Optimizing the management responses to the climate change in the boreal conditions - methods and findings

Findings based on the Motive studies on the northern boreal forests

Seppo Kellomäki, Timo Pukkala and Heli Peltola

University of Eastern Finland, School of Forest Sciences, Joensuu, Finland

Scope of the presentation

- Background and objectives
- Model development
- How to manage under climate change
- Conclusions

Background and objectives

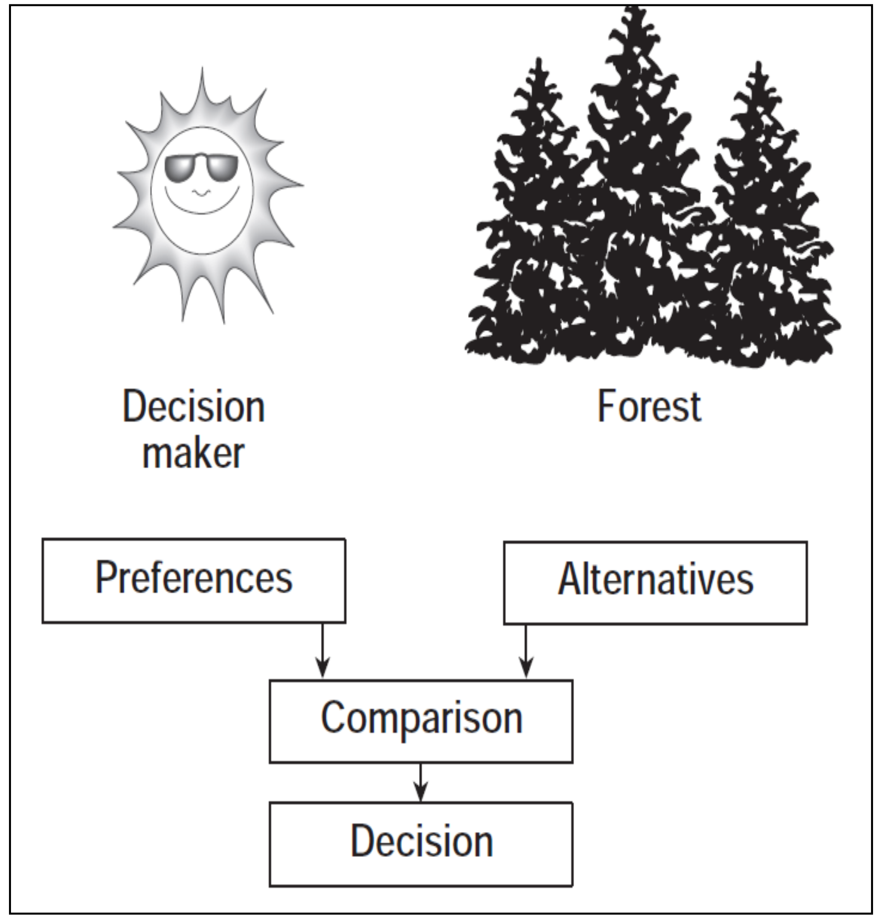
- **Under stable climatic conditions, management instructions for tree stands are expressed as recommended rotation lengths, thinning years and thinning intensities, in which the cutting years are optimized to maximize timber production or net present value.**
  - **If the true growth differs from the assumed growth rate, for instance due to climate change, management based on this kind of instructions may be non-optimal.**
  - **Under changing climate, optimization of management should produce <u>rules</u> that would allow landowners to adapt the management to changing situations.**
- **In the above context, the study demonstrates an option to introduce climate change impact into optimization of management in order to identify proper rules to adapt the management to climate change under economically uncertain conditions.**

Methodology 1(10)

- Management is optimisation problem, where the preferences of the forest owner are balanced with the constraints set by environmental conditions, legislation, economy etc.

-“Maximise income from the forest ecosystem on the conditions that the carbon storage represents a given amount”.

-Define the goals and constraints
-Produce information about alternatives
-Make decision and implement it



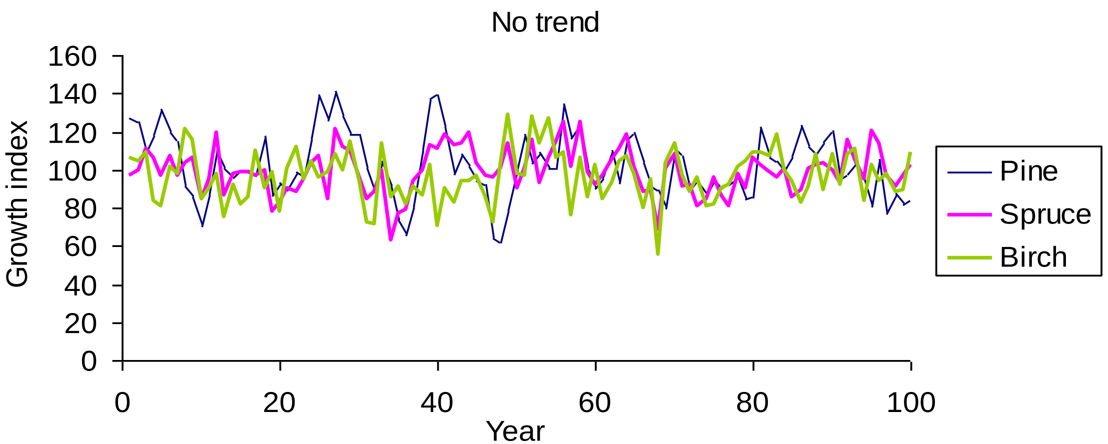
(Pukkala (2009))

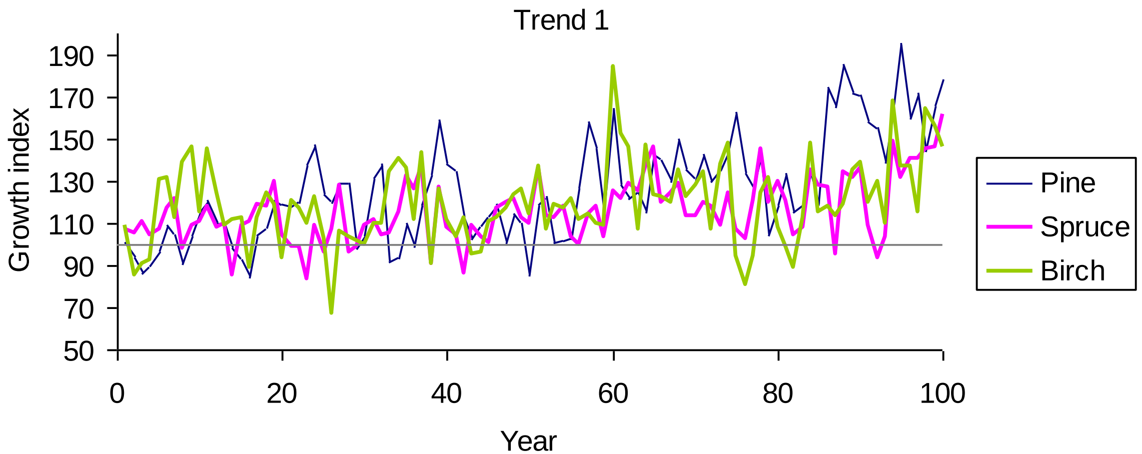
Model development 2(10)

- **To meet the study objectives, we made an planning model responsive to changing climate.**
  - **Model allows optimizing the management, if aiming at timber, sequestration of carbon and minimizing abiotic risks due to wind force and snow loading**
- **Model generates a number of treatment schedules for each stand in a selected area for varying planning periods based on a growth and yield model working properly under current climate.**
  - **Tree species choice, regeneration method, intensity and timing of thinning and rotation length can be varied in order to obtain more than one treatment schedule per stand.**

Model development 3(10)

- **Growth and yield model Monsu (e.g. Pukkala 2008) used in the model was make responsive to changing climate by correcting the radial growth under current climate with the climate change–induced change in growth.**
- **A physiological-based growth model FinnFor (e.g. Kellomäki and Väisänen 1997) was used to identify climate change-induced trend in radial growth, with year-to-year variability around the trend**

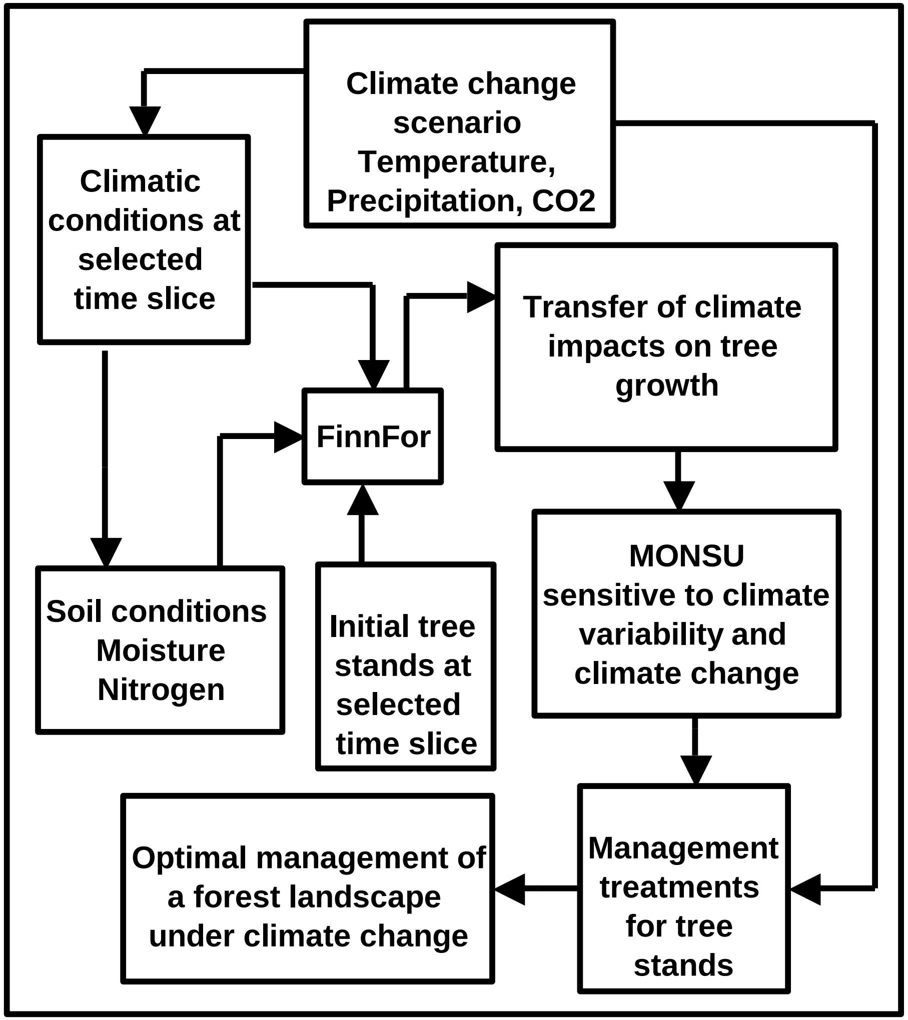




Model development 4(10)

Regarding the transfer climate change impact to growth and yield model:

- Response to climate change is species-specific
- Response to climate change is specific to maturity and position of trees
- Response is specific for spacing and position in stand
- Response is specific for site fertility
- ΔGrowth = f(climate change, site fertility, tree species, maturity (H, D), spacing, position in stand)

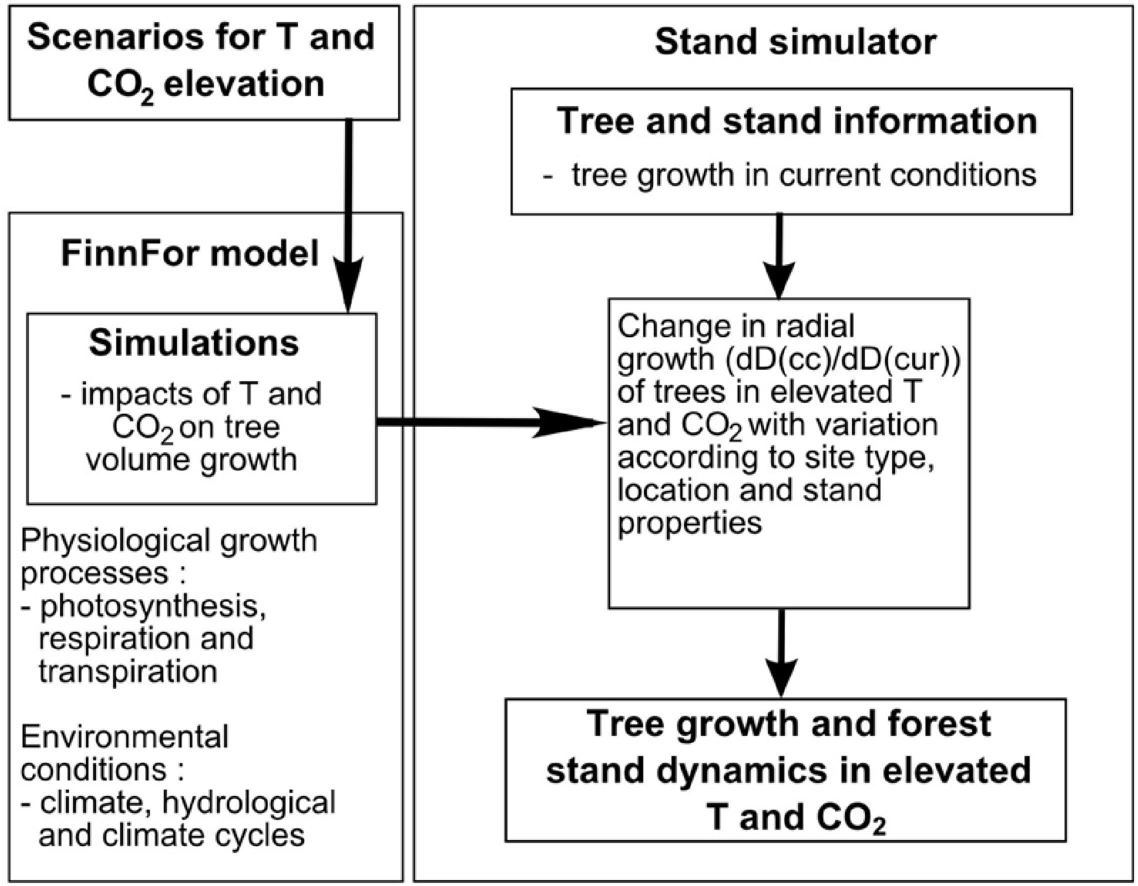


Model development 5(10)

•Ratio (relative change) between diameter growth under the current (dD(CUR) and changing (dD(CC)) climate is calculated for the 10-year periods.

•dD(CC)/dD(CUR) = f(site type, stand density, diameter, tree position, climate change(ΔT, ΔPr, ΔCO_2))

- •where ΔT is the change in temperature, ΔPr the change in precipitation and ΔCO_2 the change in atmospheric CO_2.



Model development 6(10)

In simulations:

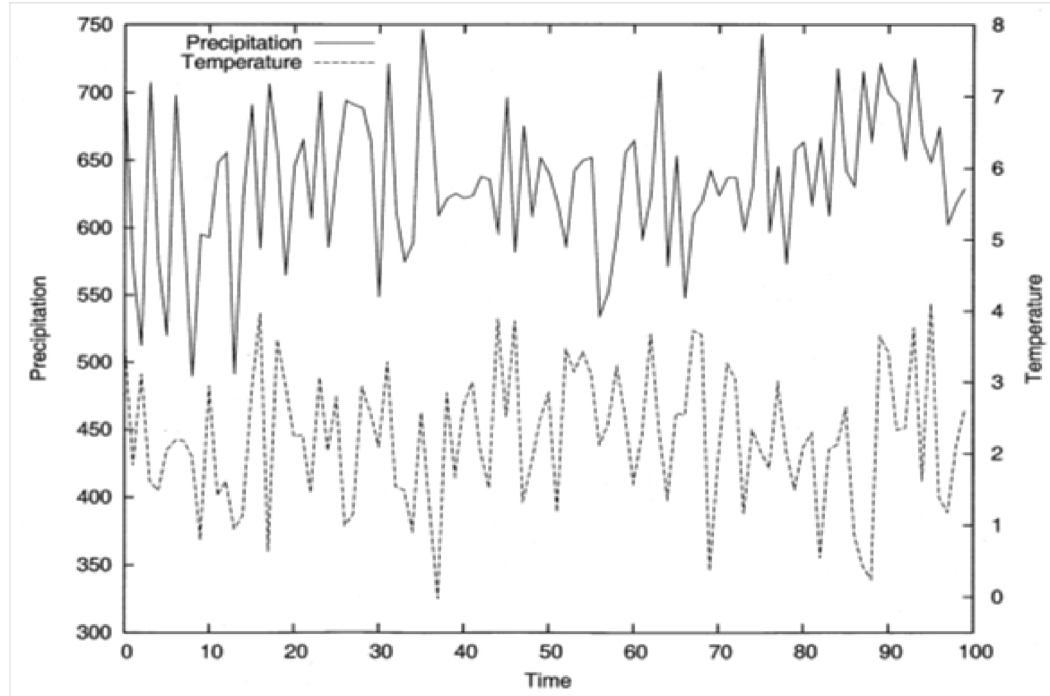
- Climate scenarios (current and changing ones) were cut in ten-year periods.
- Daily values of weather factors were used in the calculations, which utilize the initial tree stands described right.
- Simulations were done for all the density classes with three cohorts applying the all the diameter classes given left.

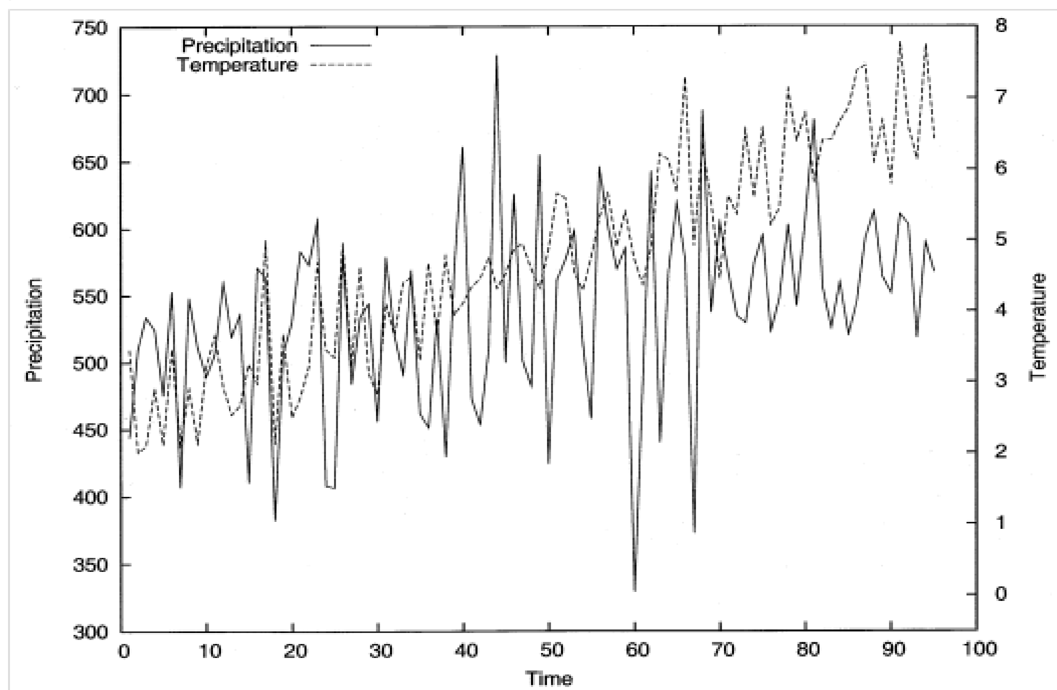
Mean diameter at the height 1.3 m), cm	Stand density, trees/ha in each cohort
3 (±2) 5 (±2) 7 etc. 9 11 13 15 17 19 21 23 25 27 29 31 33 Values in parenthesis indicate the smallest and largest diameter of trees cohorts in diameter class	600 (200 + 200 + 200 per cohort) 900 (300 + 300 + 300 per cohort) 1200 (400 + 400 + 400 per cohort) 1500 (500 + 500 + 500 per cohort) 1800 (600 + 600 + 600 per cohort) 2100 (700 + 700 + 700 per cohort) 2400 (800 + 800 + 800 per cohort) 2700 (900 + 900 + 900 per cohort) 3000 (1000 + 1000 + 1000 per cohort)

Model development 7(10)

- **The current climate represents the weather statistics (1961 - 2000) for the Joensuu airport close to the case study area (N 62° 40’, E 29° 38’, asl 94 m).**

- **The changing climate (2000 – 2100) represents the scenario provided by Motive based on the A1B downscale to the Joensuu airport**



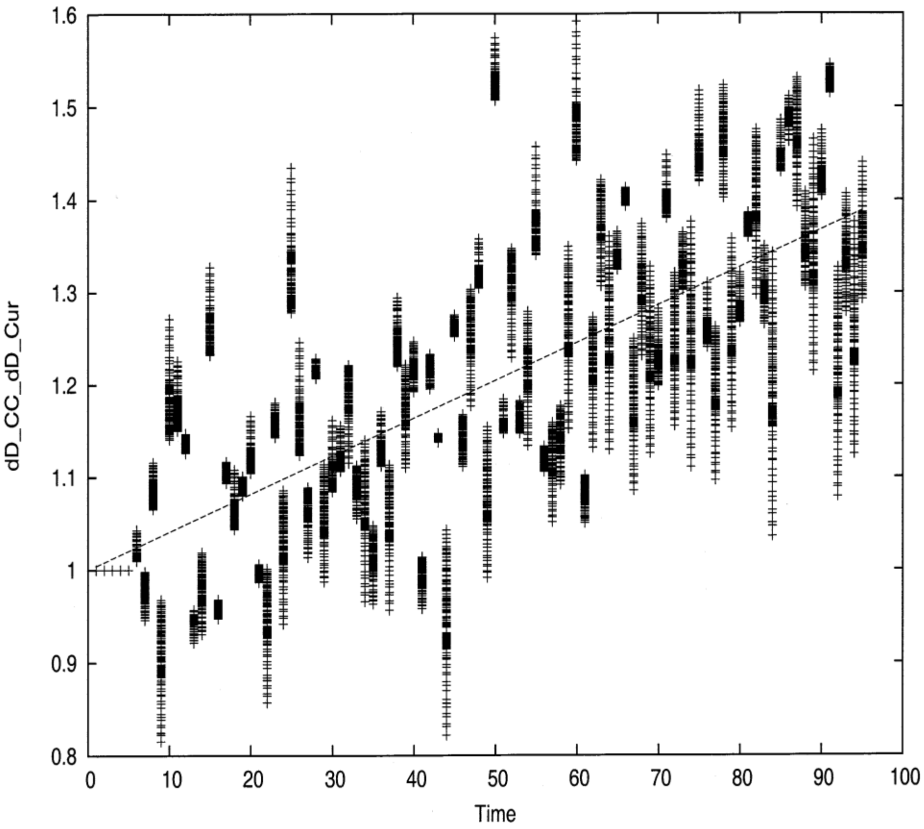


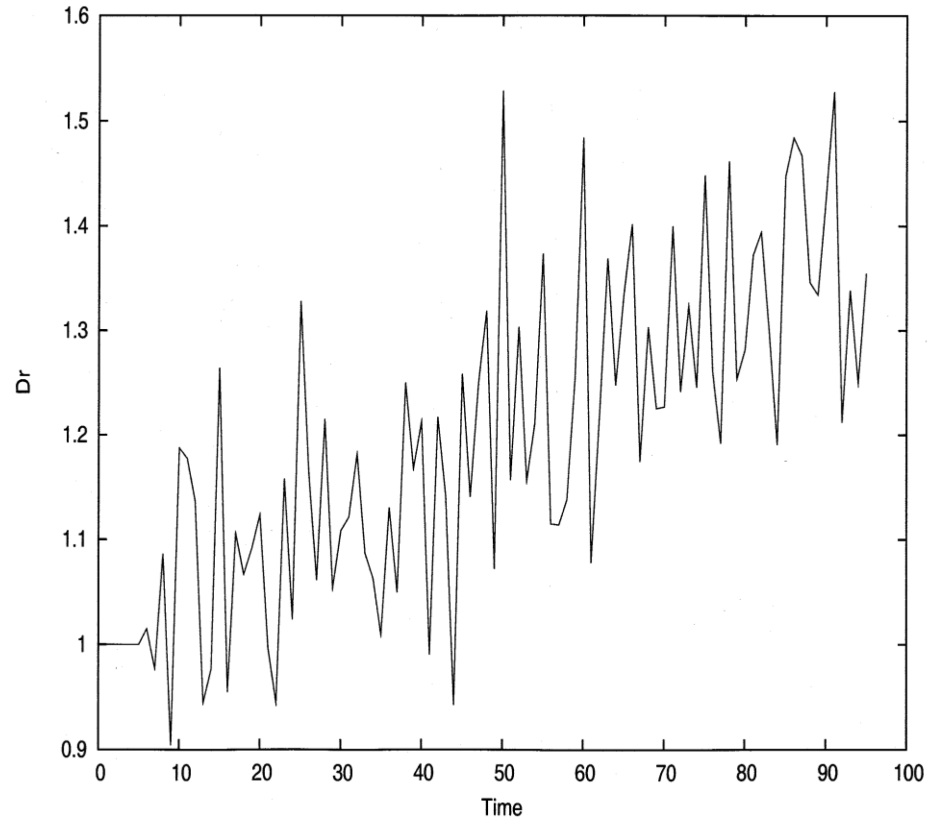
Model development 8(10)

- Climate change impact in terms of photosynthetic production and the consequent growth is specific for tree species and the availability of nitrogen, which controls the nitrogen content of foliage.
- Constant nitrogen constant in foliage over the life span of trees are used as given in Table right.
- Nitrogen content is linked to the forest type and further to the fertility of the site as indicated the dominant height at the age of 100 years.

Species	Site type	Site fertility, H_{100} or H_{50}	Nitrogen content, %
Scots pine	OMT MT VT CT	30 27 24 18	2.43 1.90 1,30 0.54
Norway spruce	OMT MT	30 27	3.74 2.92
Birch	OMT MT	26 24	4.68 3.65

Model development 9(10)





Left: Clusters of points represents how all the combinations of initial stands respond to the climate change in a particular slice of time with the given climatic conditions. Right: the same as in the left, but for the mean values of the correction factors representing each cluster.

Model development 10(10)

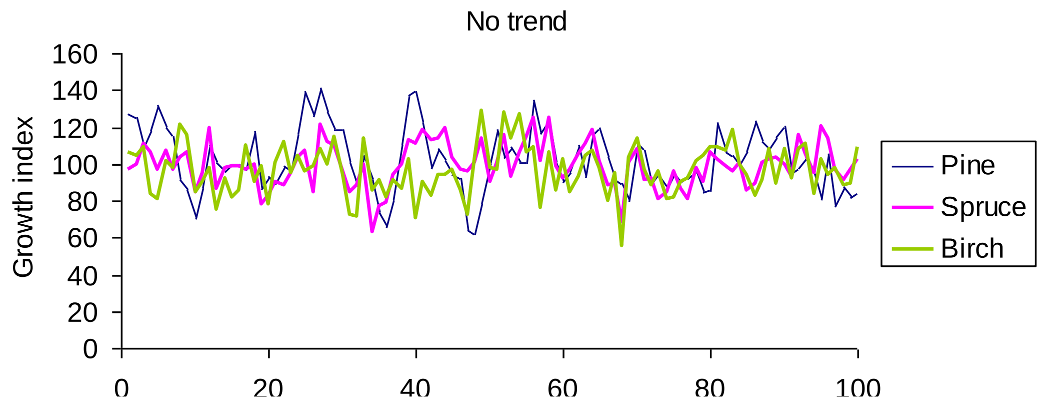
- Regardless of trees species, the climate change increased radial growth more on poor sites than on fertile sites.
- On the site of same fertility, the climate change increased radial growth more in Scots pine than in Norway spruce and birch.
- On the site of same fertility, the climate change increased the radial growth more in birch than in Norway spruce
- Growth increase:

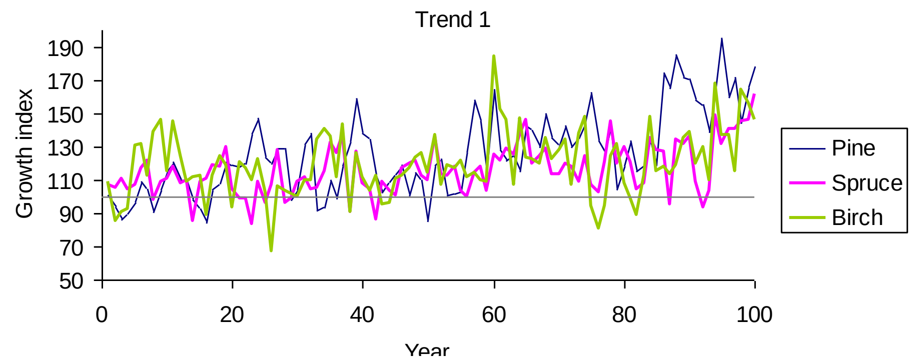
Norway spruce < birch < Scots pine

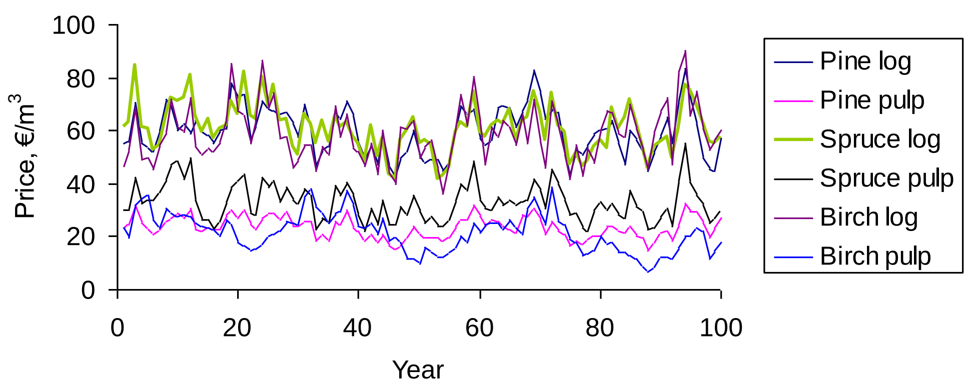
Species	Site type	Trend for radial growth, % per year
Scots pine	OMT MT VT CT	0.362 0.414 0.523 0.596
Norway spruce	OMT MT	0.266 0.293
Birch	OMT MT	0.328 0.334

Simulation example 1(3)

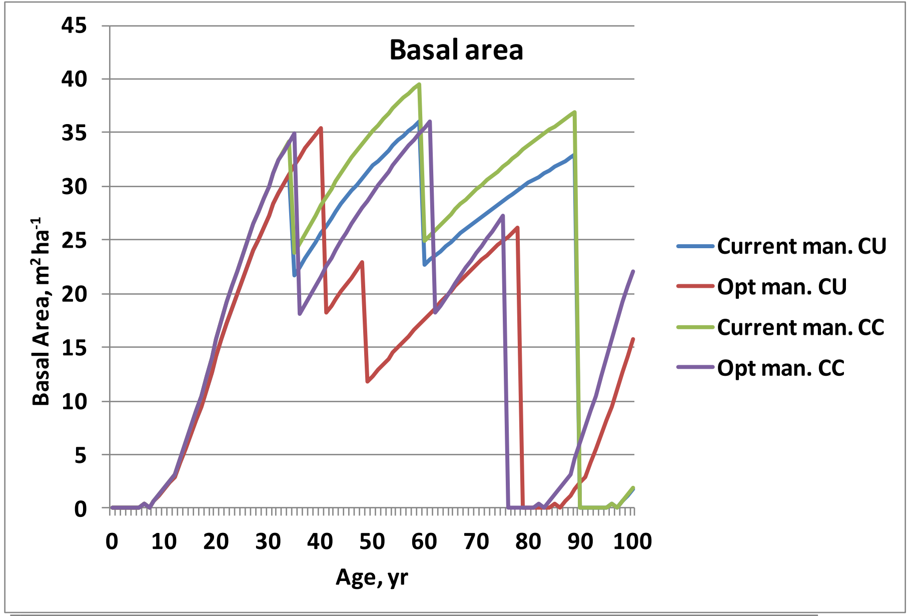
- **Initial stand**: planted Scots pine and Norway spruce (2500 seedling/ha) on sites of varying fertility.
- **Climate**: current (1961 - 2000) and changing (2000 – 2100) provided by Motive consortium.
- **Growth trend**: not included or included.
- **Management options**: timing and intensity of thinning based on dominant height/basal area rule, timing of terminal cut based on the mean diameter criterion
- **Timber prices**: stochastic
- **Optimization:** maximizing net present value (NPV)

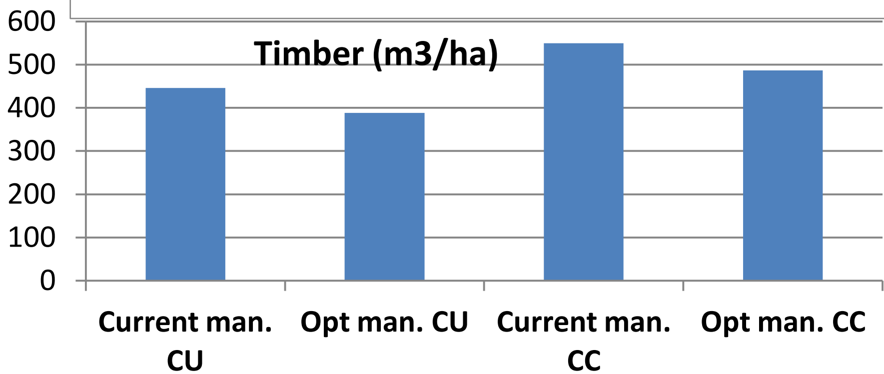


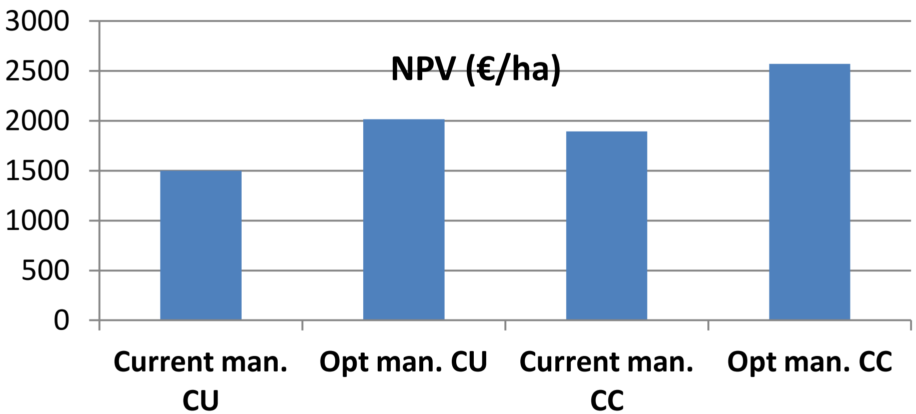




Simulation example 2(3)







Calculations

Scots pine under current (CU) and changing climate (CC) on poor site, initial stand density 2500 seedlings/ha.

- In optimized management, the timing of thinning and final cut are determined based on the value growth of trees. If it is more profitable (higher NPV with 3 % interest rate) to make thinning or final cut, then harvesting is done, and vice versa.

Under the current climate

- optimized management (red line) delayed the first thinning, but made the second thinning and final cut clearly earlier compared to current management (blue line).

Under the changing climate

- Climate change enhanced the basal area development, timber production and increased NPV.

- In optimized management, the first and second thinning were done at the same time as in current management, even though they were more intensive than in current management (violet line). Final cut was earlier in optimized than in current management (green line).

Simulation example 3(3)

Optimized management compared to management following the current rules for Scots pine and Norway spruce under the current and changing climate on sites of varying fertility on the northern-boreal case study area

Climate, species, site	First thinning	Second thinning	Final cut
Current climate			
• Scots pine, poor	Delayed, more intensive	Earlier, same intensive	Earlier
• Scots pine, medium	Delayed, more intensive	Earlier, same intensive	Earlier
• Norway spruce, medium	Delayed, more intensive	Delayed, more intensive	Later
• Norway spruce, rich	Delayed, more intensive	Delayed, more intensive	Later
Changing climate			
• Scots pine, poor	Same timing, more intensive	Same timing, more intensive	Earlier
• Scots pine, medium	Delayed, more intensive	Delayed, same intensive	Later
• Norway spruce, medium	Earlier, more intensive	Same timing, same intensive	Earlier
• Norway spruce, rich	Delayed, more intensive	Same timing, more intensive	Earlier

Summary

- Forest management involves considerable amount of uncertainty related to future timber prices and tree growth, which is likely to be changed under the climate change.
- Climate-induced change in tree growth was introduced into a forest planning model in order to identify proper timing of thinning and length of rotation.
- Outcome of optimization will be a rule, that shows to landowner how the optimal cutting decision (e.g. timing of thinning and terminal cut) depends of stand structure and timber prices under changing climate
- In the case study area, ascending growth trend was evident, with an increase of the optimal growing stock reduction of optimal rotation
- Preferring tree species mixture may be feasible under changing climate, whenever site fertility makes it possible.
- Risks related to timber price and growth tended to increase rotation length.

- Reference: Pukkala, T. and Kellomäki, S. 2012. Anticipatory vs. adaptive optimization of stand management when tree growth and timber price are stochastic. An International Journal of Forest Research. In print.