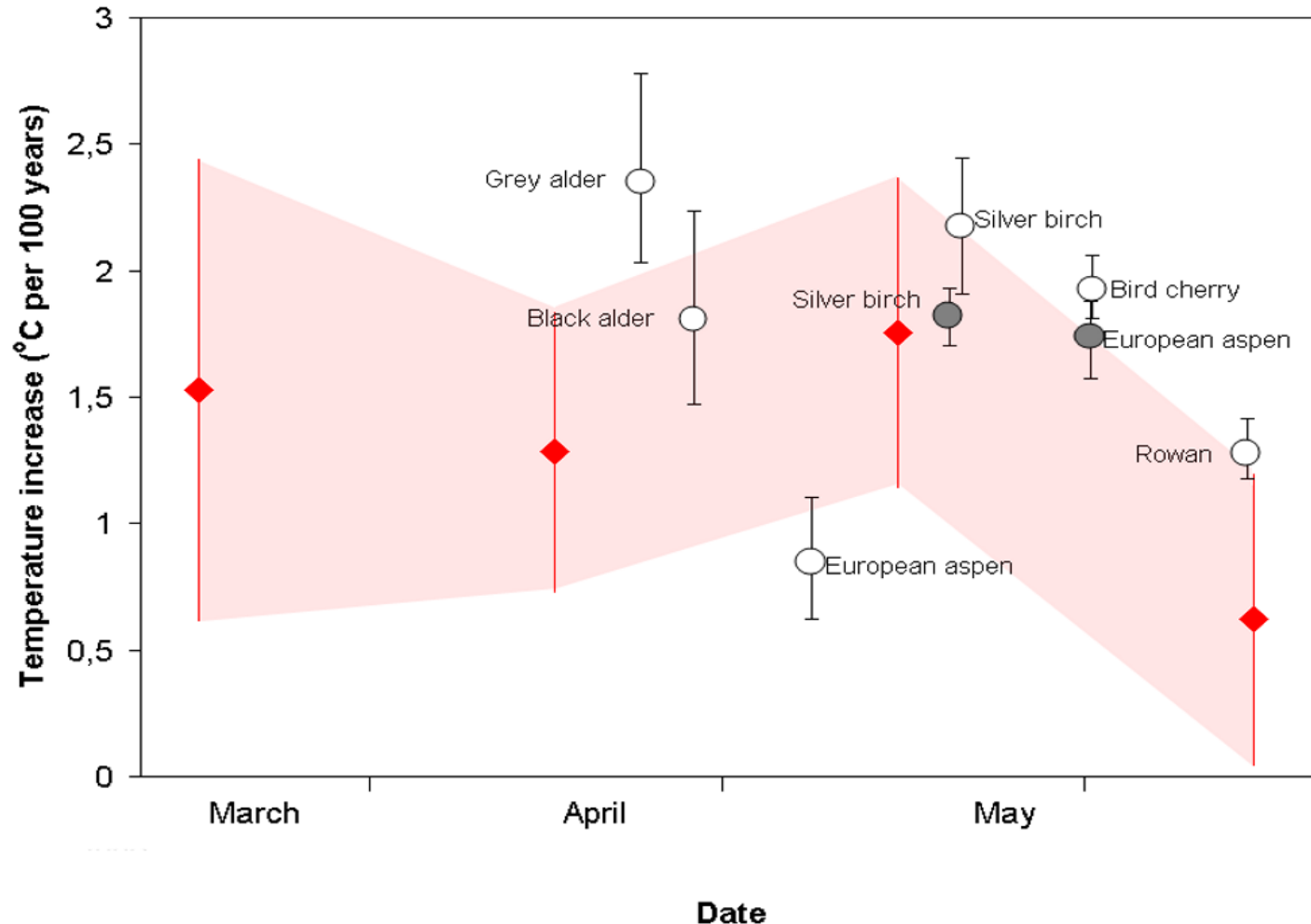
Source: Kirsti Jylhä, Finnish Meteorological Institute

Changes in forests already documented – Spring advanced by a day per decade



Source: Linkosalo et al. 2009. *Agr. For. Meteorology* 149: 453-461

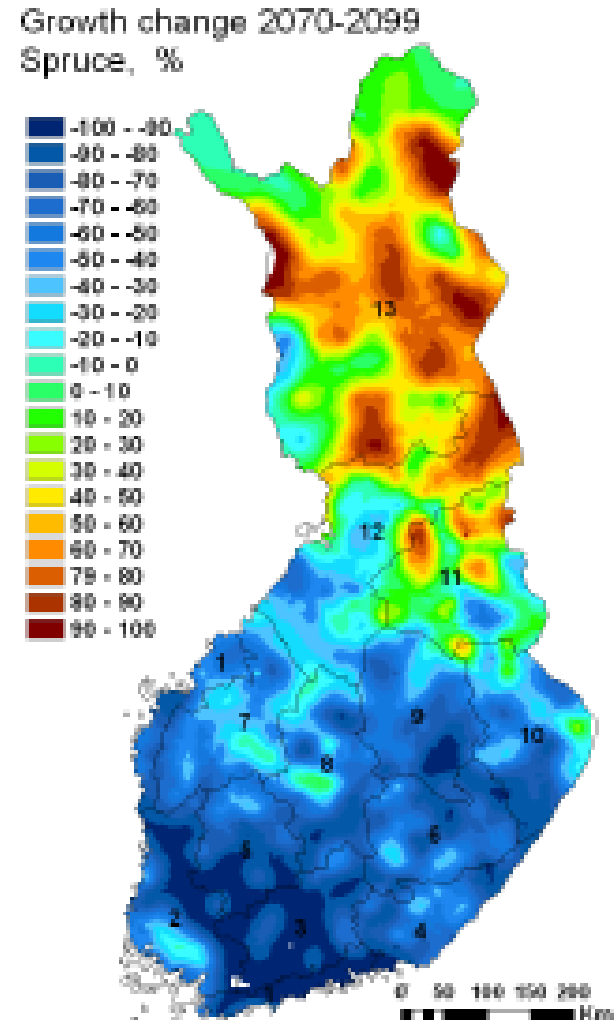
Advance in timing of flowering (white) and bud burst (grey) indicate increased spring temperatures



Source: Linkosalo et al. 2009. *Agr. For. Meteorology* 149: 453-461

Climate change driven changes in forests

- Large scale analyses predict remarkable changes in the Finnish forests.
- Decline in spruce growth
- Changes in tree species dominance predicted.



Source: Kellomäki et al. 2005. SYKE Mimeographs 344: 1-42.

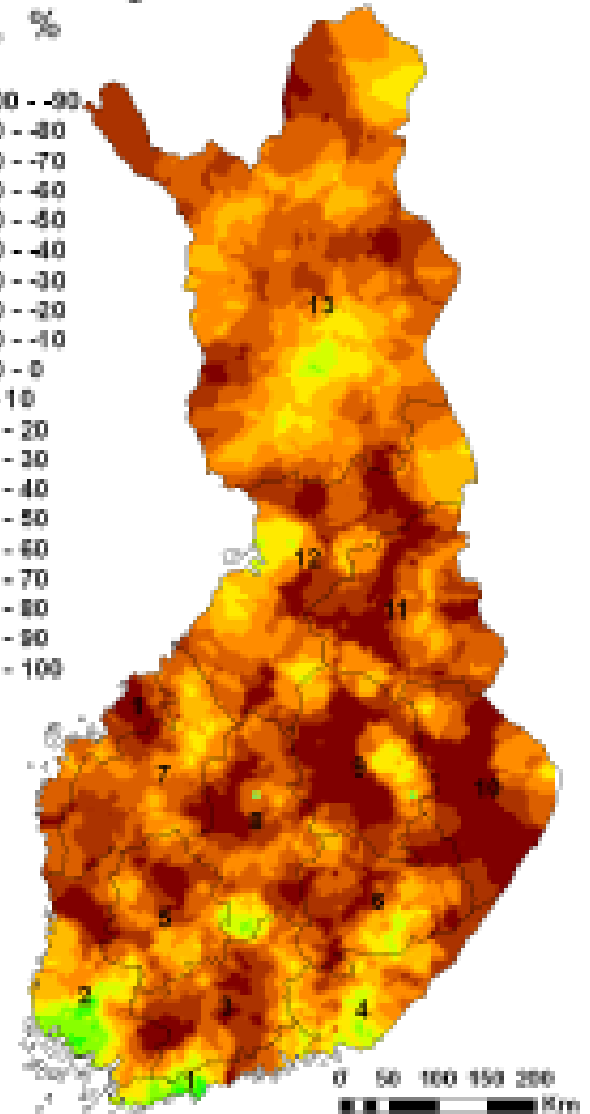
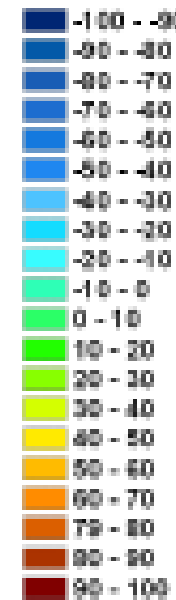
...Changes in forests

- Increased growth of deciduous birch (*Betula* spp.)

BUT

- Species sensitivity and acclimation capacities are poorly known.

Growth change 2070-2099
Birch, %



Source: Kellomäki et al. 2005. SYKE Mimeographs 344: 1-42.

Mitigation and adaptation of forests to climate change

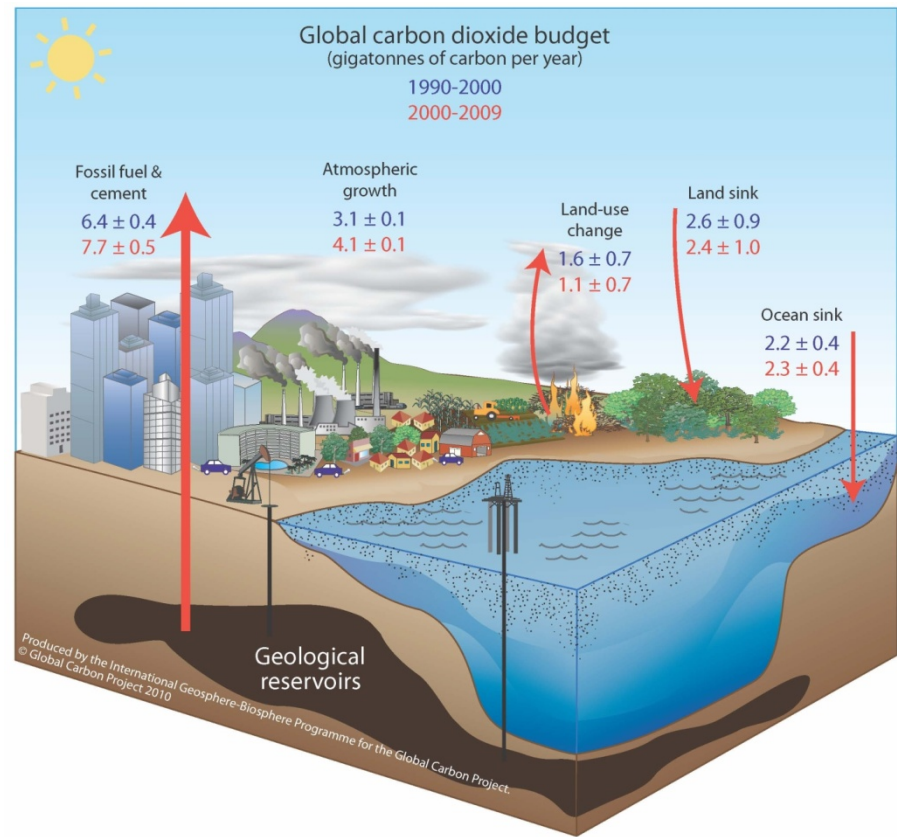
- Mitigation is a public good
 - Aim is to protect **global** climate system and to avoid influences that are harmful to any nation/citizen
 - For instance, mitigation of climate change by increasing forest carbon stock in Carelia will decrease CO₂ concentration in the atmosphere that decrease the overall risk of harmful climatic events in northern hemisphere.
- Adaptation is a private good
 - Aim is to decrease risk of harmful influences or to benefit from changing climate at local scale
 - Forest owner or regional authority have interest, since they gain the benefits of actions.

Mitigation under the Climate Convention

- Since mitigation is a public good, global agreements needed to create incentives for necessary actions
- Mitigation under the Kyoto Protocol
 - CDM-projects in developing countries, incentive for afforestation
 - JI-projects, incentive for afforestation
 - Article 3.3. Afforestation as well as slowing deforestation in Annex 1 countries
 - Article 3.4. Forest management on forested land
- REDD+, Reduction of deforestation and degradation of forests in developing countries

Mitigation options

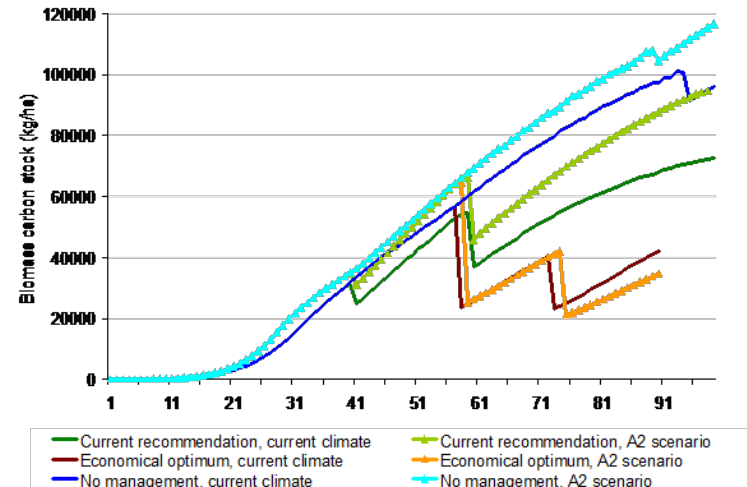
- Forests offer significant mitigation potential – but temporary
- Allow time for other options to be further developed



- Forest C sink equivalent to about 30% of global emissions (GCP 2010)

Mitigation options

- enhance existing C pools
- fire or insect control
- forest conservation
- changing silvicultural practices
- planting trees in urban areas
- use biomass to offset fossil fuel use
- replace construction materials that require more fossil fuel input
- slowing or halting deforestation
- reforestation of degraded land (forests and wasteland)



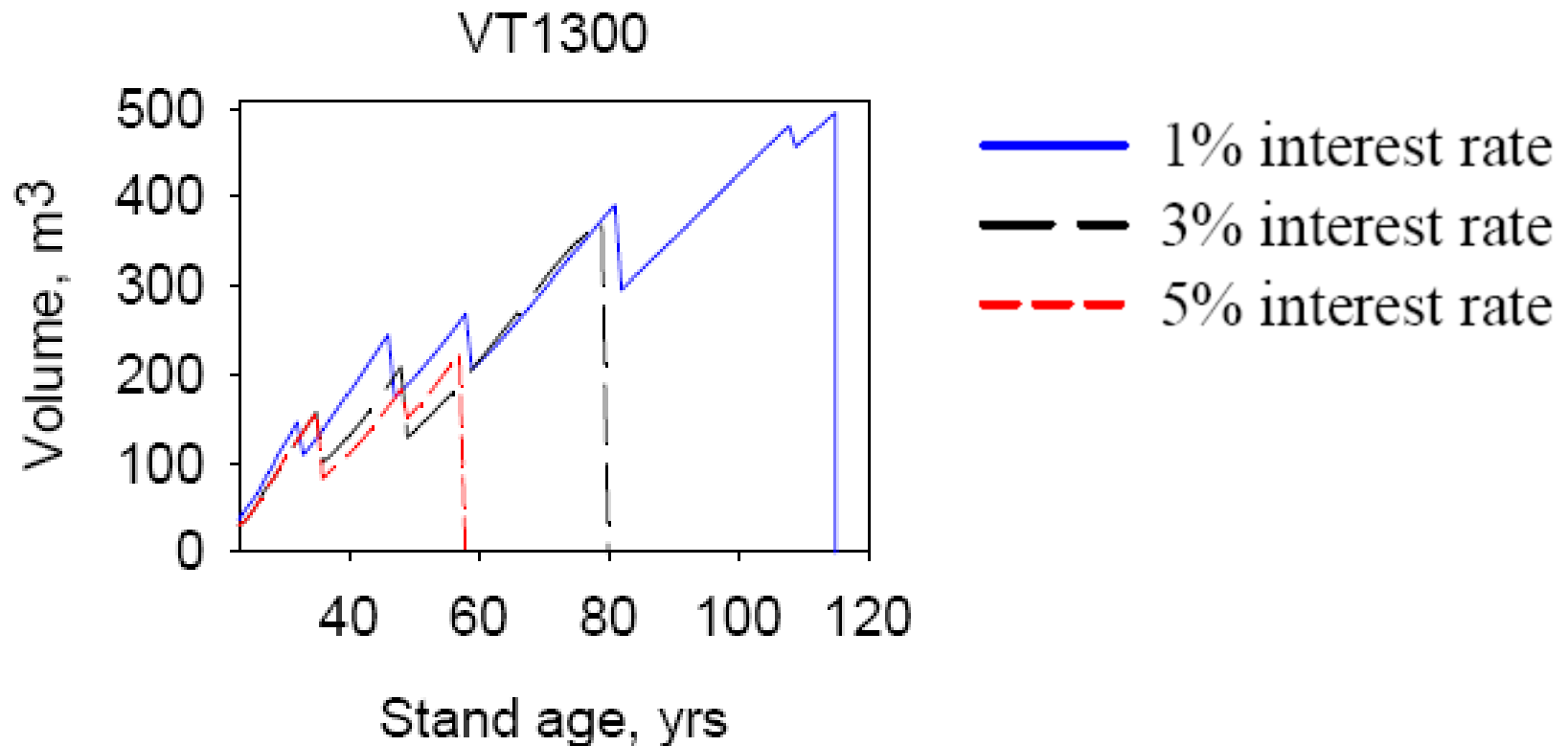
Adaptation to reduce vulnerability of forest ecosystems to harmful influences of CC

- Choise of tree species and provenances that are better adapted to changing conditions
- Adapting thinning and harvest practices to decrease vulnerability to disturbances (heavy winds, drought, pest – e.g. *Ips typographus* - and pathogens)
- Natural regeneration and increase in species and genetic diversity

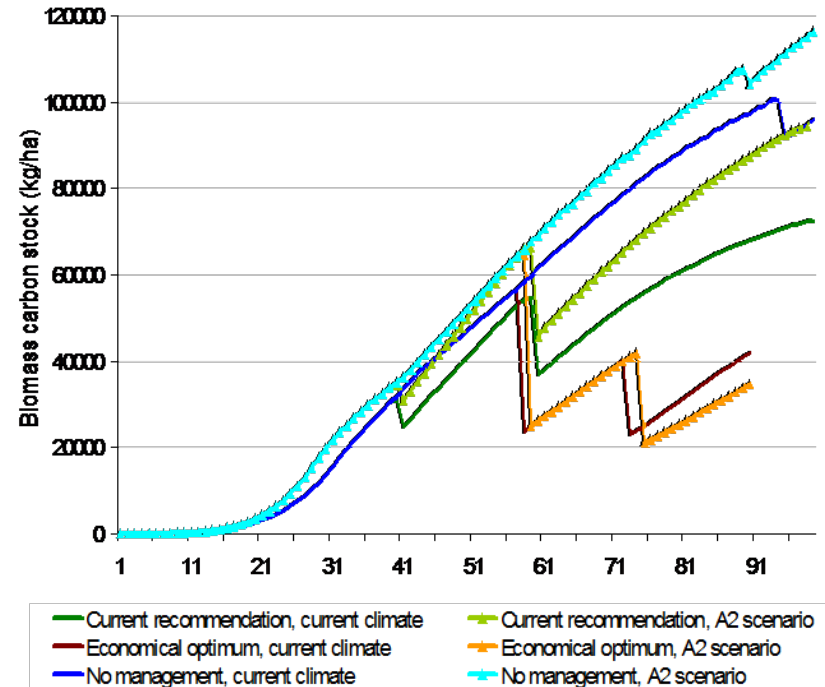
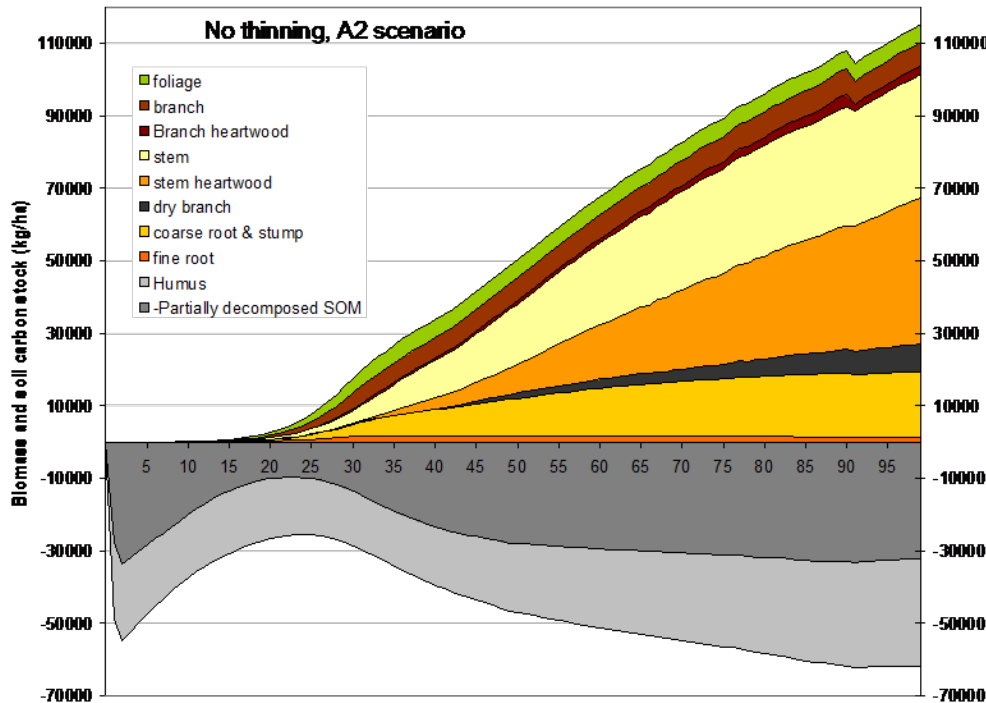


Adaptation of forest management chains to increase profitability of forestry

- Economic optimization of of forest management chains in current (below) and changing climate



Current methods and challenges



Our process-based models predict dynamics of biomass and soil organic matter in current and changing climate

Economic optimization of forest management and development of stand growth models

Models applied in optimization study will include

- Feedbacks of nitrogen dynamics between soil and vegetation
- Effects of soil water availability on production potential
- Effect of phenology
- Dynamics of the amount and quality of dead wood
- Submodel for diversity of the species dependent on dead wood
- Optimization of forest management actions represents detailed mathematically formulated multidisciplinary research

Economic optimization of forest management

- Current version of the ecological-economic model focus on timber production.
- Model will be extended into bioenergy production, forest carbon sequestration, and biodiversity.
- Optimization requires most efficient numerical optimal control methods and a vast amount of computing power (benefits from the CSC computing capacity of CREY XT4 and XT5 super-computers).

Forest Management in changing climate

- Questions to be answered
 - Which management chains maintain soil carbon stock?
 - How amount and quality of dead wood is affected by different management practices?
 - How large is amount of produced timber and carbon stock of wood products with different management chains?
 - What is optimal management chain in terms of economic profitability of forestry?

Conclusions

- Forests offer significant mitigation potential
- Potential means to increase forest C sequestration already enhanced by international agreements
- Adaptation measured under development
 - Priority to decrease vulnerability of forests to pest and pathogens in the changing conditions
 - Necessary to revise forest management recommendations after enhanced growth of forests
- Mitigation and adaptation may have conflicting interests

Thank you for your attention

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