Forest vegetation and management practices in changing climate

Raisa Mäkipää, Natural Resources Institute, Finland

Conference on Forest ecosystems in the conditions of climate change,

17-19 May 2017, Yoshkar-Ola, Mari El, Russia

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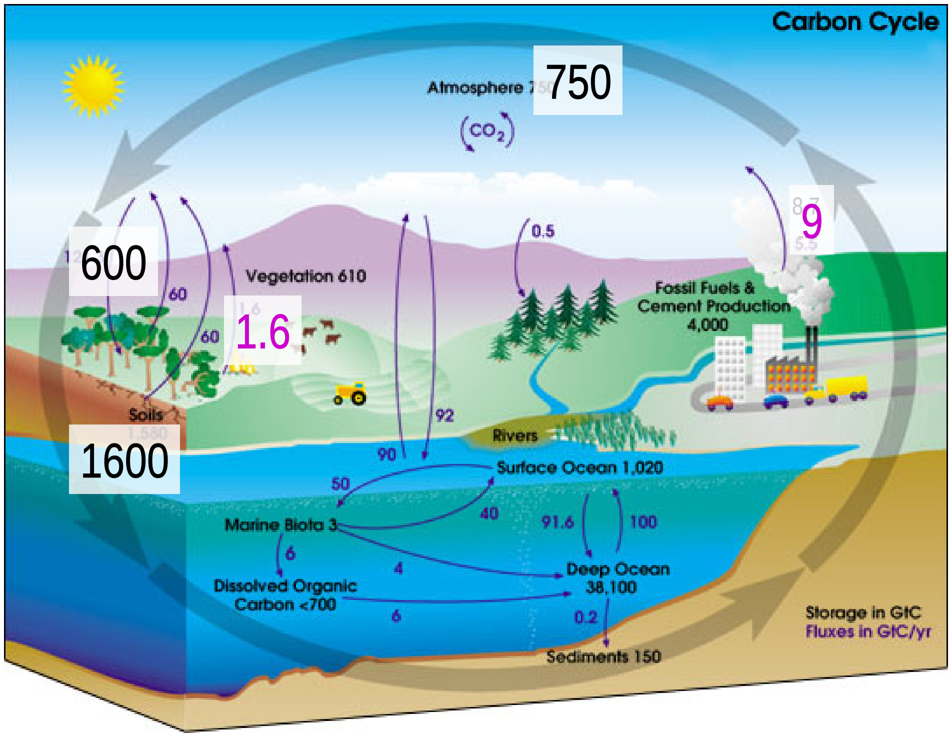
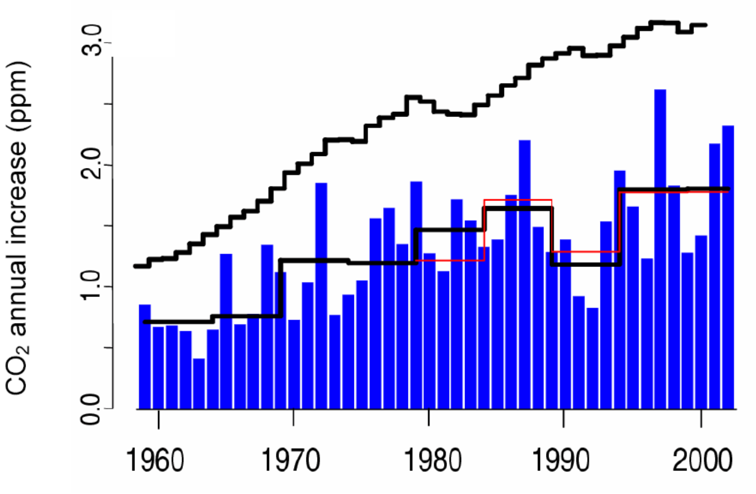
Role of forests in the global carbon balance





Source: www.globalcarbonproject.org and IPCC 4thAR

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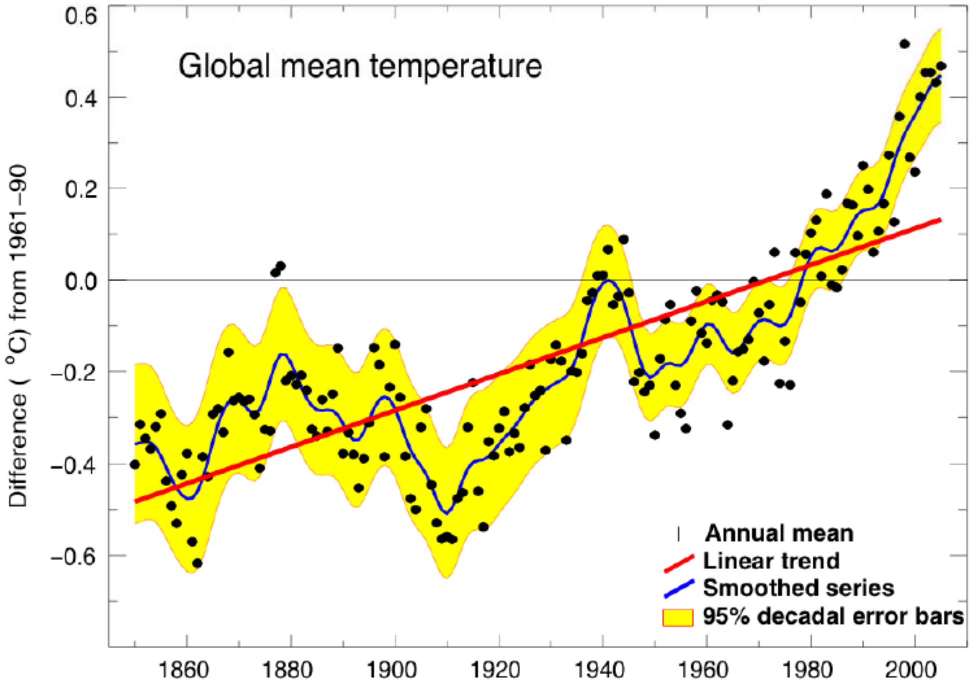
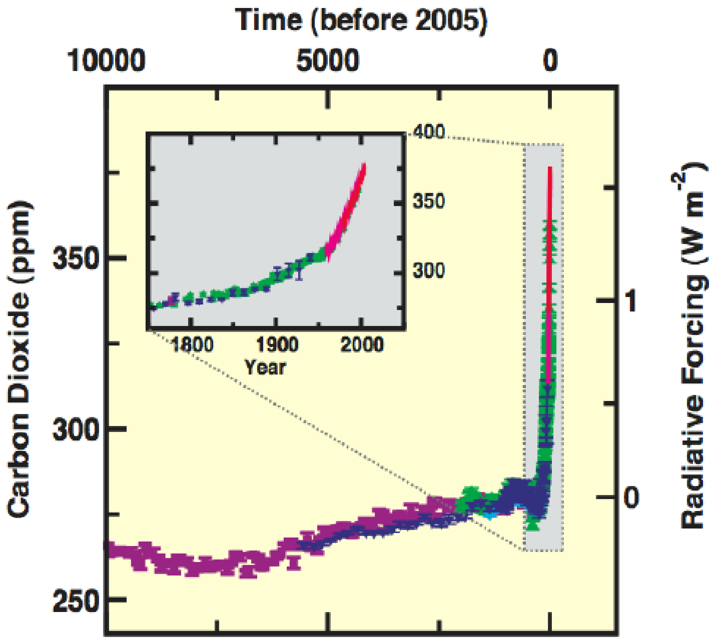
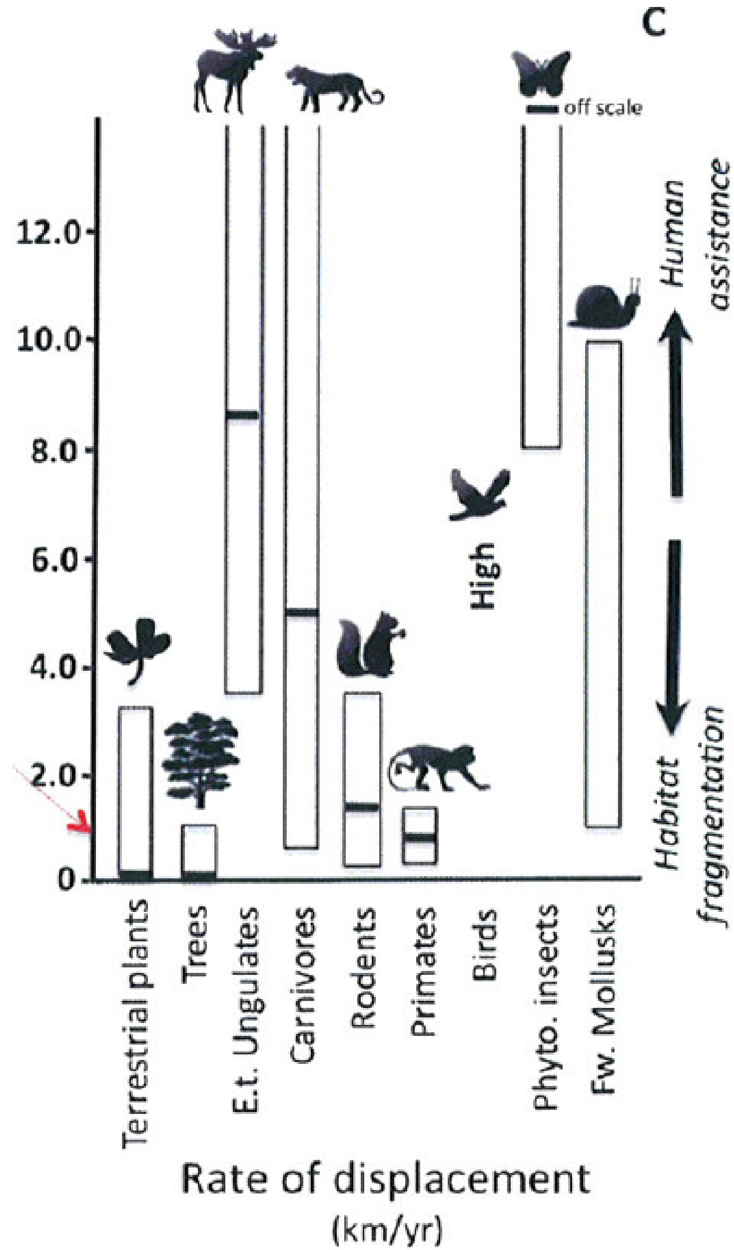
Rate of warming accelerated





Over the 70-year period mean annual temperature increased by 0.78°C as a results of increased CO_2 concentrations (IPCC 4AR 2006). Fenological events advanced by 10 days in 100 years (Linkosalo et al. 2009).

Who can adapt?



Source: IPCC WGII Fig. TS.8

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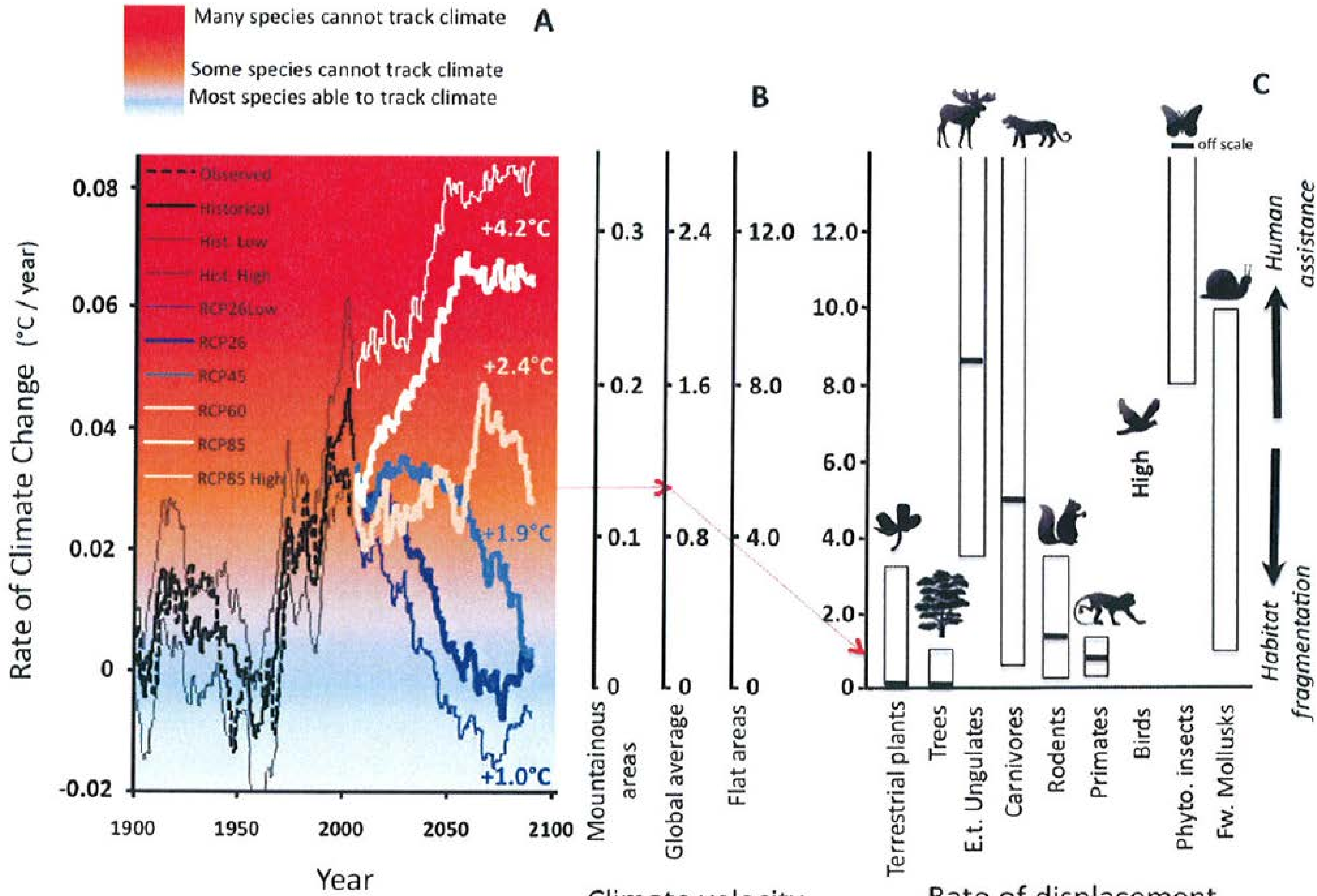
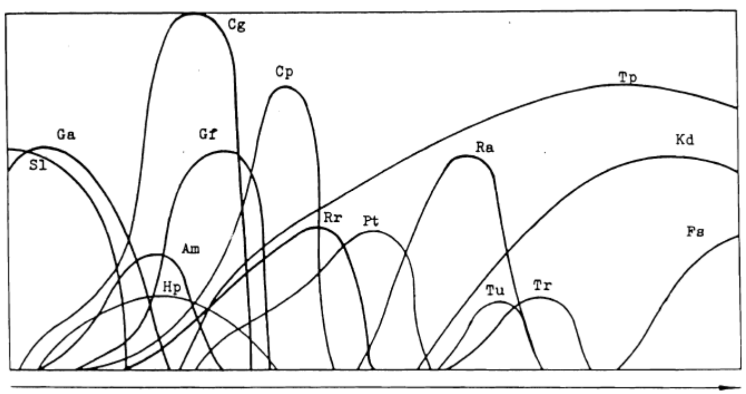


Source: IPCC WGII Fig. TS.8

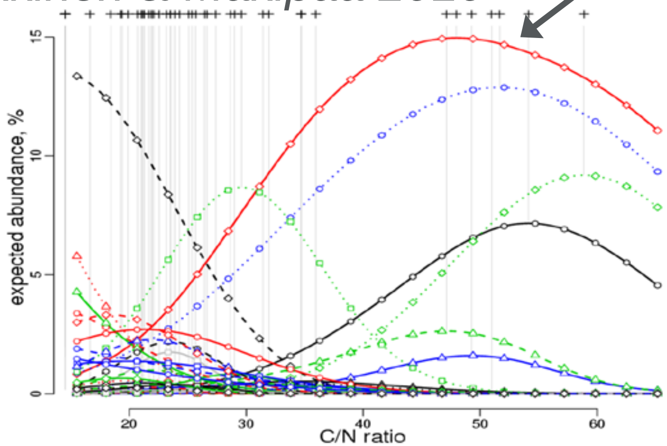
Predicting changes in the species' range of distribution

- We can constructed species-specific response models to environmental factors (including temperature)

Ramenskii 1925, Olskol River

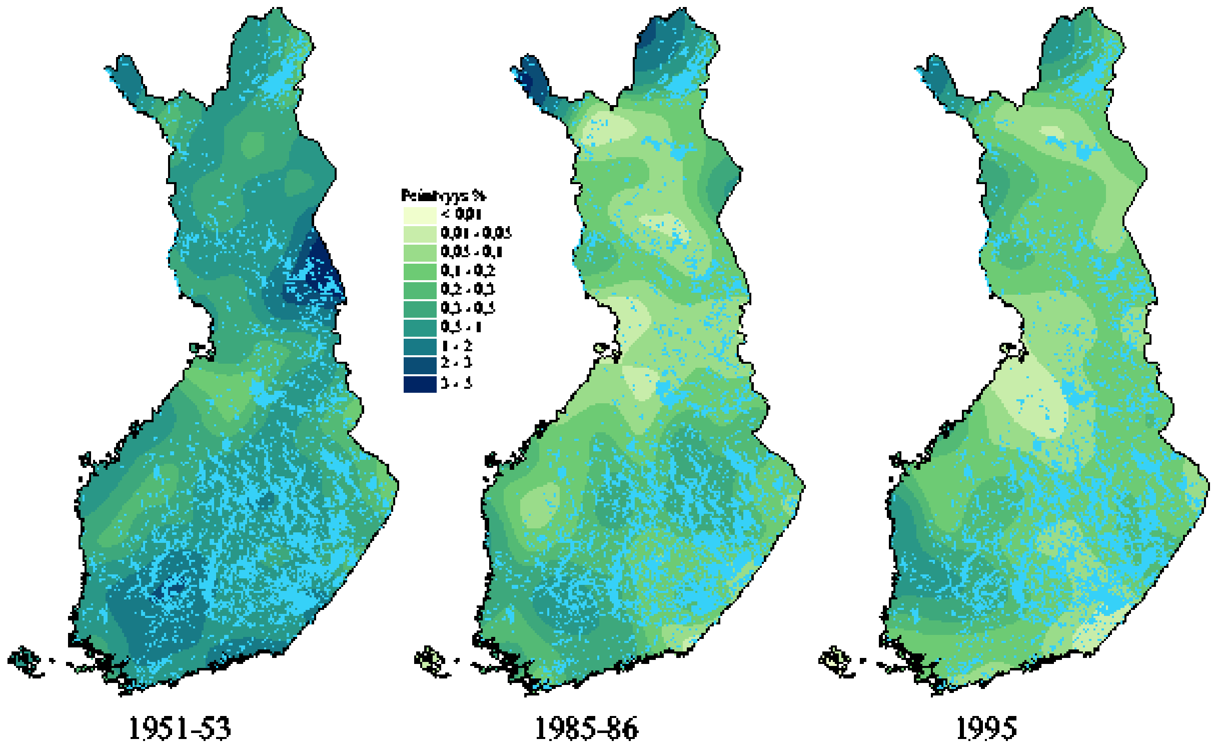


Heikkinen & Mäkipää 2010



- Then, we can predict future range of geographical distribution in changing climate

Changes in the abundance of plants species monitored since 1951 as a sub-study of the Finnish national forest inventory



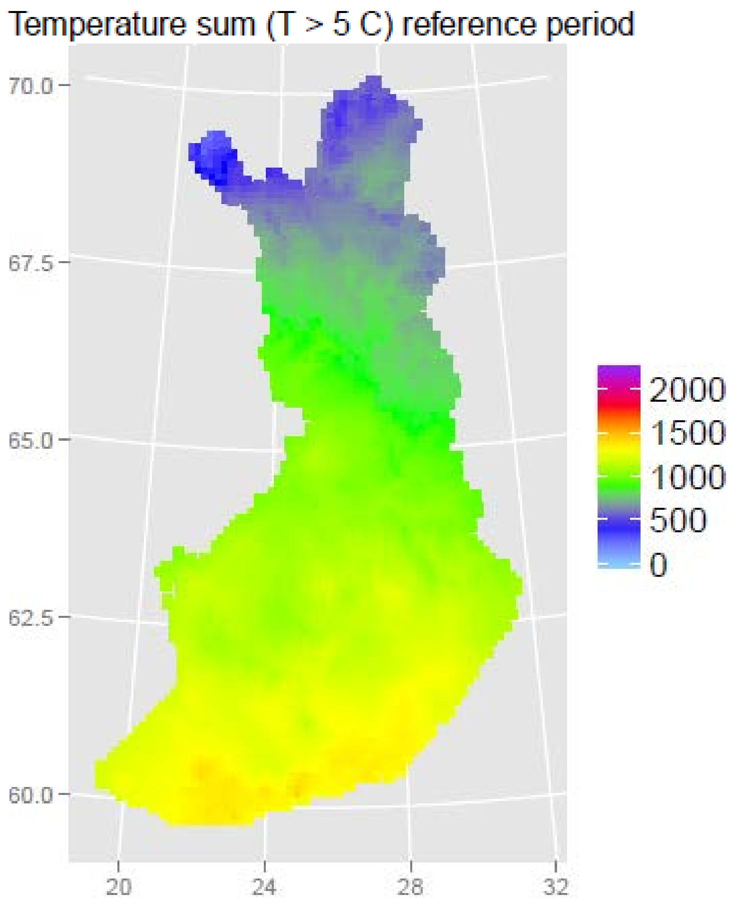
Abundance of twinflower (*Linnaea borealis*)

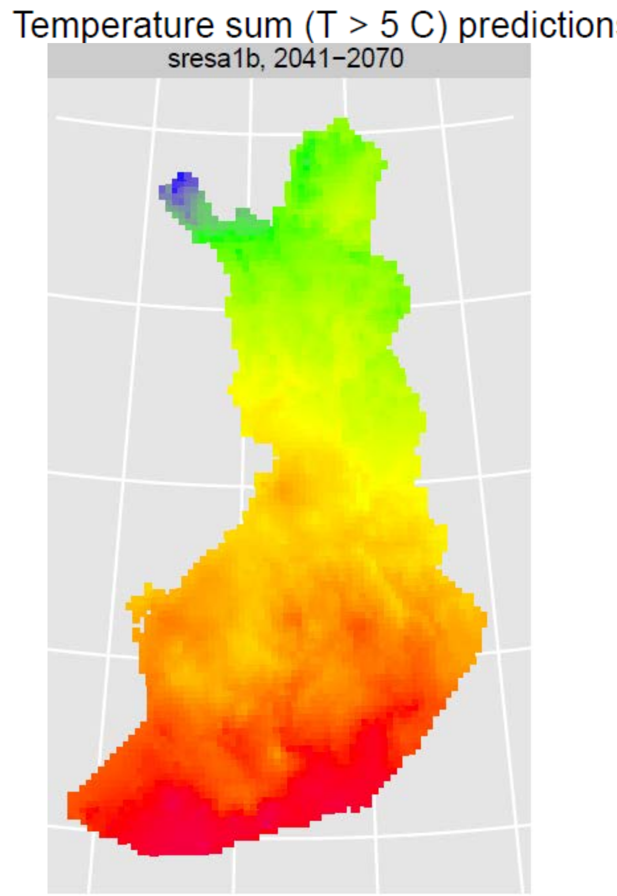
Source: Reinikainen, Mäkipää et al. (eds). 2000. Kasvit muuttuvassa metsäluonnossa. Tammi.

Modelling of plant species' responses to environmental variables

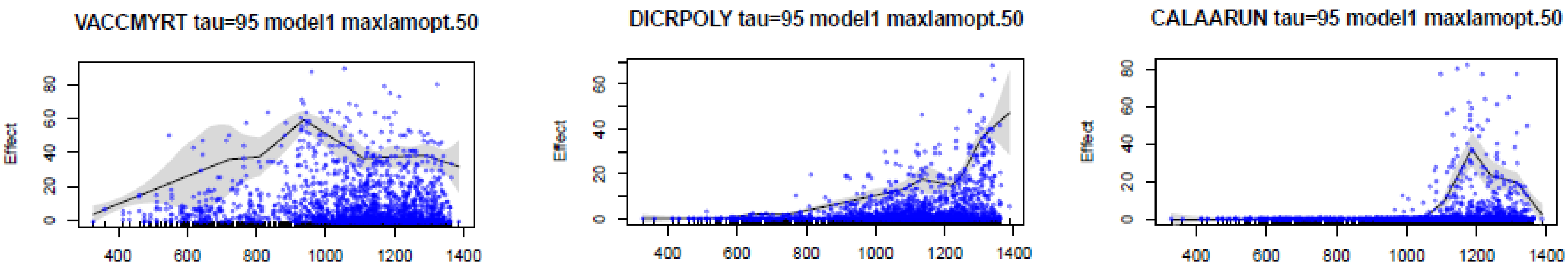
- Finnish nation-wide vegetation abundance data from 3000 sample plots.
- Soil data from a sub-sample of the plots (n=500).
- Climate data and future climate prediction in a grid scale of 1 x 1 km^2 and 10 x 10 km^2, respectively.
- Quantile regression models on species' abundance along a temperature gradient and other environmental variables
- Spatial predictions of species potential future distribution

Predicted climate change





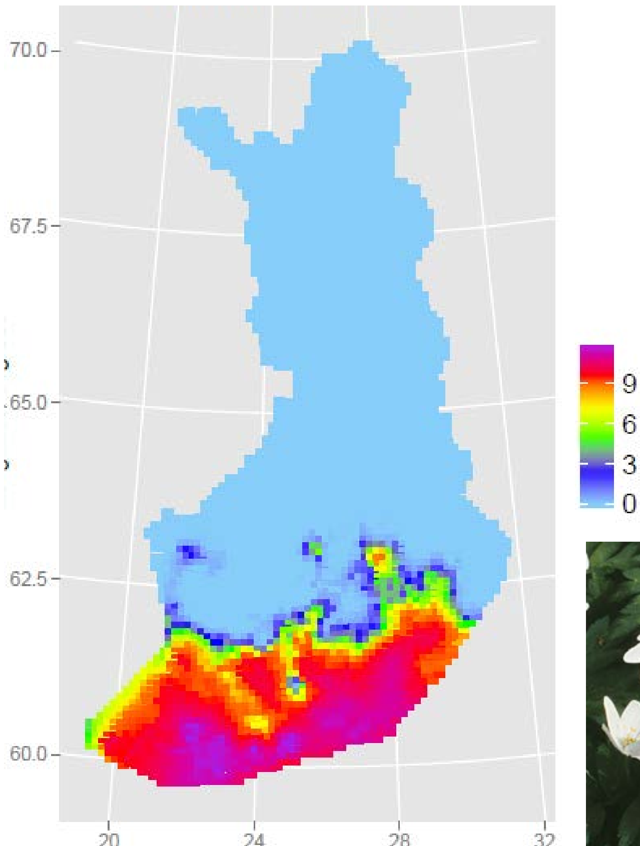
Quantile regression models for species responses



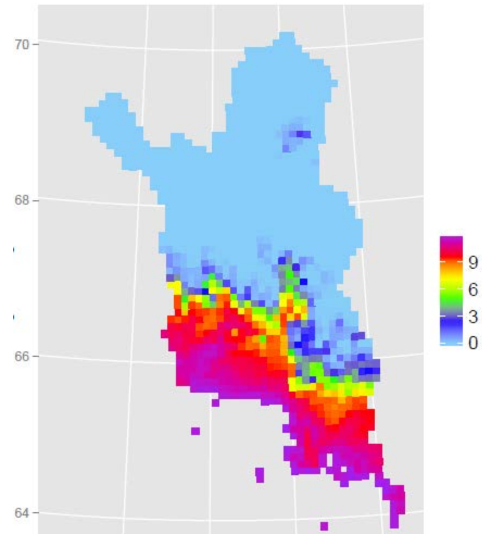
- To analyse maximum ecological response
- To estimate the effect of a limiting factor when it is actually known that other factors could be the active limiting constraint at some locations (Cade et al. 2005, Austin 2007)
- Especially suited to forecast the fate of species under future scenarios of climate change (see Jarema et al. 2009)

Predicted change in potential abundance, wood anemone (*Anemone nemorosa)*

Abundance 1985

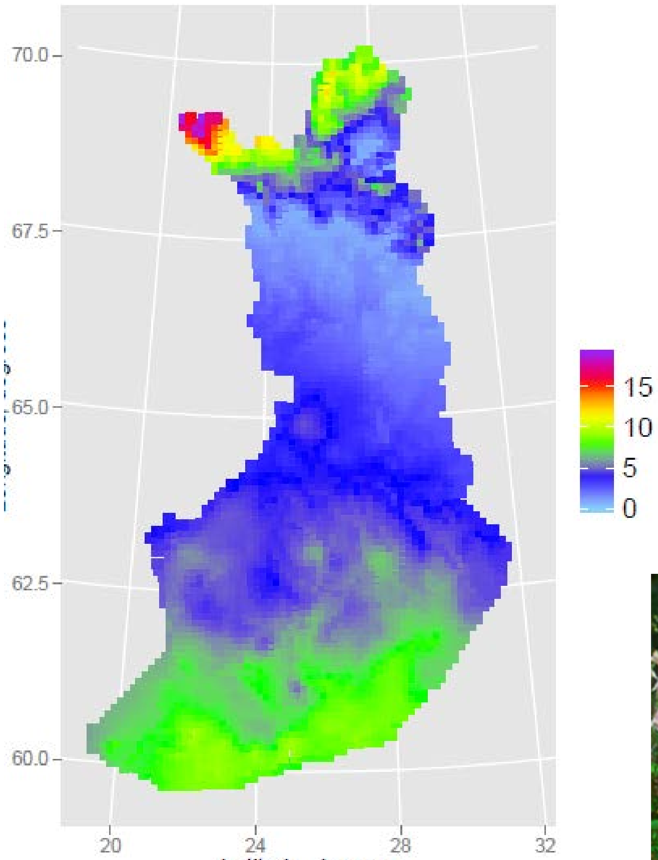


Predicted abundance, 2041-2070 climate

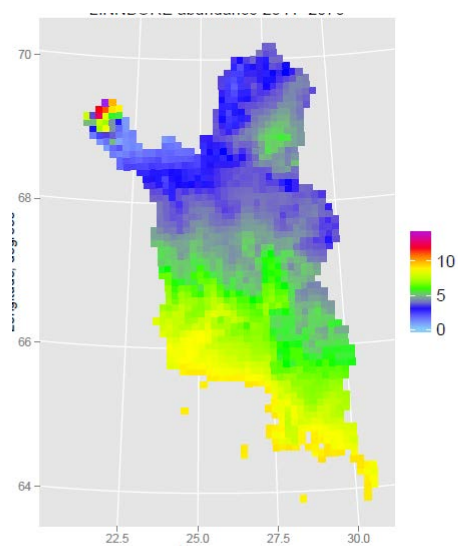


Predicted change in potential abundance, twinflower (*Linnea borealis)*

Abundance 1985

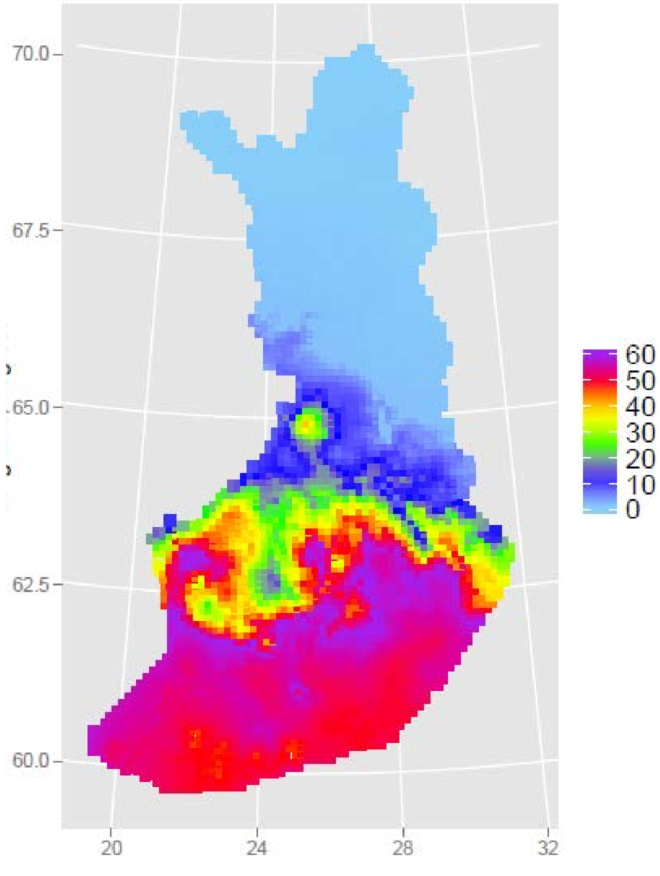


Predicted abundance, 2041-2070 climate

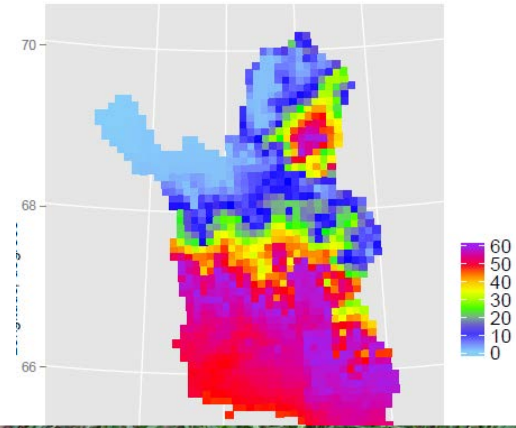


Predicted change in potential abundance Metsäkastika (*Calamagrostis arundinacea*)

Abundance 1985



Predicted abundance, 2041-2070 climate



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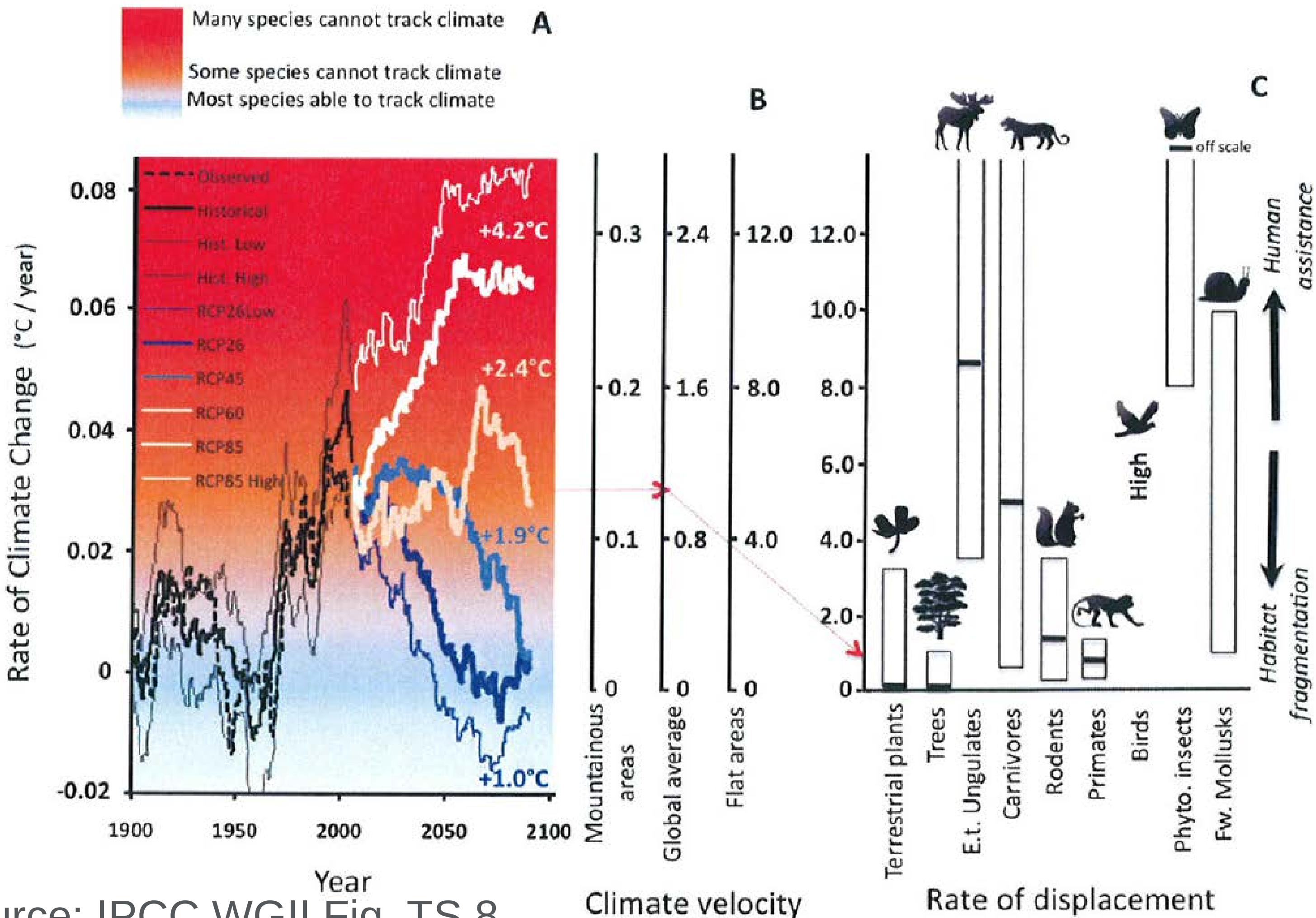
Trees in changing climate

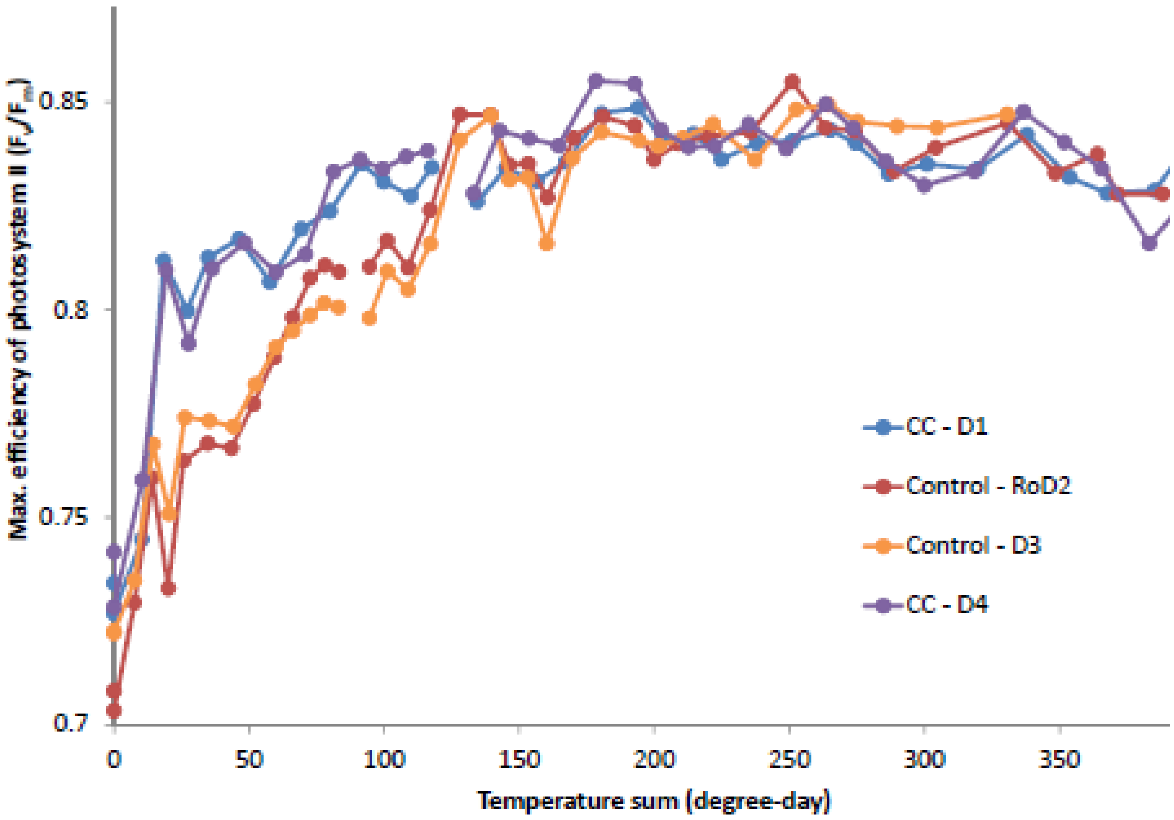
- Trees cannot track climate change by displacement – long life-span
- Are there differences in the adaptation capasity between tree species?
- Conifers and broadleaf species have different saturating temperatures for productivity:
  - 13.2 ° C for conifers and 17 ° C for birch (Linkosalo et al.)
  - 15 ° C for Norway spruce (Bergh et al. 1997), 18 ° C for Scots pine (Kellomäki in Bergh 2003), 22 °
  - 24 ° C beech (Freeman 1998)

Trees in changing climate – do they adapt?



Source: IPCC WGII Fig. TS.8

Productivity of trees affected by temperature and phenology



Elevated CO2 increase photosynthetic capasity beyond the temperature effect

 Source: Linkosalo et al 2017. Scan J For Res.

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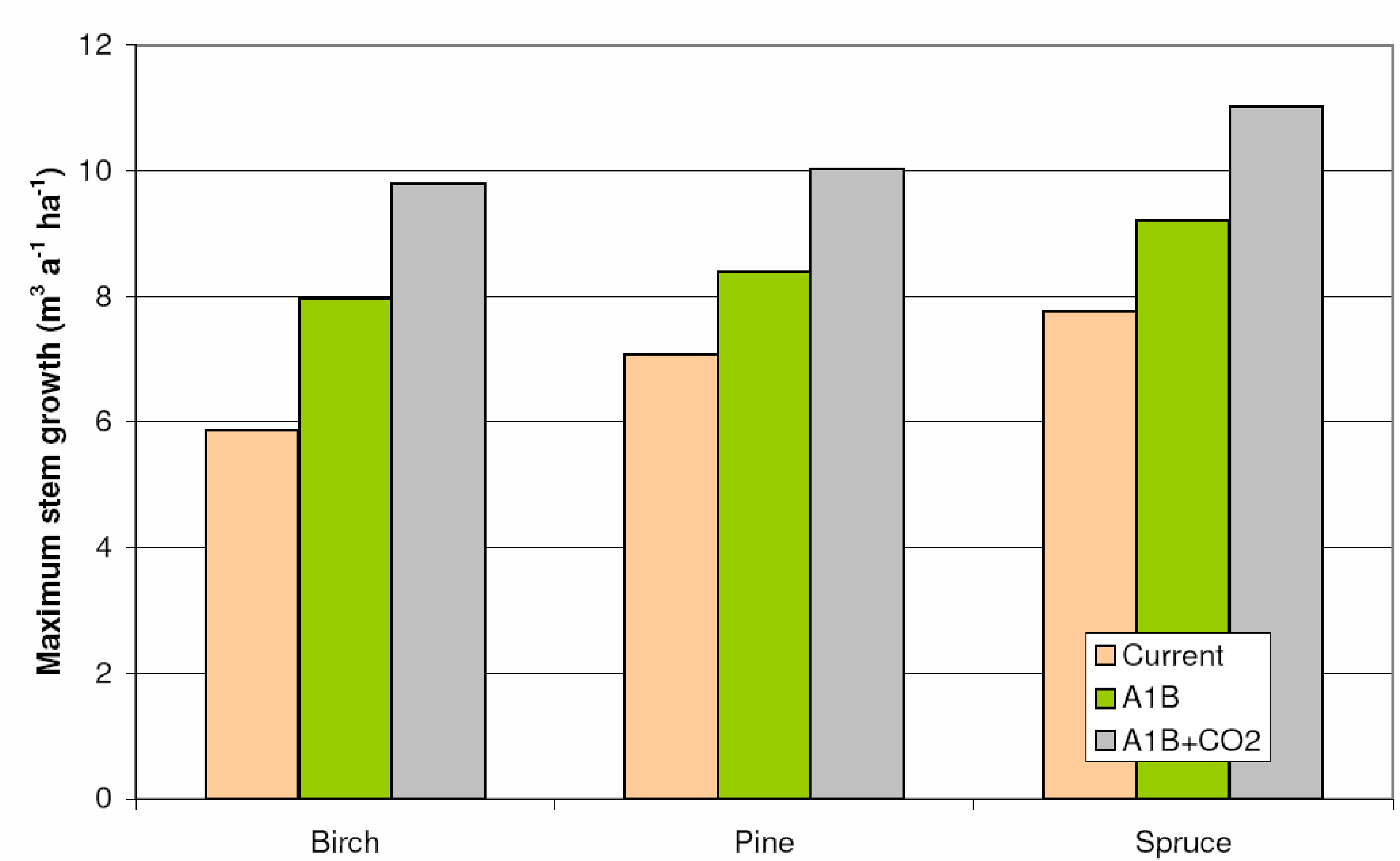
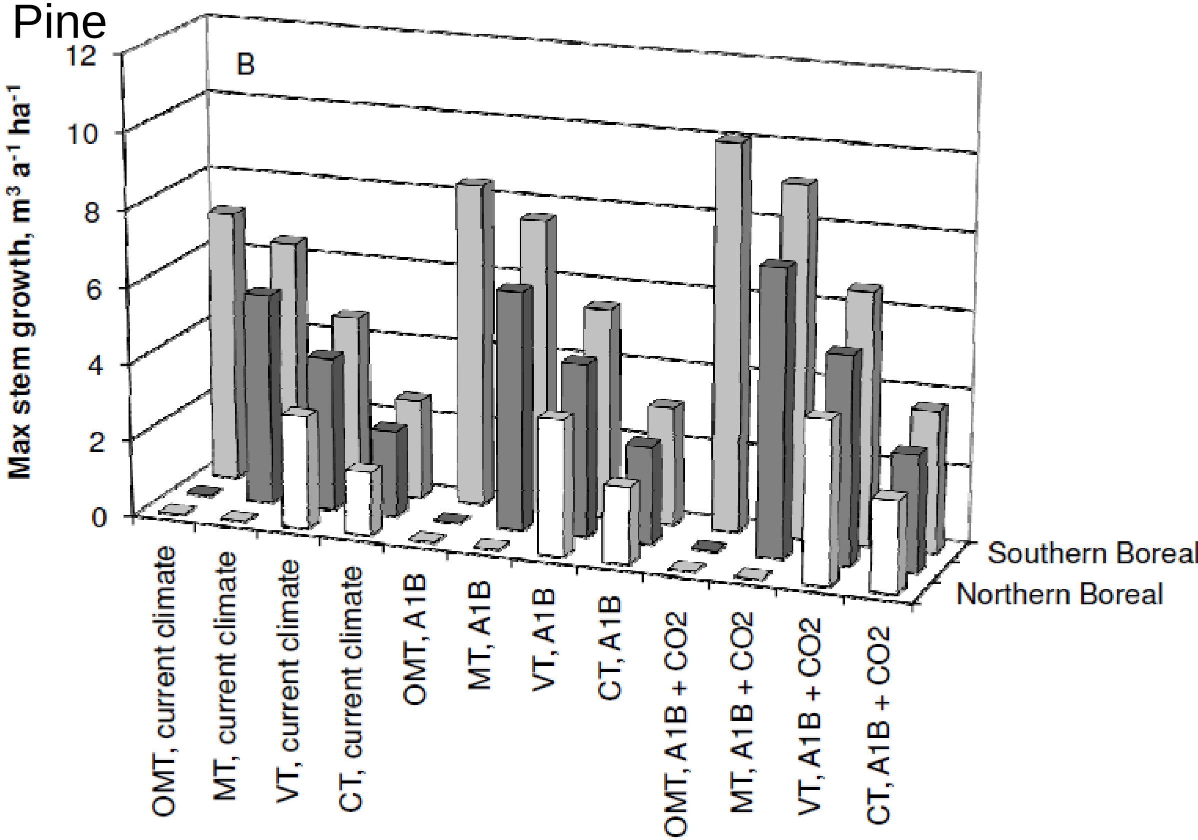
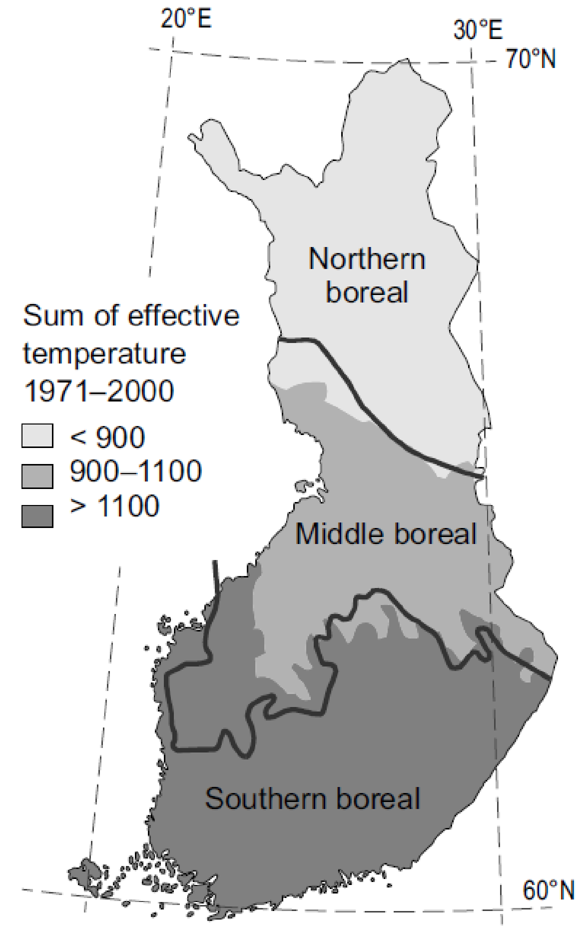
Both increased temperature and elevated CO_2 affect growth



Potential growth on fertile (OMT) sites in S Finland (Linkosalo et al. Submitted manuscr

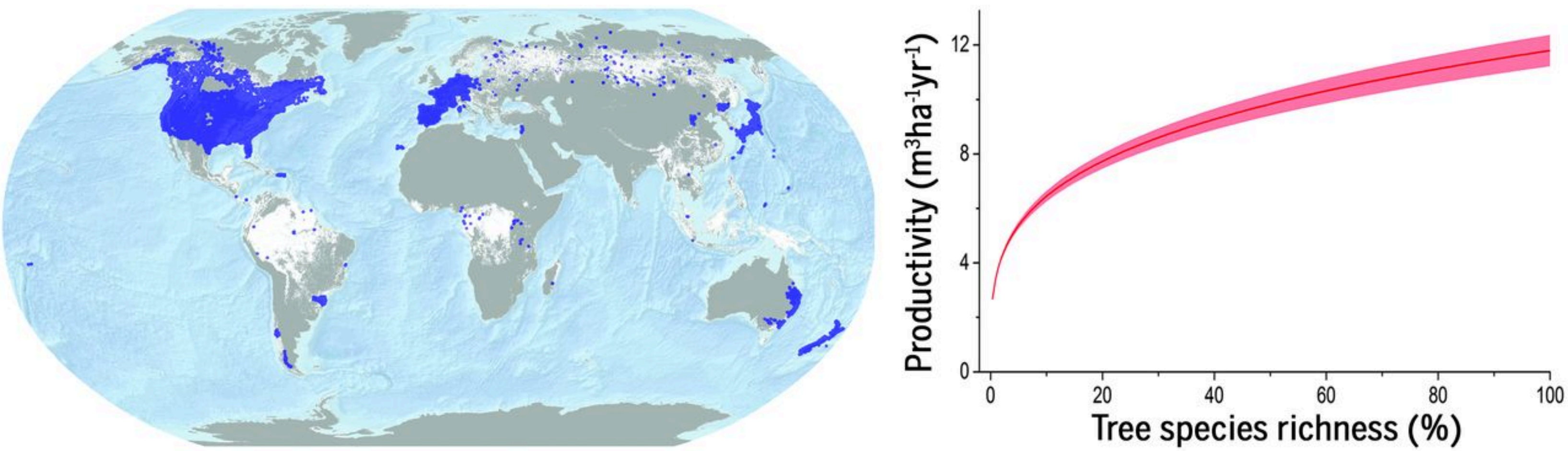
Forest growth enhanced by CO2 and temperature on all site conditions





Linkosalo et al..

Global effect of tree species diversity on forest productivity.

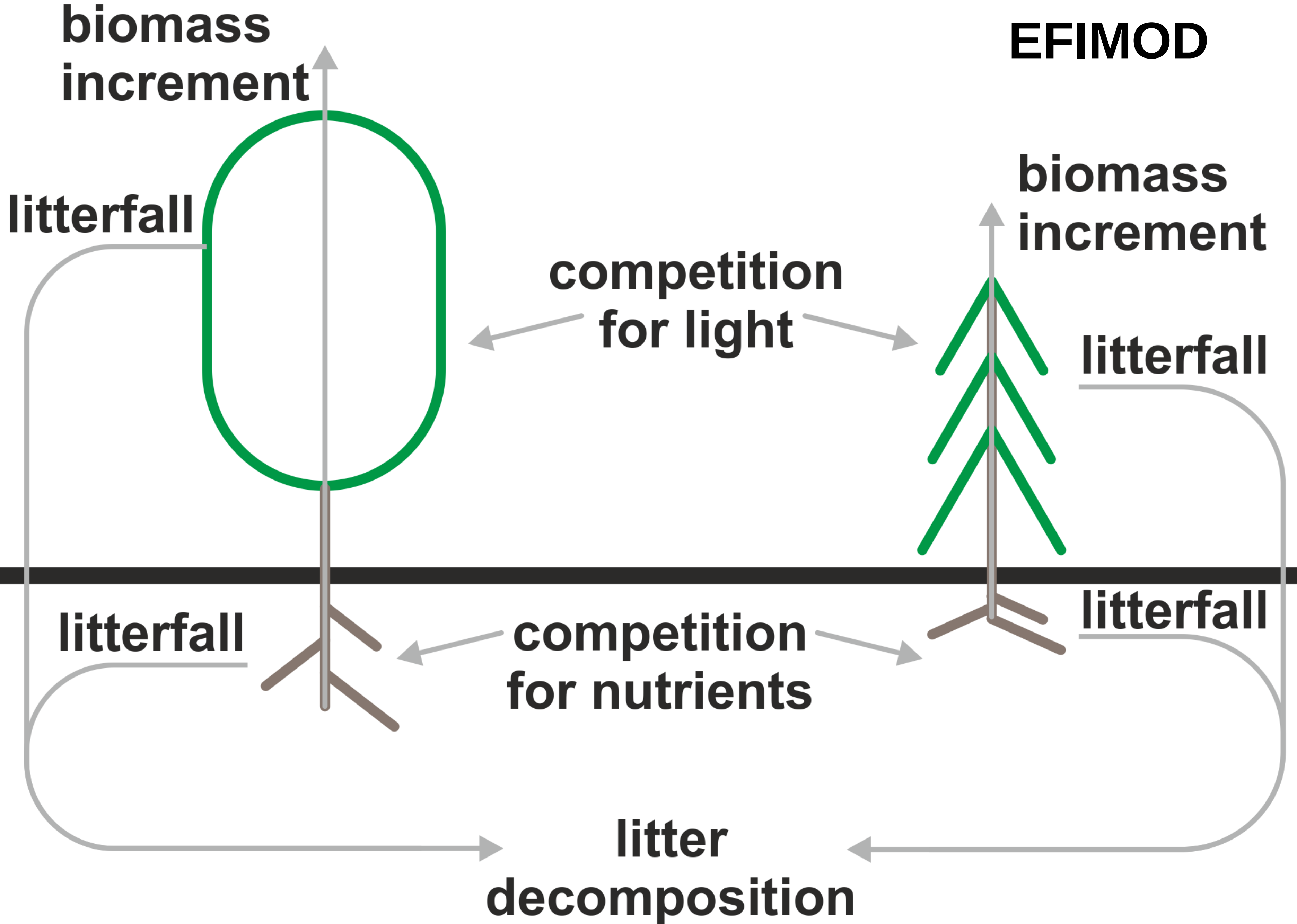


Jingjing Liang et al. Science 2016;354:aaf8957

Mixed stands in changing climate – a simulation study

- Efimod-model describes competition for both above-ground (light) and below-ground (nutrients) resources.
- Model is widely applied and published, e.g. Chertov et al. 1999, Komarov et al 2003, Palosuo et al 2008, Shanin et al. 2013

Flowchart of EFIMOD



Mixed stands in changing climate – a simulation study

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- Model is widely applied and published, e.g. Chertov et al. 1999, Komarov et al 2003, Palosuo et al 2008, Shanin et al. 2013
- Simulations on mesic site type with A1B (ECHAM5 GCM) scenario (+3.3^{o}C)
- Mixed stands with initial proportions of competitive tree species varied 90:10, 70:30, 50:50, 30:70, 10:90

Ecological Modelling 251 (2013) 232–245

Contents lists available at SciVerse ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

Carbon turnover in mixed stands: Modelling possible shifts under climate change

Vladimir Shanin[a,*], Alexander Komarov[a], Yulia Khoraskina[a], Sergey Bykhovets[a], Tapio Linkosalo[b], Raisa Mäkipää[b]

Spruce-birch mixture as well as pine dominated sites have positive response to climate change.

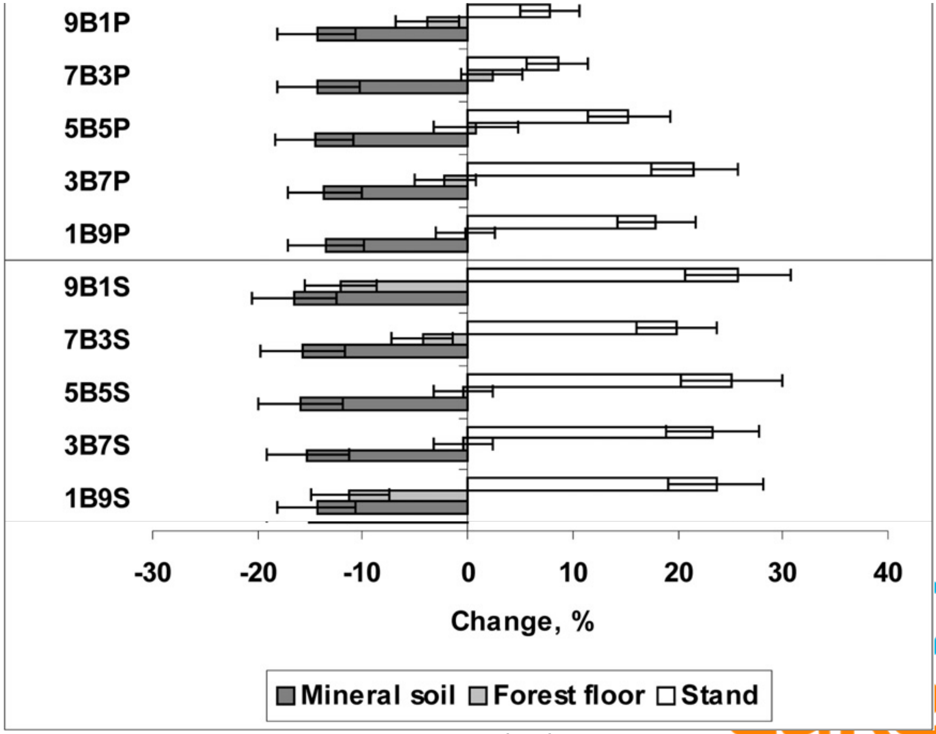
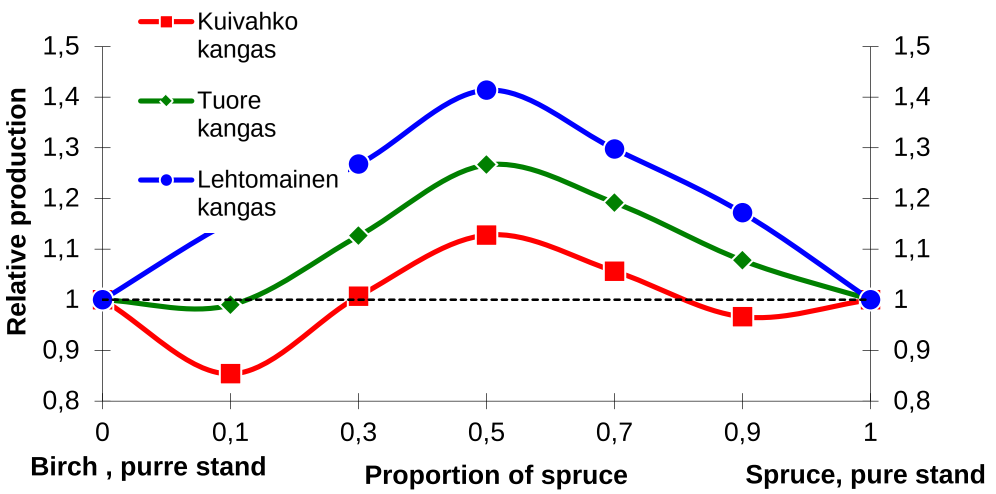


Fig. Effect of climate change on carbon stock of mixed birch-pine and birch-spruce stands. Averages over the simulation period and s.d. resulting from climatic characteristics of different climate scenarios.

Shanin, V., Komarov, A. & Mäkipää, R. Eur J Forest Res (2014) 133:273–286

Tree species composition affects productivity & carbon dynamics in boreal forests



Biomass production is higher in stands of multiple species and the effect is largest in most fertile sites.

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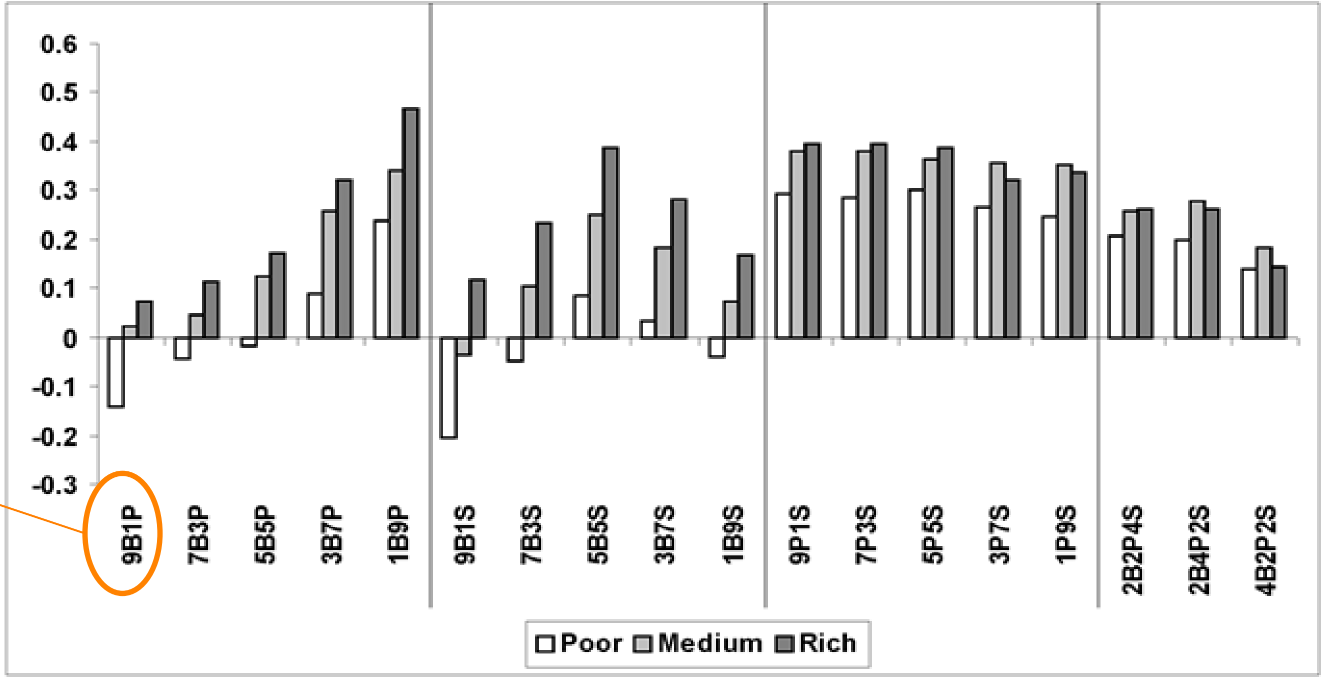
Mixed stands are productive

9B1P = 90% Birch & 10% of Pine



The mixed forest stands of two or three competing tree species (*Picea abies*, *Pinus sylvestris* and *Betula pendula*) were more productive than monocultures; the highest overyielding was observed with mixture of two coniferous species.

Source: Shanin et al 2014. Eur J For Res 133:273–286

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New methods to assess tree canopy responses to management

- 2013: Method to reconstruct comprehensive QSMs of single trees from TLS data
- 2015: Generalization to massive scale => automatic forest plot reconstruction
- Now: Use QSMs to compute classification features and detect tree species automatically after reconstruction
- Previous methods require some manual interaction, or additional data sources

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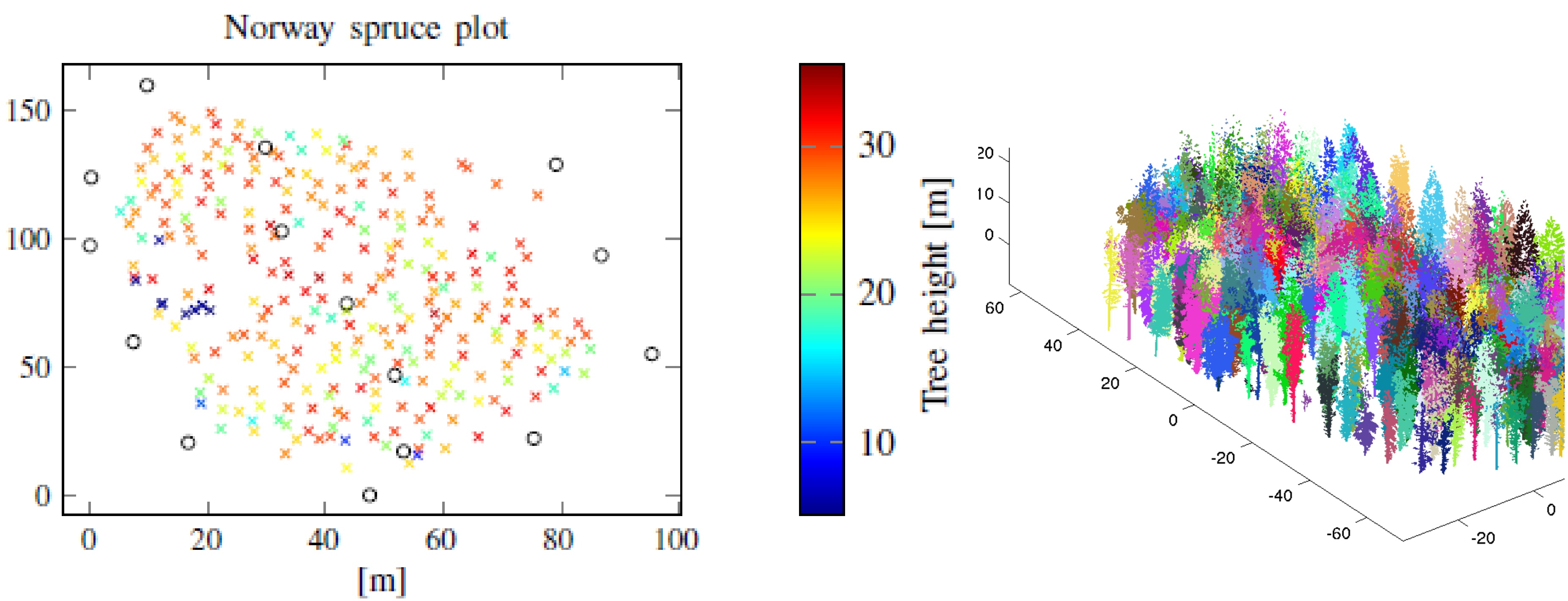
Automatic tree species recognition with quantitative structure models

Markku Åkerblom[a,*], Pasi Raumonen[a], Raisa Mäkipää[b], Mikko Kaasalainen[a]

Methods

- 3 single-species and 2 multi-species forest plots from Finland scanned terrestrial LiDAR
- Each tree detected and reconstructed automatically as a cylinder-based QSM
- 15 classification features defined and computed
- Feature combinations tested using 5 different classification approaches: k-NN, multinomial regression and 3 support vector machines

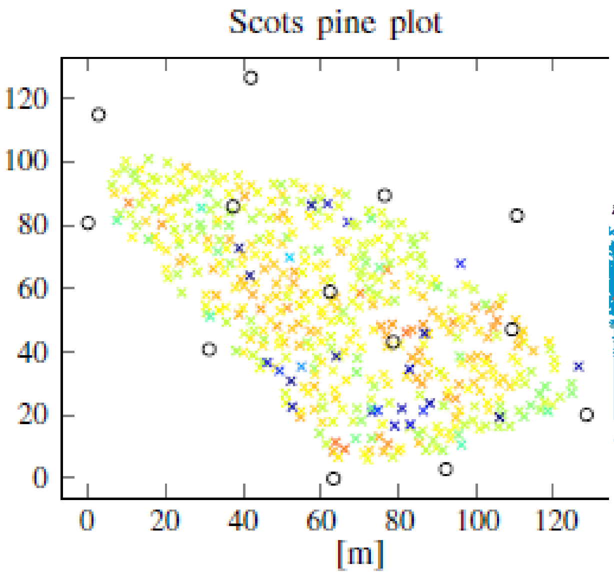
Scanned trees and fitted GSMs

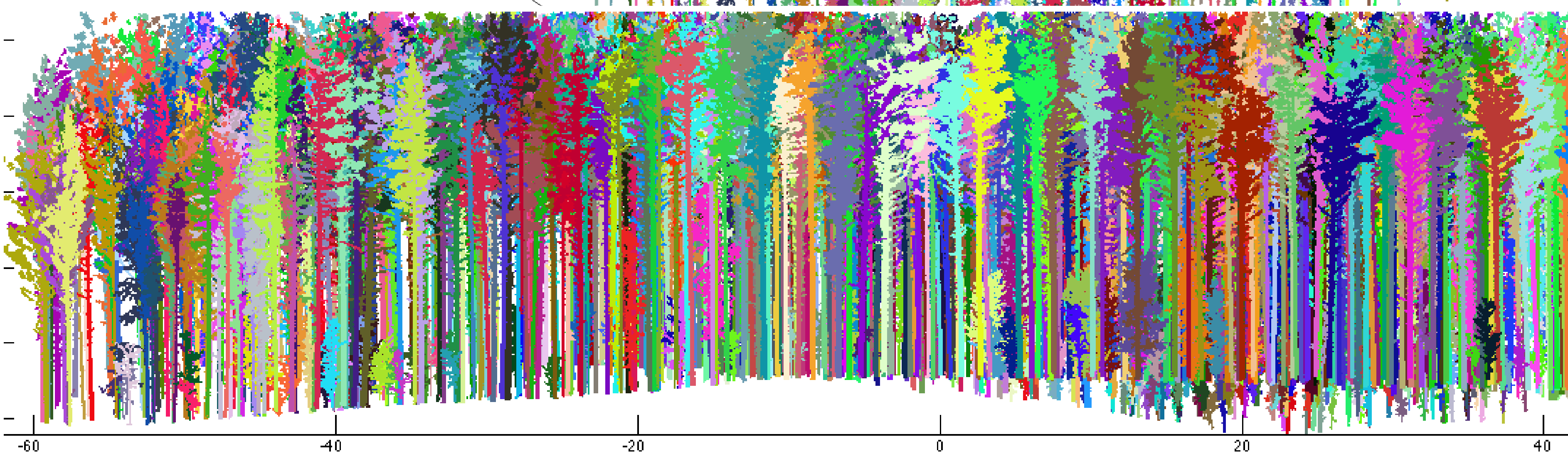


Forest plot tree location and height map (crosses) and scanner positions (circles).

Source: Åkerblom et al. 2017. Remote Sensing of Environment, doi.org/10.1016/j.rse.2016.12.002

Scanned Scots pine stand and fitted GSM





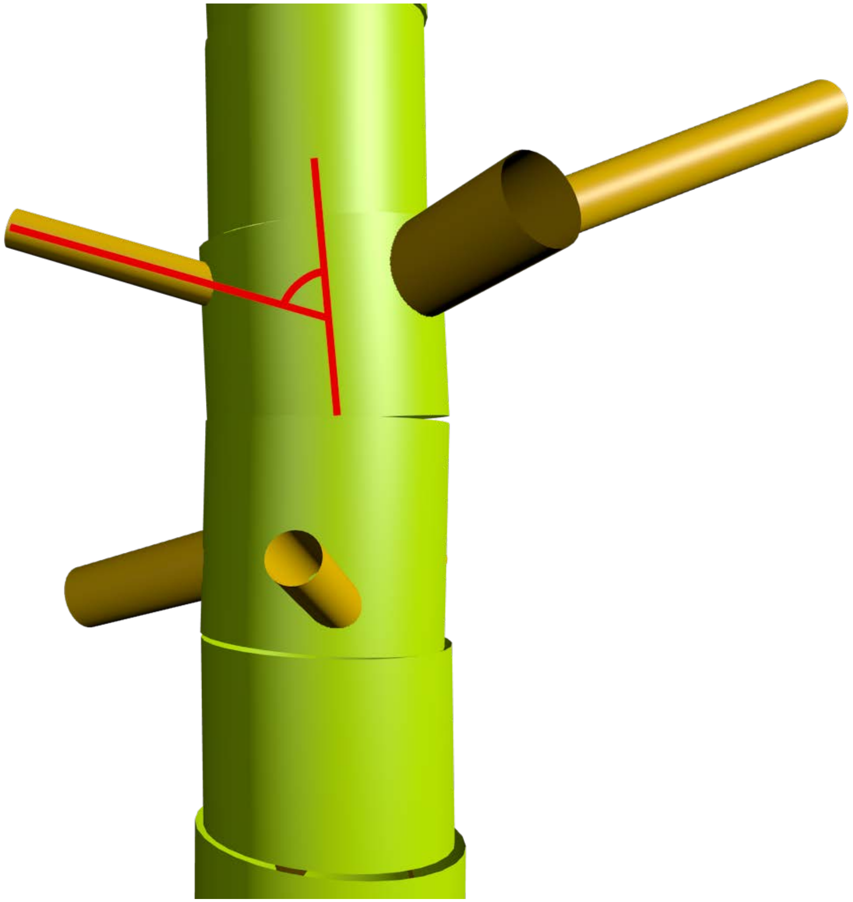
Tree features calculated from the fitted QSMs

Source: Åkerblom et al. 2017. Remote Sensing of Environment, doi.org/10.1016/j.rse.2016.12.002

Feature name	Description
Stem branch angle	Median of the branching angles of the 1st order branches in degrees. 0 is upwards and 180 downwards. [°]
Stem branch cluster size	Average number of 1st order branches inside a 40 cm height interval for 1st order branches. Each branch can only belong to one interval.
3 Stem branch radius	Mean ratio between the 10 largest 1st order branches measured at the base and the stem radius at respective height.
Stem branch length	Average length of 1st order branches normalized by **DBH**.
Stem branch distance	Average distance between 1st order branches computed using a moving average with a window width 1 m. If window is empty average distance in window is set as half of window width.
Crown start height	Height of first stem branch in tree crown relative to tree height.
Crown height	Vertical distance between the highest and lowest crown cylinder relative to tree height.
Crown evenness	Crown cylinders divided into 8 angular bins. Ratio between extreme minimum heights in bins.
Crown diameter/height	Ratio between crown diameter and height.
DBH/height ratio	Ratio between DBH and total tree height.
DBH/tree volume	Ratio between DBH and total tree volume. [m^{-2}]
DBH/minimum tree radius	Ratio between DBH and the minimum of the vertical bin radius estimates.
Volume below 55% of height	Relative cylinder volume below 55% of tree height.
Cylinder length/tree volume	Ratio between total length of all cylinders and total tree volume. [m^{-2}]
Shedding ratio	The number of branches without children divided by the number of all branches in the bottom third.

Summary & Conclusions

- Quantitative structure models (QSM) can be reconstructed from terrestrial laser scanner (TLS) data automatically
- QSM offers more than 3 data dimensions from which to derive novel species classification features
- Classification tested using 5 forest plots from Finland and over 1200 trees consisting of 3 species.



Source: Åkerblom et al. 2017. Remote Sensing of Environment, doi.org/10.1016/j.rse.2016.12.002

Further information and demos

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Remote Sensing Environment

Automatic tree species recognition with quantitative structure models

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Markku Åkerblom[a,*], Pasi Raumonen[a], Raisa Mäkipää[b], Mikko Kaasalainen[a]

http://www.sciencedirect.com/science/article/pii/S0034425716304746 see Appendix A

Video illustrations on

1. how the classification features are defined.
2. how the samples of different tree species are distributed in each feature dimension, and in particular how three example models map to these dimensions.

Take home messages

- Climate change will affect abundance of plant species
- Some common forest plant species (e.g. *Calamagrostis arundinacea*) can be used as indicator species, since they are clearly temperature dependent and may move towards north by rate of 8 km per year.
- Major tree species are positively affected by increasing temp and CO_2. Growth and timber yield may increase if risks of forest damages (insects, pathogens, and wind damages are avoided)
- Mixed stands are more productive than monocultures and species specific risks reduced.
- New methods allow detailed analyses of the canopy responses to changed management practices.

Thank you!

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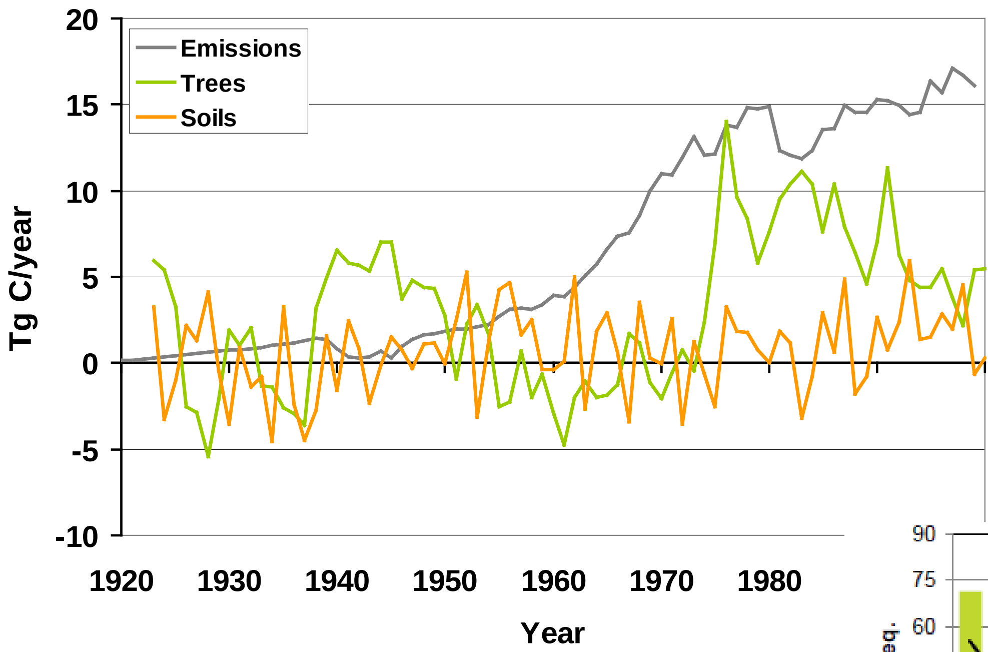
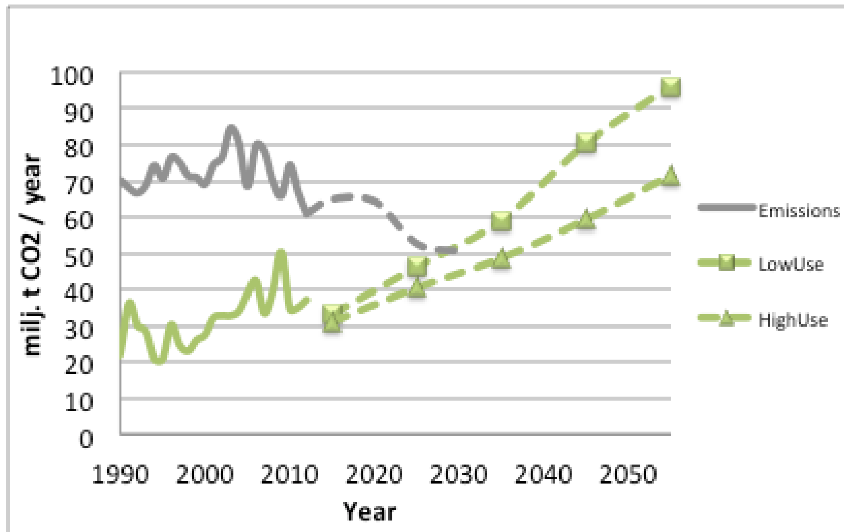
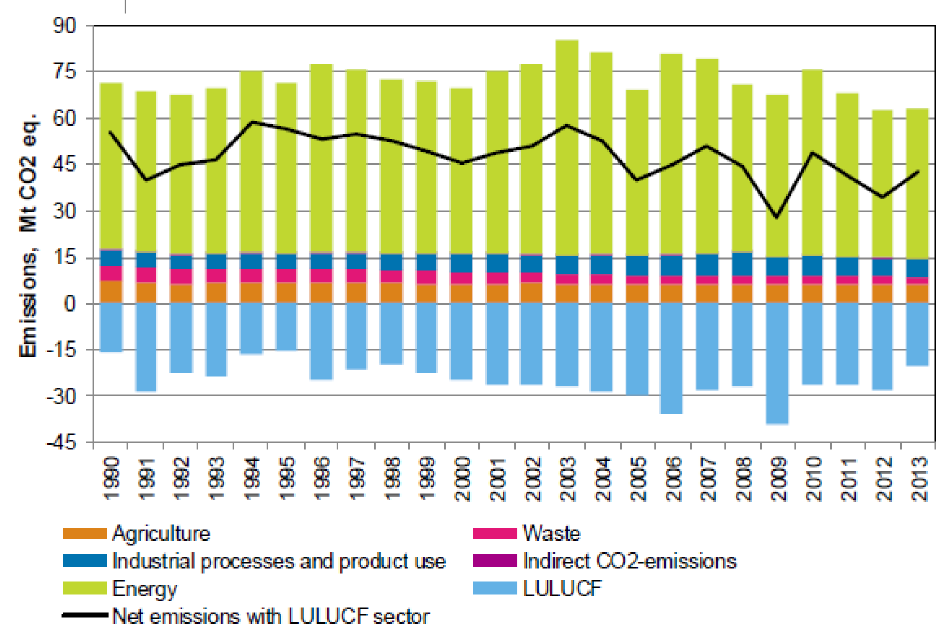
Suomen metsien hiilinielu





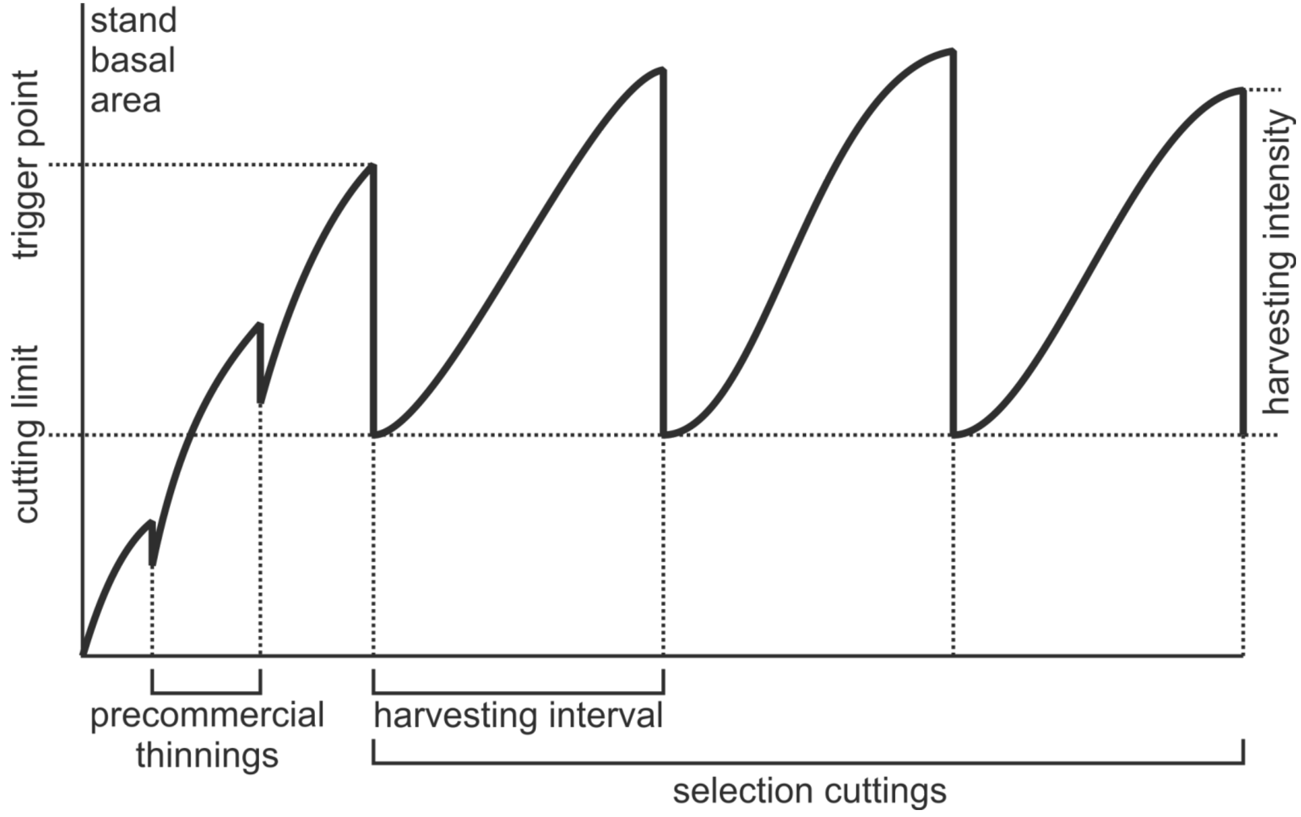


Sources: Liski et al. 2006. Ann. For. Sci. 63(7): 687-697 and Monni et al. 2003. Env. Managem. 31: 401-411, NIR Finland 2015, Sievänen et al. Luke

Current target - sustainable forest management

- Multiple targets of the forest management include timber production, recreation values, maintenance of biodiversity and mitigation of climate change by forest carbon sinks.
- Even-aged monocultures are suggested to be vulnerable to disturbances and the consequences of climate change (O’Hara et al., 2007; Seidl et al., 2011).
- The low structural diversity of the tree stand is not optimal for biodiversity, ecosystem productivity and forest carbon sequestration.
- What we can gain by continuous cover forestry? Uneven-aged forest management?

The simulated scenarios of stand development - from even-aged management to uneven-aged stand structure and management.

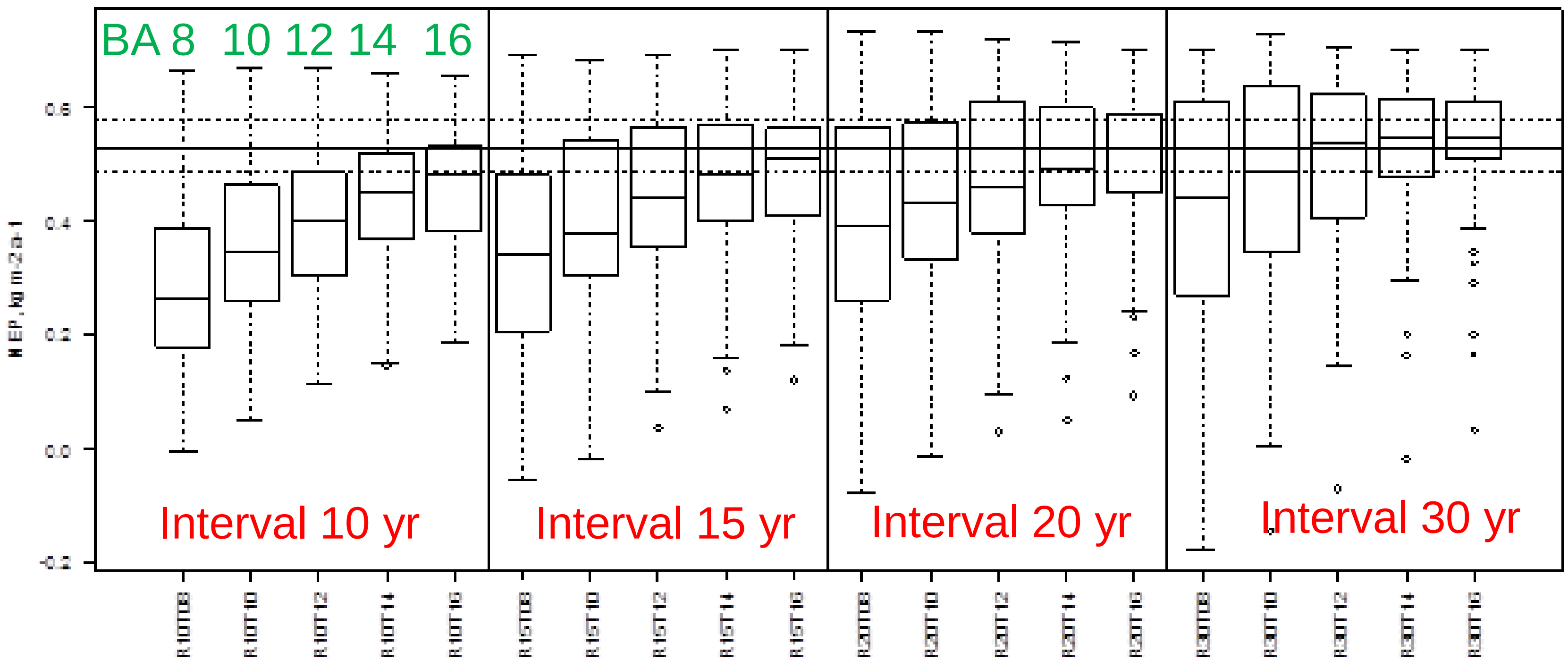


Simulated selection cutting scenarios contained variations of both harvest interval (10–30 years) and postharvest stand density (basal area 8–16 m2 ha-1).

‘R’ denotes the harvesting interval, years, and ‘T’ denotes threshold value of stand basal area, [m^2 ha^{-1}], to be reached after harvesting

Harvesting interval, years	Limiting value of stand basal area, [m^2 ha^{-1}]				
	8	10	12	14	16
10	R10T08	R10T10	R10T12	R10T14	R10T16
15	R15T08	R15T10	R15T12	R15T14	R15T16
20	R20T08	R20T10	R20T12	R20T14	R20T16
30	R30T08	R30T10	R30T12	R30T14	R30T16

Net ecosystem production (NEP) increased from 0.25 to 0.5 kg m-2 a-1 of carbon with longer harvest intervals and higher postharvest density



Net ecosystem production NEP calculated as the difference between net primary production and carbon emission due to respiration of soil biota. The solid horizontal line on upper pane is the median line for NEP at undisturbed development; dashed horizontal lines denote 1st and 3rd quantiles, respectively.

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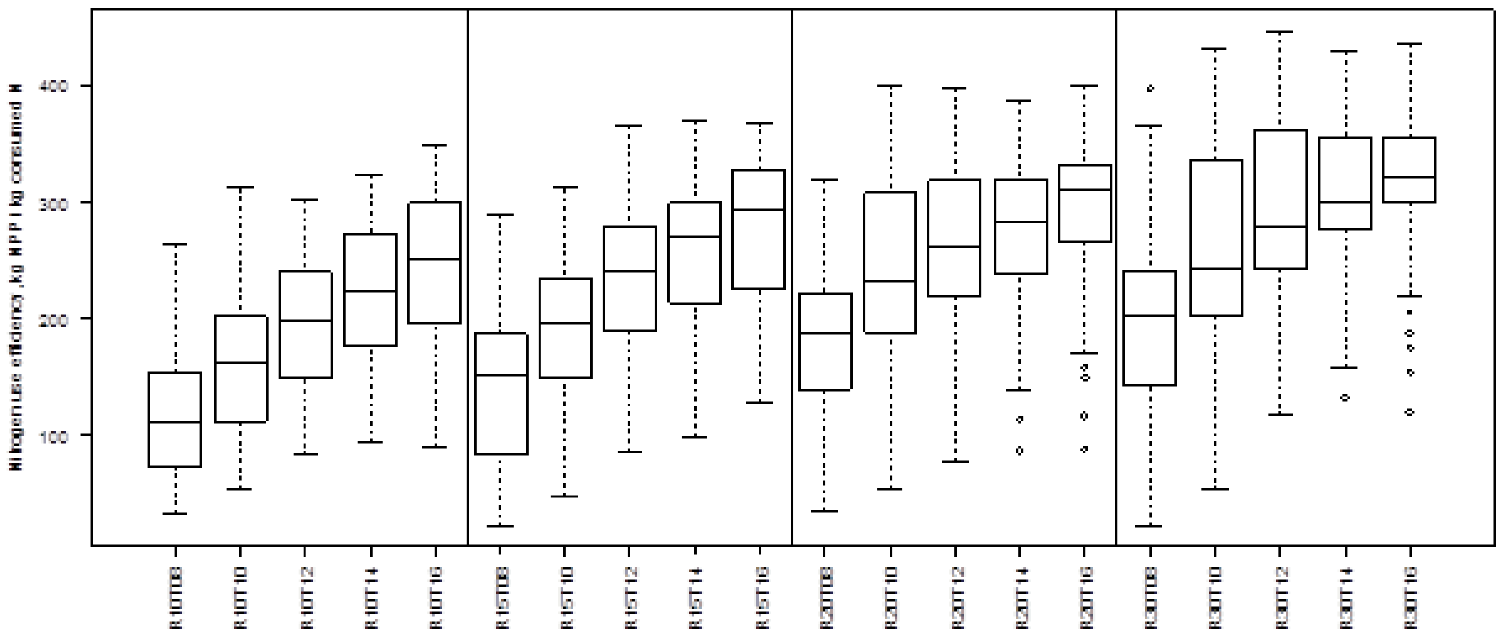
Nitrogen use efficiency (NUE) varied between from 100 kg NPP per kg consumed N in case of heavy cuttings to 300 kg NPP per kg consumed N for light removal of trees.



Nitrogen use efficiency (kg NPP per kg consumed N – lower panel) for different scenarios of management.

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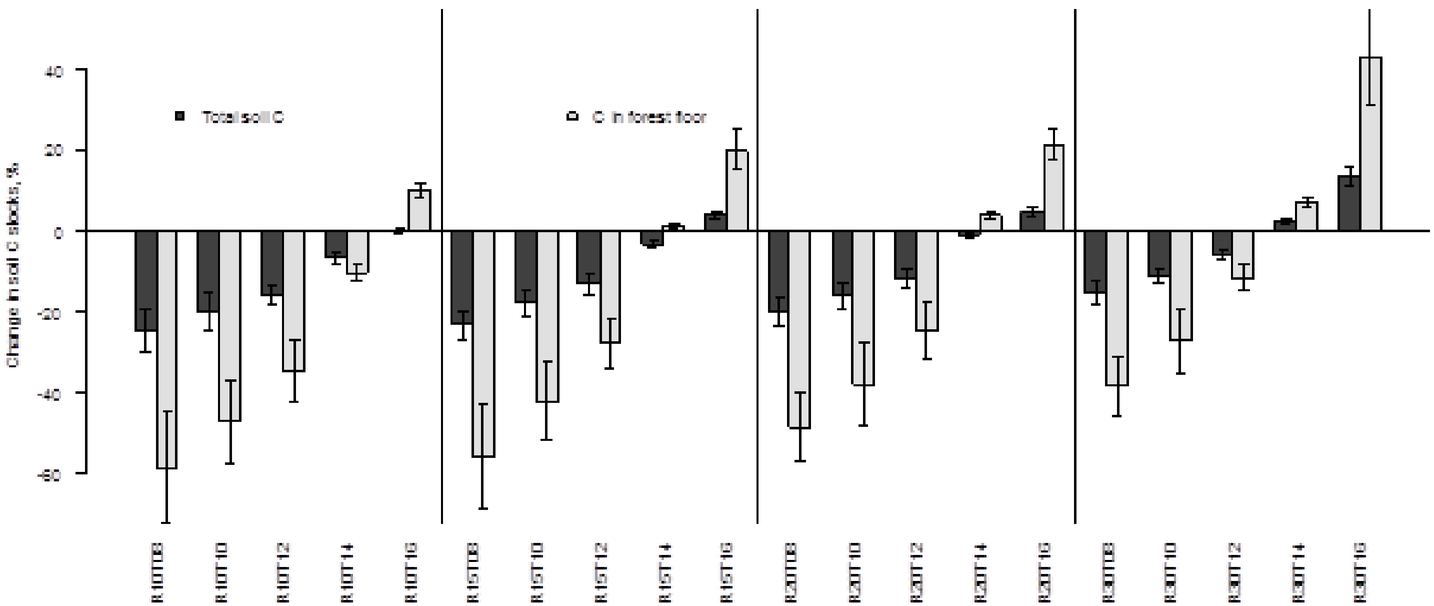
Changes in soil carbon stocks were negative for most scenarios (5–20% decline in terms of total soil C), and the decline was most pronounced with lowest postharvest density and short harvest intervals.



Changes in soil carbon stocks (% of initial values) during second half of simulation period (a series of selection cuttings). 'Whiskers' denote standard error.

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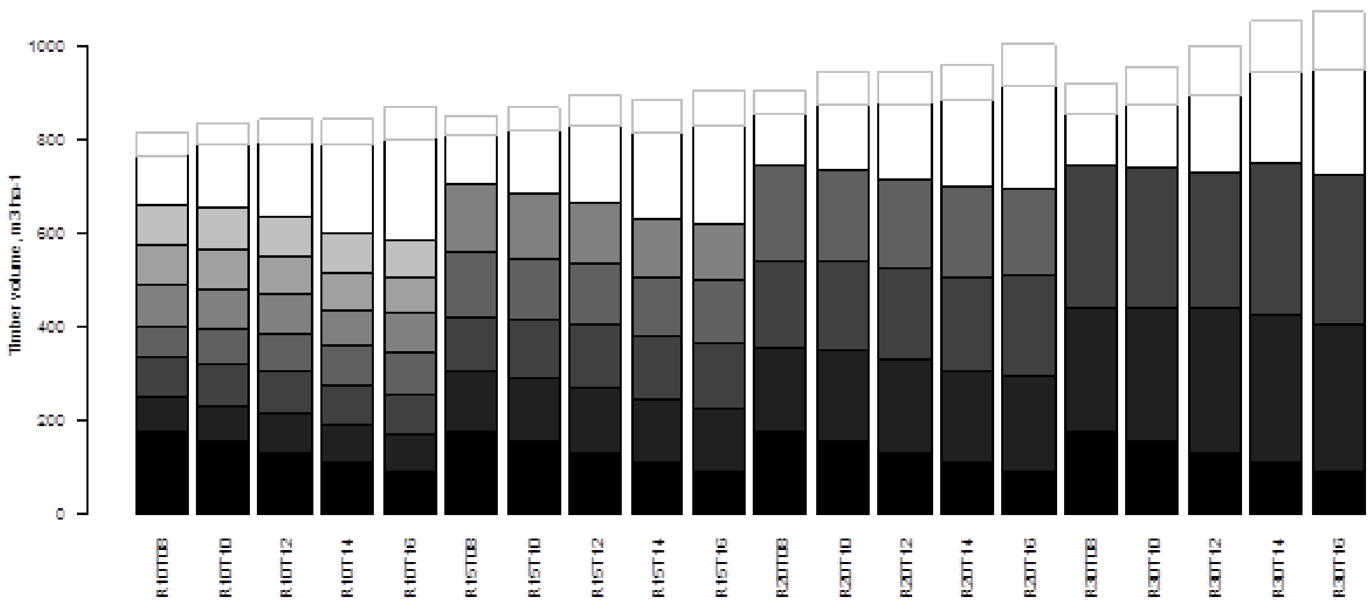
The volume of harvested timber was between 320 and 400 m3 ha-1 for the a 60-year period.

The cumulative volume of deadwood of 80–120 m3 ha-1 was substantially higher with the longest harvest interval (30 years) than with the shorter alternatives where it comprised 40–60 m3 ha-1.



Ttotal amount of harvested wood at different scenarios. Different colours indicate the volumes obtained at different selection cuttings; blank blocks with black boundary represent the standing volume at the end of simulation period, blank blocks with grey boundary are cumulative volume of dead wood.